THE MEXICAN LIVESTOCK, MEAT, AND FEEDGRAIN INDUSTRIES: A DYNAMIC ANALYSIS OF U.S.-MEXICO ECONOMIC INTEGRATION

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ABSTRACT: This study provides a comprehensive, consistent assessment of the potential impacts of freer U.S.-Mexico agricultural trade on the Mexican livestock, meat, and feedgrain industries. Background information of the Mexican livestock, meat, and feedgrain industries is provided. A theoretical model of U.S.-Mexico trade in livestock, meat, and feedgrains is developed which is validated through historical simulation and sensitivity analysis. The model is used to simulate the market effects of the unilateral liberalization of Mexican livestock, meat, and feedgrain trade over 10-year period prior to the implementation of NAFTA. In general, the analysis indicated that the Mexican policy shift to more open markets substantially impacted Mexican livestock, meat, and feedgrain trade. The results also clearly indicated that the effects of liberalizing Mexican livestock, meat, and feedgrain trade were highly dependent on the level and direction of change in per capita income during the period of liberalization.

The **Texas Agricultural Market Research Center (TAMRC)** *has been providing timely, unique, and professional research on a wide range of issues relating to agricultural markets and commodities of importance to Texas and the nation for more than twenty-five years.* **TAMRC** *is a market research service of the Texas Agricultural Experiment Station and the Texas Agricultural Extension Service. The main* **TAMRC** *objective is to conduct research leading to expanded and more efficient markets for Texas and U.S. agricultural products. Major* **TAMRC** *research divisions include International Market Research, Consumer and Product Market Research, Commodity Market Research, and Contemporary Market Issues Research.*

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Executive Summary

This study provides a comprehensive, consistent assessment of the potential impacts of freer U.S.-Mexico agricultural trade on the Mexican livestock, meat, and feedgrain industries. As background to the development of a theoretical model to analyze that trade, the characteristics of the Mexican livestock, meat, and feedgrain industries are first considered. After presenting the underlying assumptions of the model, the Mexican livestock, meat, and feedgrain supply and demand relationships are discussed.

Three demand model formulations (LA/AIDS, ROTTERDAM, and single equation) are discussed for the Mexican meat sector. Gross complementarity among meats is found in the LA/AIDS and the ROTTERDAM which prevents the use of these demand specifications. The single equation meat demand formulation is integrated to the supply system and the parameters of the Mexican livestock, meat, and feedgrain model are estimated. The model is then validated through historical simulation and sensitivity analysis. Summary statistics show good performance and high stability of the estimated model.

The fully integrated supply and demand model is used to simulate the effects of Mexico's trade liberalization on the Mexican livestock, meat, and feedgrain sectors under several scenarios. Liberalization of Mexican markets benefits both the livestock and feedgrain sectors in Mexico because the resulting increased demand for livestock generated an increase in demand for feed that more than offset the negative effects generated by increasing feed imports.

The Mexican meat processing industry also benefits from Mexican market liberalization. Even though the simulation results indicate that meat production is lower on average after the liberalization of trade, total revenues actually increase because the inelastic nature of meat demand in Mexico results in a much larger percentage increase in retail prices of meat.

Changes in real per capita income in Mexico are an important factor in determining the likely consequences of trade liberalization on Mexican meat imports. If real per capita income in Mexico had been only one standard deviation lower than was actually the case during the 1986 to 1991 period of unilateral liberalization, the model simulation results indicate that Mexican meat demand would have dropped enough to eliminate meat imports altogether, possibly even creating excess Mexican supplies of meat for export.

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Trade liberalization has been a recurrent theme in recent economic literature. A number of countries have formed or are negotiating the terms for trade associations of various types to stimulate their economies. Trade associations or agreements that reduce tariff and non-tariff barriers among countries allow freer trade and increase the size of the market for goods and services of the participant countries. The recently concluded GATT talks were a multilateral effort to reduce world trade barriers and eliminate the market distortions from years of world-wide government trade intervention. The European Union (EU), formerly known as the European Community (EC) is the best known example of the trend towards economic integration through trade barrier reduction. More recently, the countries of Argentina, Brazil, Paraguay, and Uruguay in South America signed a commercial treaty in 1991 referred to as MERCOSUR.

In North America, the U.S. and Canada signed a free trade agreement in 1988 which was expanded to include Mexico to create the North American Free Trade Agreement (NAFTA). Because of the pre-existing agreement a free trade agreement between the U.S. and Canada and because Canada-Mexico trade is relatively low, a main focus of the NAFTA negotiations was the discussions between the U.S. and Mexico. Given the relative size of the Mexican economy and the fact that trade with the U.S. accounts for about two thirds of total Mexican exports, NAFTA could have a potentially large impact on U.S.-Mexico trade and on the Mexican economy in particular.

All sectors of the U.S. and Mexican economies are not likely to be impacted equally by freer trade between the two countries. Several sectors, including agriculture, however, are likely to be impacted significantly. Within the agriculture sectors of both countries, the livestock, meat, and feedgrain industries are likely to be among the most directly impacted. U.S. livestock and products exports to Mexico more than doubled over the last decade. In the last half of the 1980s, livestock products accounted for 85% of the total.

Meat plays an important role in Mexican diets from both a cultural and nutritional point of view. Meat products account for a substantial share of consumer food expenditures in Mexico. According to the 1984 Mexican Expenditure Survey (INEGI), meat represents 26% of total food consumption in Mexico. Mexicans devote almost 45% of their expenditures to food with meat representing nearly 12% of those expenditures.

The U.S. also imports livestock and products from Mexico. Those imports are growing and are dominated by live animals, primarily feeder cattle. Mexico also began importing more grains to satisfy a growing demand for livestock feed in the early 1970s and has become an increasingly important export market for U.S. feedgrains in particular.

What the specific impacts of the NAFTA might be on the U.S. and Mexican livestock, meat, and feedgrain industries, however, are not clear. Relatively little research has been done to evaluate the likely effects of NAFTA on the agricultural sectors of either country. Most of what has been done is qualitative in nature, providing information for the development of hypotheses regarding the likely effects of NAFTA but providing little insight on the likely specific behavioral response of various market agents to freer U.S.-Mexico agricultural trade.

The empirical research that has been done, however, either treats agriculture at a much too aggregate level or considers only a few selected commodities. A comprehensive study of the likely effects of NAFTA on key agricultural sectors like livestock, meat, and feedgrains using a consistent methodology and database across commodities and products has not been attempted. Such a study is needed to provide U.S. agricultural producers, agribusiness firms, and policy makers with reasonable, internally consistent estimates of not only the likely effects of NAFTA but also the potential market in Mexico for U.S. agricultural commodities and products and the possible competitive threat posed by Mexico.

Before outlining the particular objectives of this proposed study, existing studies relating to freer U.S.-Mexico agricultural trade and livestock, meat, and feedgrain markets are briefly reviewed to identify those specific areas in which research is needed and the empirical methodologies that may be used to investigate the likely effects of freer U.S.-Mexico trade on the Mexican livestock, meat, and feedgrain markets.

Literature Review

The studies relevant to this proposed study are divided into three groups: (1) qualitative and quantitative assessments of the effects of a NAFTA on U.S./Mexico agricultural trade, (2) studies of the Mexican livestock, meat, and feedgrain sectors, and (3) studies that have attempted to empirically model and measure behavioral parameters in livestock and meat industries.

Studies of the Effects of a NAFTA on Agricultural Markets

The most recent and comprehensive qualitative work in this area has been done by the Texas Agricultural Market Research Center (TAMRC) at Texas A&M University. The TAMRC *U.S.-Mexico Free Trade Issues for Agriculture Series* is a collection of studies analyzing the likely implications of a U.S./Mexico FTA for specific U.S. agricultural commodity sectors and non-commodity issues, including general agricultural issues (Williams and Rosson); fresh vegetables and melons (Fuller and Hall); grains and feeds (Waller, Williams, and White); livestock and meat (Rosson, Schulthies, and White); cotton (Taylor); agricultural transportation (Fuller); natural resources and the environment (Ozuna and Guajardo); agricultural law (Boadu); dairy products (Schulthies and Schwart); agricultural labor (Goodwin); and the general Mexican economy (Rosson and Angel).

One of the earliest qualitative assessments of U.S./Mexico agricultural trade and trade barriers motivated by the possibility of a U.S./Mexico FTA was a report by the U.S. General Accounting Office to the U.S. House Committee on Agriculture in 1990 (USGAO). This was followed by a series of reports by the U.S. International Trade Commission on the likely effects of a U.S./Mexico FTA in which agriculture was treated to some extent (USITC, April 1990a; USITC, April 1990b; USITC, October 1990; and USITC, February 1991). Numerous other qualitative studies have also considered various agricultural implications of a U.S./Mexico FTA (e.g., Thompson and Martin; Sek; USDA, April 1991; Polyconomics; Lich and McKinney; and Weintraub *et al.*).

In comparison, few studies have attempted to quantify the likely impacts of NAFTA on agriculture. Most have focused on the general economic effects of liberalized trade between the U.S. and Mexico with only limited, disaggregated consideration of agriculture sector effects. Robinson *et al.*, for example, consider the agricultural impacts of a U.S./Mexico FTA in some detail using a computable general equilibrium (CGE) model. Although they disaggregate the agricultural sector into broad subgroups (food corn, program crops, fruits/vegetables, other agriculture, food processing), their treatment of agriculture is much too general to provide any meaningful assessment of likely impacts of a NAFTA for specific commodities like livestock, meat, and feedgrains. Also, their study considers only the long-run impacts of a U.S./Mexico FTA and, therefore, does not provide any indication of the time path of likely changes in export opportunities from the implementation of NAFTA. Because NAFTA will be phased in slowly over time, the likely short-run, intermediate, and/or long-run effects are of interest to producers, policymakers, and others for strategic planning purposes. Finally, CGE models of the type used by Robinson *et al.* cannot provide forecasts that can be compared against actual data (Stern). A few studies have attempted to quantitatively measure the effects of NAFTA on U.S./Mexico trade in specific agricultural commodities (e.g., Krissoff *et al.* and Lyford). Although moving in the right direction, these studies have used quite different methodologies and have considered only few commodities.

Studies of the Mexican Livestock, Meat, and Feedgrain Industries

Existing studies of the Mexican livestock, meat, and feedgrain industries are mainly descriptive with little or no quantitative analysis attempted. Engels and Segarra, for example, provide a description of government intervention in the Mexican livestock sector and measure the extent of government subsidization to agricultural producers and consumers. They do not, however, quantitatively assess government policy impacts on Mexican livestock, feedgrain, and meat markets.

Bredahl, Burst, and Warnken focus on Mexican cattle production systems and policies to explain the growth and structure of the Mexican cattle industry. They link production systems and land requirements to geographical areas, pointing out the differences that exist among areas. They identify two essential goals of government policy: (1) redistribution of the land and (2) inexpensive food for the urban poor. No empirical work is attempted in this study either, however.

Another approach to the study of the Mexican livestock sector is presented by Perez-Espejo. She identifies the importance of livestock and meat in the Mexican economy in terms of GNP participation, land usage, contribution to nutritional needs, and foreign exchange earnings. She describes the structure of the sector and analyzes the characteristics of the cattle, hog, and poultry subsectors. Finally, she argues that Mexican agriculture was oriented to produce grains to feed animals instead of humans during the 1970s but that the situation is changing. She concludes that after flourishing in the 1970s, the Mexican livestock sector is now in decline. Although providing an in-depth analysis of the Mexican livestock sector, she does not attempt an empirical analysis.

Chauvet-Sanchez agrees with Perez-Espejo in concluding that the Mexican livestock industry is experiencing a serious crisis in both production and consumption. Her analysis, however, implies that the problems in the Mexican livestock industry is the result of more open world markets which puts less developed countries at a serious disadvantage. As most studies on the Mexican livestock industry, this one falls in the descriptive category with no empirical work.

Probably the most detailed description of the Mexican livestock sector and its history is provided in a paper published by the Universidad Autonoma de Chapingo in Mexico in 1989. This study maintains the thesis that the Mexican livestock sector lived its golden age in the 1970s only to decline drastically in the 1980s. The study analyzes the development of the livestock sector from the early 1900s to the 1980s and provides an excellent description of what has happened to the livestock sector in Mexico over the last 80 years. Again, however, no empirical work is done.

Studies That Model Livestock and Feed Markets

The estimation of own-, cross-price, and income elasticities of meat demand has been the focus of many studies. Among the 21 papers presented at a recent conference on the economics of meat demand, only one included the supply side of the sector, however (Brandt *et al.*). The variables included in that model are beef, pork, chicken, eggs, turkey, and dairy products. Although the model is used to project the likely impact of foreign trade on the U.S. livestock market over the subsequent decade, no attempt was made to analyze the likely effects of freer U.S.-Mexico agricultural trade.

Other studies have focused primarily on modeling the livestock-feed sector. Egbert and Reutlinger, for example, use a dynamic recursive model of the U.S. livestock-feed sector for the purpose of making long-run projections. The model consists of a recursive system of supply and demand equations. They make projections by setting three alternative prices for corn and relative price levels for other feeds. They conclude that meat production falls as feed prices increase but meat product prices increase by relatively more.

Kulshreshtha and Wilson developed a model of the Canadian beef cattle sector to estimate the simultaneous relationships existing among demand, supply, price, and export variables using a two-stage, least-squares procedure. They conclude that the magnitude of the demand elasticities found are greater than those found in other studies of the Canadian beef sector.

Freebairn and Rausser analyze the U.S. livestock industry using a model of the production, consumption, trade, and farm prices of fed beef, other beef, pork, poultry, and inventories of livestock. They derive a set of reduced-form equations from a simultaneous equation model. A set of multipliers is calculated to evaluate the effects of changes in annual beef imports. They do not include, however, appropriate linkages for analyzing U.S.-Mexico livestock and meat trade.

Arzac and Wilkinson developed a quarterly econometric model of U.S. livestock and feedgrain markets and draw some implications for policy. They design an econometric model to provide quarterly forecasts for livestock and grain production and prices, farm-to-retail spreads for meat products, and consumer demand for meat. The model consists of 42 equations that explain the demand and supply of fed and non-fed beef, pork, chicken, and corn. They estimate dynamic multipliers for corn exports, non-fed beef imports, government inventories of corn, corn yield, disposable personal income, and corn support price. Again, however, U.S.-Mexico trade was not considered in the study.

Martin and Heady also developed a quarterly model of the U.S. livestock-feed industry which shares many of the features of earlier models of that subsector. Nevertheless, the model contains a number of advances not included in earlier efforts. They use a block recursive model in which the equations of the simultaneous block are primarily estimated by a truncated, two-stage least squares estimator. Some multipliers are derived to evaluate the effect of an increase in the level of beef imports on U.S. markets. As with other studies, Mexican markets are not considered.

Leuck analyzes the EC feed-livestock sector. Although the study does not consider the demand side of the livestock sector, it does include detailed supply interrelationships in the EC feed and livestock sectors. Leuck analyzes the effects of the EC Common Agricultural Policy on the production and prices of feedgrains, oilseed meal, and livestock products.

An interesting approach to link the livestock-feed sectors in Nebraska to the "Rest of the U.S." (ROUS) is provided by Azzam, Yanagida, and Linsenmeyer. They contend that if a state is a large producer and consumer of livestock and feed products, a feedback linkage between state and national variables is a necessary component of state-level livestock models. They build an econometric model consisting of five submodels: (1) corn, (2) beef, (3) hog, (4) market clearing equations and identities, and (5) government policy variables. They conclude that the Nebraska cattle sector adjusts relatively quicker to market shocks than the ROUS because Nebraska is a dominant cattle feeding state with inherent comparative advantages in feed and water resources and geographic proximity to major marketing centers. Although this study was obviously not intended to study U.S.-Mexico trade, some of the feedback linkage concepts may be useful in efforts to model U.S.-Mexico trade.

Wahl analyzes the dynamic adjustments in Japanese livestock markets under trade liberalization. For the analysis, he develops a model of the Japanese livestock industry which integrates an Almost Ideal Demand System (AIDS) model for meat demand in Japan with a dynamic livestock supply model. The model is used to analyze the effects of the U.S./Japan Beef Market Access Agreement. His supply system does not include feedgrains and oilseeds as inputs of livestock production. The whole system, however, is a useful example of meat and livestock supply and demand modeling. He concludes that the opening of Japanese beef markets to imports will have relatively little impact on the domestic Wagyu cattle industry in Japan even though imports are likely to increase significantly.

Tsai examines the economic structure and policy environment of the Taiwanese livestock, meat, and feedgrain markets. This study integrates the livestock and feedgrain models with a meat demand system to simulate the impacts of trade liberalization on those markets. The meat demand system is tested for structural change and price endogeneity and three different specifications are examined because of the complementarity problem found. He concludes that there is evidence of a structural change on the Taiwanese meat demand sector, that prices may be treated as exogenous, and that the LA/AIDS model with no cross-price elasticity restriction imposed performs better for simulation purposes. His analysis provides a good example of how to integrate meat, livestock, and feedgrain sectors for simulation purposes.

Objectives

The general goal of this proposed study is a comprehensive, consistent assessment of the potential impacts of freer U.S.-Mexico agricultural trade on the Mexican livestock, meat, and feedgrain industries. The specific objectives are to:

1. Qualitatively assess the economic structure and government policy intervention in the Mexican livestock, meat, and feedgrain industry to provide the basis for refining hypotheses and conducting the necessary empirical tests and analyses;

2. Develop econometric techniques to measure and analyze the key parameters affecting the behavior of the supply, demand, price, trade, and other relevant variables in Mexican livestock, meat, and feedgrain markets;

3. Develop and validate econometric simulation models of Mexican markets for livestock, meat, and feedgrains using the econometric results obtained;

4. Analyze the likely impact of freer U.S.-Mexico trade on U.S. exports of livestock, meat, and feedgrain to Mexico and the likely competitive threat from Mexican imports over the trade liberalization period through model simulation analyses under various possible scenarios, including:

a. the elimination of tariffs and quantitative trade barriers affecting the trade in only livestock and livestock products between the U.S. and Mexico;
b. the same scenario, except for only feedgrains;
c. the same scenario but including both livestock and products and feedgrains;
d. economic events like alternative rates of real economic growth of the Mexican economy.

THE MEXICAN LIVESTOCK, MEAT, AND FEED SECTORS

This section analyzes the characteristics of the Mexican livestock, meat, and feed sectors. Government policies that have influenced the development of these sectors in Mexico are also discussed. First, the general characteristics of the Mexican livestock and meat sectors are presented. Then, the conditions of market supply, demand prices, and trade for each livestock and meat subsector are discussed. The feed sector is then described. Finally, the Mexican policies affecting livestock, meat and feedgrains including PROCAMPO and NAFTA are analyzed.

The Mexican Livestock and Meat Industry

The word "agriculture" has a particular meaning in Mexico. Generally, livestock and crops are considered to be part of the agriculture sector. In Mexico, however, agriculture refers only to crops. Agriculture and livestock are included in what is called the primary sector. Following this convention, the word agriculture will be used to refer only to the crops subsector in this section.

The Mexican livestock industry flourished more than the agriculture industry in the decade of the seventies. This fact gave rise to the phrase "ganaderización de la agricultura" (the livestocking of agriculture), meaning that agricultural resources were being diverted to promote the livestock industry. This shift to livestock was accompanied by a change in land usage and in cropping patterns. The land devoted to livestock grew from 55.5% in 1960 to 78% in 1980. In crops, sorghum and other forage crops accounted for 2.8% of the total harvested area in 1960 but had grown to 11.2% by 1980. The "livestocking" process began to reverse itself in the 1980s, however. The livestock share of the GNP of the primary sector dropped from 36.5% in the 1970s to 32.6% in the 1980s, while the agriculture subsector remained somewhat stable (Table 2.1). By 1991, the share of livestock and agriculture in the total GNP was still high compared to that in the U.S. (6.89% in Mexico vs less than 2% in the U.S.) Nevertheless, shares of total GNP accounted for by agriculture and by livestock have been falling steadily as expected for a developing country.

The meat consumed by Mexicans comes mainly from cattle, swine, and chicken. Other types of meat consumed include lamb, goat meat, fish, and turkey. Fish, however, is not considered to be part of the Mexican consumer meat budget because its consumption is rather seasonal, especially during the Lent season. Lamb and goat meat are mainly regional commodities and turkey is consumed mainly during the Christmas season.

Mexican data are not readily available nor reliable. Lack of consistency is a particular problem for livestock and agriculture data, especially when they come from different sources. For example, Tables 2.2 and 2.3 show meat production in Mexico from two different sources: the Mexican President's report to Congress and the U.S. Department of Agriculture (USDA). A comparison of the means and standard deviations of the corresponding data series indicate clearly that they differ quite substantially. Chapter IV describes the problems encountered in developing the data for this study.

Total per capita consumption of meat in Mexico grew steadily from 1970 until 1982 reaching a high of 41.65 kilograms per capita, three times the consumption of 1970 (Table 2.4). This trend, however, was reversed by the financial crisis that began in 1982. Meat consumption declined drastically until the late 1980s when it stabilized somewhat. By 1991, per capita consumption of meat was still at mid-1970s level.

Beef comprised over 50% of the meat consumed in Mexico in the early 1970s (Table 2.5). Strong growth of pork and chicken consumption significantly reduced the beef share by the late 1970s. By 1975, per capita pork consumption surpassed that of beef. Pork consumption, however, suffered a setback in 1986 and beef became again the most consumed meat for the rest of the decade.

At the same time, chicken emerged as a cheap alternative to both beef and pork, particularly after the 1982 financial crisis. After remaining near 15% during the 1970s and early 1980s, the chicken share of meat consumption jumped to 30% by the early 1990s. Consumption of beef, pork, and chicken in Mexico appear more balanced in the 1990s than in the 1970s.

Meat prices in Mexico have not always been determined by market forces. Beef prices have normally been subject to strict government controls in Mexico over the years. Because beef prices serve as an indicator for other meat prices, the Mexican Government has tended to regulate them. Still, a very large proportion of the population has not been able to consume beef because of the cost.

Both cattle and beef prices have followed cyclical patterns in Mexico in real terms (Table 2.6). The real prices for cattle and beef increased in the early 1980s but declined for the rest of the decade until they once again reached the level of the early 1970s. Real cattle farm prices reached their highest level in 1983 but dropped an average of 3.7% annually during the remainder of the decade. Real retail beef prices rose almost 50% from 1980 to 1986 only to fall almost 40% over the following four years. Real hog farm prices grew during the 1970s although real pork prices suffered a decline during the same period. In the early eighties, both hog and pork prices maintained their levels in real terms until 1984 after which they began falling again, especially hog prices. The real retail price of chicken has been falling since 1970, dropping more than 40% by 1991.

The Mexican Cattle and Beef Industry

In Mexico, cattle are often divided into three groups: (1) dairy, (2) beef, and (3) dual purpose. The production process in the cattle industry in Mexico is quite different from that in the U.S. In Mexico, cattle are mainly grass fattened and feedlots are not common (Bredahl *et al.*). Most Mexicans consume grass-fed beef because it is generally leaner and less costly. There is, however, a higher income sector in Mexico that can afford grain-fed beef which is supplied either by the Mexican beef packing industry or by imports, mainly from the U.S. Lower prices of grain-fed beef might mean more consumption of this type of meat.

Three ecological regions of Mexico define the cattle industry: (1) the arid-semi-arid north region, which compiled for 27% of the Mexican cattle inventory, (2) the southern tropical region, which accounts for 42% of the herd, and (3) the temperate central region, which had 31% of Mexican cattle inventories in 1988.

The northern region is the most important livestock region in the country. Twenty years ago accounted for 75% of the area devoted to livestock. Conditions in that zone are more suitable for extensive, low yield type of livestock production. Low rainfall and poor soils are most common in that region. Production of feeder cattle is more common than production of cattle for slaughter in the northern region. Consequently, this region provides a large percentage of the feeder cattle exports to the U.S. Two northern Mexican states (Chihuahua and Sonora) account for more than 60% of national feeder exports with only 13% of the national herd (Bredahl *et al*.) Some grass-fed cattle produced in this region are slaughtered for local consumption or are sent to the interior of the country for slaughter where demand for meat is growing rapidly. Although feedlots for beef cattle are not yet common, there are possibilities for such development, especially if low-priced imported feedgrains from the U.S. can profitably be used for feeding.

The tropical region is the zone that has experienced the most growth in livestock production over the last 20 years. Production systems are more complex and heterogeneous in this region than in the north. Cattle production is more intensive and frequently involves dual purpose livestock operations (i.e., milk and meat production). Cattle are mainly grass-fed in this region, although some feed concentrates and forages are used as supplements. A high percentage of the consumption of beef in Mexico City and surroundings areas is supplied by this region.

The central temperate region is more oriented to crop rather than to livestock production but competition for land usage between livestock and crop production has been intense. A main characteristic of this region is that milk production is more important than meat production so that beef is produced primarily as a by-product. Cattle enterprises in the temperate region, both cattle and dairy, depend upon crop production. Cattle are grazed on fall-seeded grains during the winter months and on crop residue following harvest. The remainder of the year, various amounts of feed may be supplemented (Bredahl *et al.*)

An example of the inconsistency in Mexican livestock data can be seen by examining cattle and hog inventories in Table 2.7. Sources (1) and (3) indicate that cattle inventories increased until the early 1980s and then dropped to mid-1970 levels by 1991. Source (2), which is a more recent official data set, show a steadily increasing but substantially smaller inventory of cattle. As stated before, chapter IV deals with data issues and the criteria used to choose data sources.

Mexican cattle trade has mainly consisted of feeder cattle exports and slaughter cattle imports. Mexican beef data reflects the good livestock production years of the 1970s and the bad years of the 1980s (Table 2.8). Production exceeded consumption until 1979 giving Mexico an opportunity to export beef. In the 1980s, however, Mexico became a net importer of beef. Beef imports represented more than 3% of Mexican beef consumption between 1989 and 1991. Mexican beef production increased until 1982 only to fall during the following three years. In 1986, the Mexican beef industry benefited from the decline of the domestic pork industry. Mexican beef production reached record levels in 1986, 1987, and 1988 but has subsequently declined.

The Mexican Hog and Pork Industry

In contrast to the cattle industry where extensive production is most common, the Mexican hog and pork industry has become more developed due to both national and foreign investment and the adoption of new technologies. Consequently, the hog industry has developed a solid structure independent of weather conditions. By late 1960s and early 1970s, modern production techniques began to appear in the Mexican hog sector, mainly in the states of Sonora and Sinaloa. Technological developments permitted the industry to reduce the amount of feed per kilogram (kg) of weight gain from 5.5 kg in 1970 to 3.5 kg in 1980. Between 1960 and 1970, hog carcass weights increased from 62 kg to 70 kg per head (Gomez Cruz *et al.*)

The Mexican hog industry is composed of three types of production processes. The intensive or technified sector accounts for only 17% of the inventory but generates 35% of pork production in Mexico. The semi-technified sector accounts for 30% of the inventory and produces 35% of the meat. Finally, the rural or low technified sector accounts for 53% of the inventory but contributes only 30% of the pork production (Gomez Cruz *et al.*)

From 1971 to 1983, hog slaughter grew more than 420% (Table 2.9). Pork production followed the same trend as well as pork consumption. The following seven years, however, the industry experienced a decline due mainly to increasing costs and a drop in prices. With the cancellation of the sorghum subsidy, by which livestock producers could obtain low-priced sorghum in Mexico, the cost of feeding hogs rose considerably driving a number of small and medium-sized hog farms out of the industry. Hog inventories dropped more than 33% from 1983 to 1991, while pork production and consumption fell 47% and 45%, respectively in over that period. Pork imports began to increase at the end of the 1980s. Imports accounted for 3% of pork consumption in 1989 and 1990 and about 4% in 1991.

The Mexican Chicken Industry

The poultry industry also experienced a rapid technological change that started in the 1950s. Feeding cycles were reduced and productivity increased as a result of imported management and breeding and feeding technologies. Also feed requirements were reduced as in the case of hogs. In 1950, 4.5 kg of feed were required per kg of weight gain for poultry in Mexico. By 1988, only 2.1 kg were necessary per kg of weight gain, a drop of almost 55%. The feeding cycle of 91 days in 1950 dropped to 56 days by 1985. The structure of the industry is defined by four kinds of producers: (1) small individual producers with 2,000 to 10,000 birds that do not produce their own feed and that have little or no access to the main marketing channels; (2) associated producers, owners of 10,000 to 50,000 birds that mix their own feeds and that have access to genetic material; (3) semi-integrated producers with 50,000 to 100,000 birds; and (4) large integrated enterprises with more than 100,000 birds (Gomez Cruz *et al.*)

Sorghum is one of the main components of the balanced feed used in the poultry and the hog industries in Mexico. When the sorghum subsidy was eliminated in 1984, the poultry industry suffered a setback in the growth trend experienced during the 1970s and early 1980s. From 1970 to 1984, poultry meat production rose almost fourfold at an average annual rate of 11% (Table 2.10). The relative low cost of chicken helped to rise its consumption steadily over the last 30 years. Although chicken production did not drop as did pork production after 1984, consumption has outfaced production in Mexico leading to an increase in imports. Imports represented more than 7% of total poultry consumption in 1988.

The Mexican Feed Industry

The dynamic development of the hog and poultry sectors made the development of the animal feed industry in Mexico necessary. The Mexican animal feed industry first began to develop in about 1945. Over the period of 1960 to 1975, the industry expanded at an annual rate of 14.1% while GDP grew at only 6.6% (Burst *et al.*). From 1970 to 1987, Mexican animal feed production grew more than 57%. The main inputs of the Mexican feed industry are sorghum and soybean meal (soymeal). Sorghum represents 60% to 80% of mixed feeds while soymeal represents 15% to 20% (Gomez Cruz *et al.*). Although corn is considered a better input than sorghum from an animal nutrition standpoint, high government guaranteed corn prices and restrictions on the use of corn for feeding animals have limited its use as a feed ingredient in Mexico.

Mexican Sorghum Supply and Demand

Changes in the production of sorghum provide perhaps the best example of the Mexican orientation towards the production of livestock during the 1970s. Sorghum was produced on only 116,000 hectares (ha) in 1960 and accounted for only 1.6% of the total harvested area in Mexico. However, by 1980 sorghum area reached 1.5 million ha and 10% of the total national area in 1979, second only to corn. The increase in production during that period, however, fell short of consumption, leading to increases in imports of grain sorghum, especially in the late 1970s and early 1980s (Table 2.11). In 1982, for example, imports accounted for almost 44% of total sorghum consumption in Mexico. With growing production and increasing imports, sorghum use almost tripled from 1970 to 1985. However, after the elimination of the sorghum subsidy in 1984, use fell almost 40% in 1986. By 1990, pressure from the growing livestock industry pushed sorghum consumption back to 1985 levels.

Mexican Soybeans and Soymeal Supply and Demand

Soybean meal is important to the Mexican mixed feed industry for use in balancing livestock rations. Sorghum and soymeal rations provide a balanced ration of protein and energy for livestock. Harvested area of soybeans grew more than 300% from 1970 to 1985 with a 285% increase in production during that period (Table 2.12). As in the case of sorghum, the rate of growth of soybean consumption outfaced that of production, generating a need for imports. In the case of soybeans, however, the gap between production and consumption was much larger. Imports represented almost 60% of total soybean use during the 1980s. The use of soymeal has followed the same trend (Table 2.13). In 1984, soymeal consumption was more than six times that in 1970. Although increasing, imports have not been as important for soymeal as for sorghum or soybeans.

Mexican Corn Supply and Demand

Corn has been the main crop in Mexico for centuries. Most small farmers plant corn but much is consumed on-farm. Corn has been the most protected crop in Mexico. As a consequence, guaranteed prices have been normally higher for corn than for any other crop, limiting its use as an animal feed. Imports have not accounted for a large proportion of total corn consumption. Corn prices averaged almost 60% more per MT than sorghum prices between 1970 and 1991 (Table 2.14). NAFTA will likely boost Mexican corn imports which will increase corn supply and lower corn prices. This fact will make the use of corn as animal feed more attractive.

Mexican Agricultural Policy

Mexican agricultural policy has attempted to achieve two conflicting goals: (1) to increase agricultural output and the incomes of small farmers and (2) to provide low-priced food for poor, largely urban, consumers (Burst *et al.*). Mexican land tenure laws have worked to prevent the attainment of those goals and have had a largely negative impact on agricultural production levels by limiting land per individual to only 500 ha (Bredahl *et al.*). Government intervention has been manifest in several ways including public investment, price controls, subsidies, trade measures, etc. Engels and Segarra present a detailed description of the Mexican Government intervention in the livestock sector. Some of the following discussion of Mexican agricultural policy implications for livestock and meat are based on their work. The North American Free Trade Agreement (NAFTA) and the latest Mexican agricultural program (PROCAMPO) are also discussed.

A much criticized regulation in the Mexican Constitution limited land holdings and improvements done on the land devoted to livestock. This regulation impeded the vertical integration of livestock operations in Mexico in the past.

However, in November of 1991, a proposal was approved to reform several articles of the Constitution and modifies land tenure and improvement regulations as well as the structure and functioning of small land holdings (ejidos). This long-awaited measure had been delayed because of the potential political implications but was deemed to be an essential part of the Mexican government's economic reform program.

Public investment in the agricultural sector has been focused largely on irrigation development and technical assistance. Through the Comisión Nacional de Irrigación (National Irrigation Commission) and later the Secretaría de Recursos Hidráulicos (Secretariat of Water Resources), the Mexican Government developed 827,000 ha of irrigated land during the period from 1926 to 1946. Irrigated area increased at an average annual rate of 7.2% during the 1940s and 1950s or slightly over 100,000 ha annually. This tendency slowed somewhat during the 1960s when the development of irrigated land was about 65,000 ha per year. Irrigated area grew at an annual average of 80,000 ha in the 1970s. Technical assistance has been provided free through extension services, although it is mainly available to small land holders (ejidatarios).

The policies that have most affected the livestock sector are price controls and supply management. Cattle and beef ceiling prices have been set by the government at all levels in the market. Although pork and chicken meat prices are not controlled, the substitutability between pork and chicken meat with beef has meant that price controls on beef have affected those prices as well (Engels and Segarra). Although beef is too expensive for low income groups despite price controls, beef prices are the main indicator for pricing other meats and animal proteins. Because a maximum price for beef is set to benefit consumers, the government has often had to allow imports to rise or restrict exports to relieve upward pressure on prices.

Mexican livestock trade policy has been neither very clear nor consistent over time. Allowing imports of cheap beef from overseas helps to keep prices low in Mexico. However, Mexican authorities often restrict beef imports to respond to producer demands. At the same time, a quota on cattle exports (mainly feeder cattle) to the U.S. has existed but has often been modified according to domestic supplies. For example, in response to limited domestic supply and increased prices in 1979, live cattle and beef exports to the U.S. were temporarily suspended (Bredahl *et al.*)

One of the most important agricultural policy instrument over the years has been the guaranteed price for the principal crops produced in Mexico. This measure has allowed the government to increase or reduce the level of income of agricultural producers and to change the product mix of agricultural output as needed. On several occasions, the state-run agricultural marketing board (CONASUPO) has subsidized feed and livestock producers selling crops at prices below the purchase price. Imports of feed inputs and of animal proteins have also been controlled by the government. Historically, government agencies like Conasupo have been responsible for grain imports and they could store or sell the grain in order to enforce the guaranteed price policy (Burst *et al.*)

Credit has been subsidized through several official institutions especially to low and middle income producers. Official banks used to lend money sometimes below the average of costs paid by banks in Mexico. Undervaluation of the peso has also been used as a trade policy to stimulate exports and reduce imports. Insurance, rail transportation, fuel (diesel), and genetic inputs like breeding stocks, are forms of subsidy given to Mexican producers, especially ejidatarios.

PROCAMPO is the latest of a series of measures intended to bring support to the Mexican agriculture. This innovative program, however, includes direct support for farmers for the first time in Mexican agricultural policy. With this support, the Mexican Government intends to gradually eliminate the implicit subsidy that was in effect through guaranteed prices. This kind of support will be assigned on a hectare basis, thus reaching even those farmers that produce for self-consumption. Prices will likely decrease gradually until they reach the international level (Salinas, 1993). In this way, prices reflecting international levels will benefit consumers with low prices. Producers will receive a transfer from the government regardless of prices or production levels.

Non-tariff border measures have played an important role in economic policy in Mexico. For example, 60% of the total value of imports required import permits in 1980. However, although traditionally a protectionist country, Mexico started a trade liberalization process in the mid-1980s. Mexico became the 92nd member of the General Agreement of Tariffs and Trade (GATT) in 1986. Searching for an economic realism that was absent in the 1970s and the early 1980s, Mexico accelerated its trade liberalization process in the late 1980s. By 1990, only a small number of products continued to have an import permit requirement. Carlos Salinas de Gortari, who took office in December of 1988, continued the efforts toward freer trade. In April of 1990, a Mexican forum on the commercial relationships between Mexico and the world drew several important conclusions (Nacional Financiera). One of them was that commercial relationships with the U.S. and Canada should be strengthened, given the geographical proximity of those two countries. Given that a free trade agreement (FTA) already existed between Canada and U.S., the possibility of signing an FTA between Mexico and U.S. seemed reasonable. Canada asked to be included in a three-way FTA. The North American Free Trade Agreement (NAFTA) was approved in 1993 by the three participant countries and entered in force on January 1, 1994.

NAFTA

The NAFTA intended to form a free trade zone of more than 360 million people with an estimated GNP of 6,000 billion dollars. This trade zone is now the largest free trade area in the world. NAFTA deals with a reduction of tariff and non-tariff barriers among these three countries without interfering in the commercial policies toward third countries. The NAFTA is intended to gradually eliminate tariffs and non-tariff barriers and develop a just and rapid mechanism to solve controversies.

Several impacts are expected as a result of the NAFTA. Among the expected effects are an increase in the trade of livestock and livestock products, with Mexican feeder cattle exports to the U.S. accounting for most of the expansion (Rosson *et al*.) Also, increased imports of processed meat by Mexico are expected, particularly if the expected increase in Mexican per capita incomes take place. If the U.S. has a comparative advantage in producing grains, as many say, Mexico could develop a grain-fed beef industry using cheaper grain from the U.S. and Mexican cheap labor. A phased reduction of tariff barriers is expected. The section on simulation analysis provides an analysis of the likely implications of freer U.S.-Mexico trade for the Mexican livestock, meat, and feedgrain sectors.

Summary

This section has presented the characteristics of the Mexican livestock, meat and feedgrain sectors. Livestock and meat production flourished during the 1970s prompting the expansion of the feed sector. Beef has traditionally been the main meat consumed by Mexicans. However, during the mid-1970s to mid-1980s, pork had a bigger consumption share than beef. After the 1982 Mexican economic crisis, meat consumption decreased dramatically. Chicken emerged as a cheap alternative for beef and pork. Since the early 1980s, real meat and livestock prices have been declining consistently. Chicken prices, however, have dropping in real terms since the early 1970s. The Mexican government has influenced the trade of livestock and meat as well as of the feedgrains. Sorghum and soymeal constitute the main components of animal feed in Mexico. Although corn is a close substitute for sorghum, price and Mexican regulations have limited its use as on animal feed. Cheap corn coming from the U.S. might mean more livestock consumption of corn.

PROCAMPO is the latest program of the Mexican government intervention in agriculture. This program, however, intends to gradually eliminate the guaranteed price scheme and to bring agricultural prices to a world level. Mexican government has influenced the livestock and the feedgrain sectors mainly by imposing ceiling prices to beef and by controlling trade. However, Mexico started a trade liberalization in 1986 that resulted in the NAFTA.

Table 2.1. Mexico: Agriculture and Livestock Production as Percentage of Primary Sector and Total GNP

	Share of Primary GNP		Share of Total GNP		
Year	Agriculture	Livestock	Agriculture	Livestock	Agr.+Liv.
	%	%	%	%	%
1970	58.40	36.16	7.09	4.39	11.48
1971	59.42	35.43	7.17	4.28	11.45
1972	58.03	36.22	6.42	4.01	10.43
1973	57.89	36.49	6.71	4.23	10.94
1974	57.87	36.57	6.67	4.21	10.88
1975	57.21	37.35	6.37	4.16	10.53
1976	56.10	38.26	5.95	4.06	10.01
1977	57.30	36.61	6.02	3.85	9.87
1978	58.37	35.55	5.98	3.64	9.62
1979	56.12	37.06	5.14	3.40	8.54
1980	58.85	32.78	4.85	2.70	7.55
1981	59.77	31.90	4.80	2.56	7.36
1982	57.83	33.46	4.58	2.65	7.23
1983	58.45	33.34	4.73	2.70	7.43
1984	58.71	32.80	4.91	2.74	7.65
1985	59.73	31.92	5.05	2.70	7.75
1986	58.18	33.48	4.98	2.86	7.84
1987	58.97	32.09	5.04	2.74	7.78
1988	58.24	32.29	4.73	2.62	7.35
1989	58.52	31.89	4.48	2.44	6.92
1990	60.47	30.70	4.69	2.38	7.07
1991	60.00	31.25	4.53	2.36	6.89

Source: Carlos Salinas de Gortari. *Quinto Informe de Gobierno*. Noviembre 1993.

Table 2.2. Mexico: Meat Production. Mexican Data

Year	Beef	Pork	Chicken	Total
	Thousands of Metric Tons			
1970	436	239	74	749
1971	459	251	78	788
1972	706	572	215	1493
1973	735	641	229	1605
1974	752	719	248	1719
1975	770	810	269	1849
1976	845	909	288	2042
1977	887	1009	310	2206
1978	948	1084	335	2367
1979	993	1166	366	2525
1980	1065	1250	399	2714
1981	1163	1306	426	2895
1982	1200	1365	449	3014
1983	1030	1485	468	2983
1984	962	1455	489	2906
1985	979	1293	588	2860
1986	1247	959	672	2878
1987	1272	914	672	2858
1988	1217	861	627	2705
1989	1162	726	611	2499
1990	1113	757	750	2620
1991	1188	811	857	2856
Mean	960	935	428	2324
St. Dev.	241	347	213	688

Source: Carlos Salinas de Gortari. *Quinto Informe de Gobierno*. Noviembre 1993.

Table 2.3. Mexico: Meat Production. USDA Data

Year	Beef	Pork	Chicken	Total
	Thousands of Metric Tons			
1970	590	317	79	986
1971	581	351	84	1016
1972	625	573	241	1439
1973	664	651	245	1560
1974	700	731	285	1716
1975	1038	811	244	2093
1976	1079	735	271	2085
1977	990	653	280	1923
1978	1038	781	296	2115
1979	1116	838	328	2282
1980	1209	921	411	2541
1981	1271	852	446	2569
1982	1381	1009	467	2857
1983	1229	1136	435	2800
1984	1323	942	474	2739
1985	1339	865	502	2706
1986	1200	911	472	2583
1987	1205	950	409	2564
1988	1754	980	540	3274
1989	2140	937	633	3710
1990	1790	817	694	3301
1991	1670	855	781	3306
Mean	1179	801	392	2371
St Dev.	412	199	179	733

Source: Mexico: Livestock Data, *PS&D View* USDA/ERS 1992.

Table 2.4. Mexico: Per Capita Meat Consumption

Year	Beef	Pork	Chicken	Total
	Thousands of Metric Tons			
1970	7.60	4.71	1.46	13.77
1971	7.84	4.79	1.49	14.12
1972	11.96	10.54	3.96	26.46
1973	12.43	11.59	4.11	28.13
1974	12.59	12.58	4.30	29.47
1975	12.47	13.48	4.54	30.49
1976	13.08	14.67	4.73	32.48
1977	13.21	15.86	4.94	34.01
1978	13.77	16.63	5.19	35.59
1979	14.65	17.42	5.57	37.64
1980	15.29	18.10	5.90	39.29
1981	16.41	18.53	6.25	41.19
1982	16.50	18.84	6.31	41.65
1983	13.78	19.89	6.33	40.00
1984	12.61	19.07	6.53	38.21
1985	12.65	16.59	7.70	36.94
1986	15.67	12.06	8.62	36.35
1987	15.71	11.26	8.45	35.42
1988	14.87	10.59	8.17	33.63
1989	14.18	8.91	7.74	30.83
1990	13.27	9.08	9.10	31.45
1991	14.00	9.63	10.11	33.74

Source: Carlos Salinas de Gortari. *Quinto Informe de Gobierno*. Noviembre 1993.

Table 2.5. Mexico: Shares of Meat Consumption

Year	Beef	Pork	Chicken
	%	%	%
1970	55.19	34.20	10.61
1971	55.52	33.92	10.56
1972	45.20	39.83	14.97
1973	44.19	41.20	14.61
1974	42.72	42.69	14.59
1975	40.90	44.21	14.89
1976	40.27	45.16	14.57
1977	38.84	46.63	14.53
1978	38.69	46.73	14.58
1979	38.92	46.28	14.80
1980	38.92	46.07	15.01
1981	39.84	44.99	15.17
1982	39.62	45.23	15.15
1983	34.45	49.73	15.82
1984	33.00	49.91	17.09
1985	34.24	44.91	20.85
1986	43.11	33.18	23.71
1987	44.35	31.79	23.86
1988	44.22	31.49	24.29
1989	45.99	28.90	25.11
1990	42.19	28.87	28.94
1991	41.49	28.54	29.97

Source: Carlos Salinas de Gortari. *Quinto Informe de Gobierno*. Noviembre 1993.

Table 2.6. Mexico: Livestock and Meat Prices

Year	FPC	RPB	FPH	RPP	RPCH
	1978 Mexican Pesos				
1970	16.04	56.10	28.40	54.10	36.04
1971	17.68	59.91	31.50	47.00	34.41
1972	17.29	61.04	31.90	52.10	36.26
1973	18.87	69.70	32.80	50.20	33.16
1974	21.70	63.66	33.20	46.70	33.12
1975	18.48	60.54	31.70	44.20	31.98
1976	19.64	52.38	29.50	40.50	31.77
1977	20.23	57.67	31.90	38.30	30.07
1978	19.74	62.95	35.50	39.20	30.14
1979	22.18	72.32	34.60	40.90	31.85
1980	22.13	65.83	37.00	46.30	32.38
1981	25.23	63.00	37.50	44.90	32.36
1982	24.78	70.17	40.00	48.60	24.79
1983	26.38	61.86	36.10	43.40	23.83
1984	20.21	73.90	38.60	45.20	21.60
1985	21.14	71.34	37.00	42.80	22.77
1986	24.87	91.31	36.92	37.63	22.57
1987	24.46	54.39	30.50	33.61	20.83
1988	22.47	57.18	25.53	34.28	22.02
1989	23.69	65.94	22.68	42.00	22.24
1990	17.59	57.39	21.75	36.62	23.56
1991	19.32	53.99	21.77	38.57	21.12

Note: FPC = Farm Price of Cattle.

RPB = Retail Price of Beef.

FPH = Farm Price of Hogs.

RPP = Retail Price of Pork.

RPCH = Retail Price of Chicken.

Source: Roberto Garcia Mata.

Table 2.7. Mexico: Livestock Inventories

Year	Cattle Inventories (1)	Cattle Inventories (2)	Cattle Inventories (3)	Hog Inventories (1)	Hog Inventories (2)	Hog Inventories (3)
	1,000 Heads					
1970	25499	21136	24876	10541	9462	10297
1971	26265	21247	26053	10747	9555	9970
1972	27335	21397	27335	11372	10015	11372
1973	28103	21506	28105	11743	10244	11743
1974	28816	21606	28816	12313	10639	12313
1975	29602	21714	29200	13179	11280	13179
1976	30461	21830	29900	14097	11951	14100
1977	31410	21956	30410	14814	12440	14200
1978	32439	22091	31300	15534	12921	15534
1979	33545	22233	32150	16233	13375	16200
1980	34590	22365	33000	16890	13784	16680
1981	35689	22503	34000	17562	14197	16480
1982	37191	22801	34700	18096	14490	17150
1983	37522	22959	33873	19364	15359	16460
1984	30374	22222	33917	19393	15236	13137
1985	31489	22477	33853	17233	13411	12320
1986	35237	23046	32167	18397	14181	13115
1987	34565	23089	33603	18722	14295	12357
1988	33756	23118	35378	15884	12013	10879
1989	33068	23162	34999	16157	12104	9003
1990	32054	23170	31747	15203	11281	8563
1991	31822	23271	30005	15902	10260	8593
Mean	1856	22314	31336	15426	12386	31336
St. Dev.	3344	696	2998	2781	1865	2722

Sources: (1) Carlos Salinas. *Cuarto Informe de Gobierno*. Noviembre 1992.

(2) Carlos Salinas. *Quinto Informe de Gobierno*. Noviembre 1993.

(3) USDA. *PS&D View*.

Table 2.8. Mexico: Cattle and Beef S upply, Demand, and Trade

	Cattle				Beef and Veal			
Year	Stocks	Imports	Exports	Slaughter	Production	Imports	Exports	Consumption
	1,000 Heads				1,000 Metric Tons			
1970	21136	13	934	2567	436	1	52	385
1971	21247	15	757	2697	459	1	49	411
1972	21397	23	968	3391	706	1	58	649
1973	21506	34	553	3737	735	1	38	698
1974	21606	39	363	3891	752	0	20	732
1975	21714	38	269	3995	770	1	21	750
1976	21830	42	528	4214	845	1	35	811
1977	21956	30	535	4387	887	1	45	843
1978	22091	34	905	4493	948	1	45	904
1979	22233	26	446	4887	993	2	6	989
1980	22365	17	340	5255	1065	1	1	1065
1981	22503	79	365	5733	1163	9	1	1171
1982	22801	74	339	5787	1200	18	13	1205
1983	22959	8	600	4872	1030	12	13	1029
1984	22222	167	440	4751	962	0	0	962
1985	22477	119	188	4664	979	7	0	986
1986	23046	57	860	6030	1247	1	1	1247
1987	23089	39	1019	5919	1272	4	0	1276
1988	23118	218	981	5660	1217	15	0	1232
1989	23162	104	945	5644	1162	40	4	1198
1990	23170	354	1351	5254	1113	35	5	1143
1991	23271	227	1030	4539	935	50	8	977

Source: Carlos Salinas de Gortari. *Quinto Informe de Gobierno*. Noviembre 1993.

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Table 2.9. Mexico: Hogs and Pork Supply, Demand, and Trade

Year	Hogs		Pork			
	Stocks	Slaughter	Production	Imports	Exports	Consumption
	1,000 heads		1,000 Metric Tons.			
1970	9462	3691	239	0	0	239
1971	9556	3880	251	0	0	251
1972	10015	8291	572	0	0	572
1973	10244	8190	641	11	1	651
1974	10640	10199	719	12	0	731
1975	11280	11345	810	1	0	811
1976	11952	12629	909	2	2	909
1977	12441	13891	1009	5	2	1012
1978	12922	14876	1084	9	1	1092
1979	13375	15931	1166	11	1	1176
1980	13785	17058	1250	11	0	1261
1981	14198	17826	1306	16	0	1322
1982	14491	18602	1365	11	0	1376
1983	15359	20216	1485	1	1	1485
1984	15237	19881	1455	1	1	1455
1985	13411	17715	1293	1	1	1293
1986	14182	12963	959	1	0	960
1987	14296	11997	914	0	0	914
1988	12014	12662	861	16	0	877
1989	12104	11180	726	27	0	753
1990	11282	11443	757	25	0	782
1991	10261	12163	790	35	0	825

Source: Carlos Salinas de Gortari. *Quinto Informe de Gobierno*. Noviembre 1993.

Table 2.10. Mexico: Chicken Supply, Demand, and Trade

Year	Production	Imports	Consumption
	1,000 Metric Tons		
1970	74	0	74
1971	78	0	78
1972	215	0	215
1973	229	2	231
1974	248	2	250
1975	269	4	273
1976	288	5	293
1977	310	5	315
1978	335	6	341
1979	366	10	376
1980	399	12	411
1981	426	20	446
1982	449	12	461
1983	468	5	473
1984	489	9	498
1985	588	12	600
1986	672	14	686
1987	672	14	686
1988	627	50	677
1989	611	45	656
1990	750	39	789
1991	857	37	894

Source: Carlos Salinas de Gortari. *Quinto Informe de Gobierno*. Noviembre 1993.

Table 2.11. Mexico: Sorghum Production, Consumption, Trade, and Prices

Year	Harv. Area	Production	Imp. (Exp.)	Consumption	Price
	1,000 Has.	1,000 Metric Tons			1978 Pesos
1970	971	2747	(18)	2729	34000
1971	937	2565	(21)	2544	34050
1972	1109	2612	246	2858	35048
1973	1185	3270	13	3283	35333
1974	1156	3459	466	3925	43724
1975	1445	4126	835	4961	49188
1976	1251	4027	44	4071	42564
1977	1413	4325	715	5040	35679
1978	1399	4193	752	4945	35094
1979	1164	3958	1293	5251	32908
1980	1543	4689	2252	6941	36684
1981	1684	5086	3631	8717	33551
1982	1434	4712	3646	8358	33962
1983	1528	4867	3330	8197	32097
1984	1636	5038	2311	7349	37255
1985	1862	6597	2222	8819	34160
1986	1533	4833	782	5615	43413
1987	1853	6298	766	7064	34522
1988	1800	5835	1207	7042	35839
1989	1620	5002	2665	7667	33236
1990	1820	5978	2856	8834	29760
1991	1340	4308	3200	7508	32312

Source: Carlos Salinas de Gortari. *Quinto Informe de Gobierno*. Noviembre 1993. Canacintra.

Table 2.12. Mexico: Soybeans Production, Consumption, Trade, and Prices

Year	Harv. Area	Production	Imp. (Exp.)	Consumption	Price
	1,000 Has.	1,000 Metric Tons			1978 Pesos
1970	112	215	102	317	86053
1971	128	255	68	323	82900
1972	222	377	11	388	85381
1973	312	565	62	627	126250
1974	300	491	435	926	113690
1975	344	599	22	621	104688
1976	172	302	348	650	106436
1977	314	515	526	1041	93071
1978	217	334	681	1015	89484
1979	379	707	589	1296	85434
1980	154	322	522	844	80958
1981	362	707	1110	1817	91415
1982	383	645	485	1130	83076
1983	391	688	883	1571	85793
1984	389	685	1308	1993	89754
1985	476	829	1319	2148	86064
1986	381	709	827	1536	86825
1987	470	828	1062	1890	104528
1988	139	225	1099	1324	84123
1989	490	932	1170	2102	91751
1990	286	575	897	1472	64443
1991	326	725	1489	2214	63076

Source: Carlos Salinas de Gortari. *Quinto Informe de Gobierno*. Noviembre 1993. Canacintra.

Table 2.13. Mexico: Soymeal Production, Consumption, Trade, and Prices

Year	Production	Imports	Consumption	Price
	1,000 Metric Tons			1978 Pesos
1970	230	0	230	110526
1971	197	99	296	110000
1972	271	54	325	104762
1973	460	96	556	164583
1974	635	43	678	125862
1975	455	3	458	110313
1976	477	0	477	128205
1977	758	181	939	108929
1978	789	91	880	94531
1979	806	230	1036	86842
1980	905	350	1255	96842
1981	757	30	787	91525
1982	891	38	929	114130
1983	1278	68	1346	84555
1984	1447	44	1491	102765
1985	1368	85	1453	84000
1986	1211	80	1291	116773
1987	1157	49	1206	114891
1988	923	332	1255	97561
1989	1525	237	1762	67239
1990	984	158	1142	64355
1991	1477	256	1733	62990

Source: Carlos Salinas de Gortari. *Quinto Informe de Gobierno*. Noviembre 1993. Canacintra.

Table 2.14. Mexico: Corn Production, Consumption, Trade, and Prices

Year	Harv. Area	Production	Imports	Consumption	Price
	1,000 Has.	1,000 Metric Tons			1978 Pesos
1970	7440	8879	761	9638	47368
1971	7692	9786	18	9530	45000
1972	7292	9223	203	9001	42857
1973	7606	8609	1145	9723	46354
1974	6717	7848	1282	9129	50431
1975	6694	8449	2661	11104	58203
1976	6783	8017	914	8927	71794
1977	7470	10138	1985	12122	51075
1978	7191	10930	1418	12347	45400
1979	5581	8458	746	9203	46500
1980	6766	12374	4187	16561	53712
1981	7669	14550	2955	17504	59727
1982	5824	10767	250	11017	90730
1983	7421	13188	4645	17833	63662
1984	6893	12788	2428	15216	61537
1985	7590	14103	2223	16323	76198
1986	6417	11721	1703	13420	73036
1987	6801	11607	3602	15201	84126
1988	6506	10600	3302	13896	42529
1989	6470	10953	3648	14600	39215
1990	7339	14635	4102	18737	46145
1991	6947	14252	1422	15658	44430

Source: Carlos Salinas de Gortari. *Quinto Informe de Gobierno*. Noviembre 1993. Canacintra.

CONCEPTUAL MODEL OF THE MEXICAN LIVESTOCK, MEAT, AND FEEDGRAIN SECTORS

This section lays out the conceptual model of the Mexican livestock, meat, and feed sectors. First, the underlying assumptions and the conceptual framework used to construct the model are discussed. Then, the livestock and meat supply model component is presented followed by the feed supply and demand component of the model. Three alternative specifications for the meat demand model component and their characteristics are discussed later. Finally, the full conceptual model which integrates the livestock and meat supply component with each of the alternative meat demand model components is laid out and discussed in detail. The full conceptual model is the basis for the statistical model estimated in the empirical analysis section and used in the simulation analysis section to analyze the likely effects of the freer U.S.-Mexico trade on the Mexican livestock, meat, and feedgrain markets.

The complete Mexican livestock, meat, and feedgrain model includes ten commodities: three types of livestock (cattle, hogs, and chicken), three types of meat (beef, pork, and chicken meat), and four feeds (sorghum, soybean, soymeal, and corn). For every commodity there is a set of equations depicting behavioral relationships of supply and demand and a market clearing condition. The conceptual framework for each group of commodities (livestock, meat, and feeds) will first be discussed in general terms.

Underlying Assumptions of the Mexican Livestock, Meat, and Feedgrain Model

As discussed in the background section, the Mexican government has set quotas on imports and exports of beef and cattle in the past as a means of controlling beef prices. Whenever there was a threat of raising beef prices because of a decrease in the domestic beef supply, the Mexican government tended to restrict cattle exports and to open the border to beef imports. A similar situation occurs with feedgrains. Controls on imports of feed inputs and of animal proteins have been used by the Mexican government to enforce the "guaranteed price" policy. Although the situation is changing under NAFTA, the import and export of most agricultural products have been controlled by the government via permits and/or tariffs. The practical implications of these policies for modeling purposes is that imports and exports can be assumed to have been exogenously determined over much of the historical period. Animal bearing rates and production yields depend on technology developments which are also exogenous to this model. Input costs and credit availability, as well as non-feed use of feeds are also assumed to be exogenous. Weights used in the calculation of grain consuming animal units are also assumed to be determined by technology and, therefore, exogenous. Finally, economic and demographic variables such as consumer price index, wholesale price index, total population, and real per capita income are considered to be exogenous to the Mexican livestock and feed sectors.

Conceptual Framework for Livestock

The livestock supply system includes cattle, hogs, and chicken. The well-known work of Jarvis provides a framework for treating livestock inventories as capital goods and farmers as portfolio managers. Farmers are assumed to base their decisions about livestock breeding herd size on the expected profitability of raising animals. The breeding herd size is assumed to adjust slowly to the desired optimum long-run level. At the same time, profit expectations are assumed to be updated each time period based on the current forecasting error. Under this set of assumptions and following some other studies (Wahl, Gong, Tsai), producer decisions may be represented by the following theoretical breeding herd inventory model:

(3.1) $H^*_t = f(\Pi^e_{t-1}, Z_t)$,

where H^*_t is the desired breeding herd size at the end of period t, Π^e_{t-1} represents the expected profitability of raising livestock in the following period, and Z represents other exogenous variables that occur at time period t that may influence the level of desired inventory.

Assuming a partial adjustment framework and adaptive price expectations, equation (3.1) may be derive to:

(3.2a) $H_t - H_{t-1} = \tau(H^*_t - H_{t-1})$ $\quad$ $(0 \leq \tau \leq 1)$ and
(3.2b) $\Pi^e_{t-1} - \Pi^e_t = \upsilon(\Pi_t - \Pi^e_t)$ $\quad$ $(0 \leq \upsilon \leq 1)$,

where τ is the coefficient of adjustment and υ is the coefficient of expectation. Equation (3.2a) suggests that the breeding inventory herd adjusts only partially each period due to biological restrictions and adjustment costs. Equation (3.2b) assumes that the change in expected profit in period t+1 is proportional to the current error in forecasting.

Assuming a linear form and combining (3.1), (3.2a), and (3.2b) the breeding herd equation is estimated as follows:
(3.3) $H = a_0 + a_1\Pi + a_2H_{t-1} + a_3H_{t-2} + a_4Z + a_5Z_{t-1}$,
where $a_0 = \tau\upsilon\alpha$,
$a_1 = \tau\upsilon\beta$,
$a_2 = [(1-\tau) + (1-\upsilon)]$,
$a_3 = (1-\tau)(1-\upsilon)$,
$a_4 = \tau\epsilon$,
$a_5 = \tau(1-\upsilon)\epsilon$.

Also, α is the intercept and β and ϵ are the coefficients of the variables in the linear form of (3.1).

Feeder livestock inventories each year depend upon the offspring born in current and past periods. As a biological limit, cows generally have only one offspring per year while swine may bear more than one in the same period. Offspring, which are the supply of "new animals", are determined by the beginning breeding herd inventory and the bearing rate. Hence, the offspring born and the feeder inventory are modeled as:

(3.4) $Off = H * BR$
(3.5) $F = F(Off, Off_{t-1})$,

where Off represents the livestock offspring born, BR is the bearing rate, F is the ending feeder inventory, and H is still breeding inventory.

Farmers decide upon the usage of the available supply of livestock based on their profit expectations. Following Jarvis, livestock may be used for slaughter or can be held in inventory depending upon price behavior. If the farm price of livestock is high, then farmers might follow an investment behavior, that is, farmers may hold animals in inventory in order to profit from future greater inventories. On the other hand, if the retail price of meat is high, farmers will send more livestock to slaughter to take advantage of higher current output prices. In addition, the greater the supply of animals available (beginning feeder inventories), the more animals that can be slaughtered. Hence, slaughter livestock behavior is specified as follows:

(3.6) $Sl = Sl(RPM, FPL, F_{t-1})$,

where Sl is the total number of animals slaughtered, RPM represents the retail price of the meat, FPL is the farm price of the livestock, and all other variables are as defined before.

Market clearing conditions require total supply to be equal to total demand. Total supply of livestock in a given period is composed of beginning inventories of both breeding and feeder livestock, the offspring born during the period, and livestock imports. Total demand for livestock is the summation of livestock slaughter, total ending inventories, and livestock exports. The residual of this identity is accounted for by livestock loss and statistical discrepancy. The market clearing condition for livestock can be specified as:

(3.7) $H_{t-1} + F_{t-1} + Off + Ml = Sl + H + F + Xl + LD$,

where Ml and Xl are livestock imports and exports, respectively, LD is the loss and statistical discrepancy, and all other variables as defined earlier.

Because the reproductive cycle for chicken is only five to six weeks, chicken inventory behavior cannot be considered within an annual model. Slaughter of chicken, however, can be modeled to capture profit expectations of farmers. If chicken prices raise, farmers are encouraged send more chicken to slaughter. The opposite is true if the price of feed goes up. Hence, chicken slaughter behavior may be modeled as:

(3.8) Slch = Slch(RPch, PF, Z),

where Slch represents slaughter of chicken, RPch is the retail price of chicken, PF is the price of feed, and Z represent other factors such as technological change.

Conceptual Framework for Meat

Meat production depends upon slaughter. The higher the slaughter of animals the greater the production of meat. The total supply of meat includes both meat production and imports of meat. Per capita demand for meat is expected to be influenced by the own price of the respective meat, the prices of substitute meats, and the level of per capita income. Specification for meat demand is widely discussed later in this section. The supply, demand, and the market clearing condition for each meat type is defined as follows:

(3.9) TPM = Sl * CW
(3.10) PDM = TDM / Pop
(3.11) PDM = PDM(RPM, RPS_1, RPS_2, PI)
(3.12) TPM + MM = TDM + XM,

where TPM is total production of meat. CW represents the livestock average carcass weight. PDM denotes per capita demand of meat. TDM means total demand for meat. Pop indicates total population. RPS_1 and RPS_2 are the price of substitutes one and two, respectively. PI represents per capita income. MM and XM are imports and exports of meat, respectively. All other variables as defined earlier.

Conceptual Framework for Feedgrains

As Gomez Cruz *et al.* state, sorghum and soymeal represent roughly 90% of livestock mixes in Mexico. Although official regulations limit its use as animal feed input, corn is considered (and frequently used) as a substitute for sorghum. The behavior of the feed industry has been highly influenced by the livestock industry (see background section). For instance, feed demand behavior has been mainly determined by the behavior of livestock inventories. The price of the respective feed and the price of substitute feeds also affect quantities demanded. Feed supply is determined by area planted and yield of the respective crops. The area planted of each crop is determined mainly by farmer's profit expectations. Farmers are normally assumed to follow naive expectation pattern, i.e. the desired current planted area of a given feedgrain is a function of lagged profit from producing the feedgrain and other exogenous variables like expected weather and credit availability. The area harvested is a function of the planted area. Crop production is determined by the area harvested times a technologically determined crop yield. As mentioned before, this factor is considered to be exogenously determined.

The supply model for sorghum, soybean, and corn can be, thus, specified as:

(3.13) AP = AP(AP_{t-1}, PF_{t-1}, Z)
(3.14) AH = AH(AP)
(3.15) TPF = AH * CY,

where AP symbolizes area planted; PF means price of feed; Z represents some exogenous variables such as rain, input costs, or available credit; AH is area harvested; TPF is total production of feed; and CY is the crop yield per unit of area.

Production of soymeal follows a different behavior since it depends on the amount of soybean crushed. Hence, the specification for soymeal production is:

(3.16) PSM = CDSB * SMY,

where PSM symbolizes production of soymeal, CDSB is the crush demand for soybeans explained later, and SMY is the meal yield factor obtained from soybeans.

Feed demand for sorghum, soymeal, and corn is presented next. As discussed earlier, feed demand is affected by the number of grain consuming animal units, the price of the specific feed, and the prices of substitute feeds. Grain consuming animal units is the number of livestock and poultry animals weighted by the roughage consumption factors developed for high-energy, low-fiber feeds (ERS-USDA S.B.#530). Feed demand is specified as:

(3.17) FD = FD(GCA, PF, Pfs),

where FD is feed demand; GCA represents grain consuming animal units; PF is feed price; and PFs is the price of a substitute feed.

Soybean demand is structured differently due to its characteristic as an intermediate good. Crush demand for soybeans is affected by input and output prices. Also, availability of soybeans and installed capacity for crushing should have a strong influence on the volume of soybeans crushed. The crush demand for soybeans is specified as follows:

(3.18) CDSB = CDSB(PSB, PSM, SSB, CC),

where CDSB is as defined earlier; PSB is the input price (soybean price); PSM is the output price (soymeal price); SSB means supply of soybeans; and CC indicates crush capacity.

The market clearing conditions for each feed would be specified as:

(3.19) MF + TPF = FD + NFD + XF,

where MF and XF represent imports and exports of feed, respectively; NFD indicates non-feed demand; and the rest of the variables as defined earlier.

The Mexican Livestock and Meat Supply Model

Figure 3.1, 3.2, and 3.3 depict the flow of relationships for the cattle and beef, hog and pork, and chicken and chicken meat industries, respectively. Circles are used to indicate the variables that are estimated within the model (endogenous variables) while squares indicate those variables that are determined independently of the model estimation (exogenous variables). Dashed lines indicate a lagged relationship among variables.

Total cattle supply is composed by lagged feeder and breeding inventories, the calves born, and the imports of cattle (Figure 3.1). The supply of cattle either remains on inventory or is slaughtered or exported. Cattle loss and statistical discrepancy is shown as a residual. The number of calves born are determined by the inventory of breeding cattle and the bearing rate. Cattle breeding inventories are affected by the farm price of cattle, the producer price of feed which comes from the feed model, and by other exogenous variables. Farm price of cattle and retail price of beef as well as lagged supply of total cattle determine the number of slaughtered cattle. The cattle slaughtered and the average carcass weight determine the total production of beef. Total supply of beef is composed by total production and imports of beef. Consumption of beef is affected by retail prices of beef, pork, and chicken and by per capita income as shown in Figure 3.1.

Figure 3.2 depicts the behavioral relationships for the hog and pork sectors in a similar way to cattle and beef. Chicken and chicken meat sector behavior is described in Figure 3.3. Slaughter of chicken is influenced by the farm price of feed (determined in the feed model), the retail price of chicken and other exogenous factors. Chicken meat production depends directly upon the number of slaughtered chickens and the technologically determined chicken average carcass weight. Chicken consumption, as in the case of beef and pork, is affected by the prices of chicken, beef, and pork and per capita income.

Table 3.1 contains the set of equations that illustrate the supply behavior of the Mexican livestock and meat sectors. Equation [3.1] follows the behavior of the general livestock equation (3.3). Ending inventory of breeding cattle is a function of the expected profit of raising cattle as represented by the ratio of farm price of cattle (FPC) and the producer price of feed (PPF). Lagged breeding inventories and some exogenous variables (Z) also affect the breeding herd size decision of farmers. Ending inventories of feeder cattle in a given year (EIFC) are modeled, following eq. (3.4), as a function of the number of calves born during the present and past periods (equation [3.3]). Calves born are determined by multiplying the beginning inventory of breeding cattle and the corresponding calving rate factor (CR), as shown in eq. [3.2] in Table 3.1.

Equation [3.4] in Table 3.1 specifies the slaughter behavior for cattle (SLTC). The retail price of beef (RPB), the farm price of cattle (FPC), and the available supply of slaughter animals (EIFC) determine the level of cattle slaughter each year. This behavior was described in equation (3.6) in the previous section. The market clearing condition for cattle is given in equation [3.5] in Table 3.1.

Beef production is presented in equation [3.6] in Table 3.1 following the specification of text equation (3.9) in the previous section. Total production of beef (TPB) is obtained by multiplying the amount of cattle slaughtered and the average carcass weight (CACW).

The demand for beef as shown on figure 3.1 is affected by beef, pork, and chicken prices and by per capita income. As explained earlier, demand specifications will be discussed in more detail later. The market clearing condition for beef is shown in equation [3.7].

The hog and pork sector behaves in a similar fashion to that of cattle and beef. Ending breeding inventories of sows (EIBS) (equation [3.8] in Table 3.1) and ending feeder pig inventories (EIFP) (equation[3.9] in Table 3.1) follow the same specification as equations [3.1] and [3.2] for the cattle sector. The expected profit for raising hogs (FPH/PPF), lagged inventories, and exogenous variables (Z) influence farmers' decisions about hog breeding herd size (equation[3.8] in Table 3.1).

The number of piglets born (PB) is determined by the product of breeding inventories (EIBS) and the birth rate of pigs (PR) (equation [3.9] in Table 3.1). The slaughter of all hogs (SLHG) is a function of the farm price of hogs (FPH), the retail price of pork (RPP), and feeder pig inventories (EIFP) (equation [3.10] in Table 3.1).

Equation [3.12] is the hogs market clearing identity. Beginning inventories of feeder and breeding hogs plus piglets born and the imports of hogs constitute the supply of animals in the hog industry. The demand for hogs includes hog slaughter, exports of hogs, and ending inventories of feeder and breeding inventories. Again, loss and statistical discrepancy (LD) constitute the residual in the market clearing condition.

Total production of pork (TPP) is the product of the number of hogs slaughtered and the average carcass weight of hogs (HACW)(equation [3.13] in Table 3.1). Equation [3.14] is the market clearing condition for pork.

The slaughter of chickens is specified to be a function of the retail price of chicken (RPCH), the producer price of feed (PPF), and some exogenous factor (Z) (equation [3.15] in Table 3.1). Total production of chicken meat (TPCH) is the product of the number of chickens slaughtered (SLCH) and their average carcass weight (CHCW) (equation [3.16] in Table 3.1). Finally, equation [3.19] is the market clearing condition for chicken meat.

The Mexican Feed Supply and Demand Model

Figure 3.4 presents a flow chart indicating the relationships within the feed sector and between the feed and the livestock model. Area planted of sorghum, soybean, and corn are affected by lagged farm prices and input costs. The area planted of a crop determines the corresponding area harvested. Production of a particular feed is determined by the area harvested and the production yield per hectare (Figure 3.4). Feed demand is affected by prices and by the number of grain consuming animal units which is determined within the livestock sector. A weighted average of prices determine the producer price of feed which feeds into the livestock sector as discussed before.

Equations [3.18] to [3.37] in Table 3.2 detail the feed supply and demand behavior. The feed market is important to the livestock sector because feed prices are a major component of livestock production costs. As discussed earlier, breeding herd size and the number of animals slaughtered each year are affected by the market price of feed. At the same time, there is a feedback from the livestock sector to the feed industry because the larger the inventory of livestock, the greater the demand for feed.

As explained in equation (3.13), area planted is hypothesized to be affected by lagged area planted, lagged farm price, and other exogenous factors (Z). A higher lagged price is expected to encourage farmers to increase the area planted while a high input cost would produce the opposite effect. Hence, the specification for area planted for sorghum, soybeans, and corn is presented in equations [3.18], [3.23], and [3.31] in Table 3.2, respectively.

Following the general specification of text equation (3.14), equations [3.19], [3.24], and [3.32] in Table 3.2 specify the area harvested of sorghum (AHS), soybeans (AHSB), and corn (AHC), respectively, as functions of their respective area planted.

Total production of sorghum (TPS), soybean (TPSB), and corn (TPC) are presented in equations [3.20], [3.25], and [3.33] in Table 3.2, respectively. Consistent with the general form of text equation (3.13), sorghum, soybean, and corn production are specified in Table 3.2 as the product of area harvested and average yield per hectare. For soymeal, as discussed earlier, total production is the product of the amount of soybeans crushed and the technology-determined average yield of meal from soybeans in Mexico (MYSB) (equation [3.28] in Table 3.2).

The demand for feed (sorghum, corn, and soymeal) is affected by the number of grain-consuming animals (GCA), the own-price of the respective feed, and the price of substitute feeds consistent with text equation (3.17). An increase in the number of grain consuming animal units is expected to boost the demand for feedgrains. The effect of a rise in the own-price of a feed should be negative on the demand of such feed while the opposite should be true for an increase in the price of substitute feeds. Equations [3.21], [3.29], and [3.34] in Table 3.2 specifies the feed demands for sorghum, soymeal, and corn.

An animal unit is a standard unit for comparing actual animal numbers for all types of livestock and poultry (USDA-ERS S.B.#530). An animal unit is based on the dry-weight quantity of a feed consumed by the average milk cow during a base period. A set of factors is developed for each type of livestock and poultry by relating feed consumption for each type of livestock to the feed consumed by the average milk cow. Because chicken inventories do not reflect the real quantities of birds that are on feed, the number of chicken slaughtered, along with cattle and hog inventories, are used to estimate the number of grain consuming animal units.

Soybeans are consumed by livestock as a meal (soymeal) rather than as beans. Following text equation (3.18), equation [3.26] in Table 3.2 formulates the crush demand for soybeans as a function of input and output prices (PPSB,PPSM), soybean crush capacity (CCSB), and the availability of soybeans (SSB). Input and output prices are expected to be negatively and positively related, respectively, to the soybean crush while an increase in availability is expected to raise the amount of soybeans crushed. The amount of soybeans crushed also depends on the installed capacity in a given country.

Market clearing conditions for each feed are specified in equations [3.22], [3.27], [3.30], and [3.35], respectively, in Table 3.2. The identities used for calculating grain consuming animal units (GCA) and the weighted average price of feed (PPF) are given in equations [3.36] and [3.37] in Table 3.2, respectively. The factors p and ch in equation [3.36] in Table 3.2 represent the proportion of feed consumed by pork and chicken, respectively, compared to a milk cow. PPF is specified as a weighted average of prices of the principal inputs used to feed livestock. The weights for sorghum, soymeal, and corn (s, sm, and cn, in equation [3.37] in Table 3.2], respectively) are determined depending upon the proportions of the inputs used to prepare feeds.

The Mexican Meat Demand Model

The early history of empirical demand analysis was characterized not by attention to theory but by the use of single equation methodology centered around elasticity estimation (Deaton and Muellbauer, 1980a). Marshall's development of the elasticity concept led to an enthusiasm among applied economists to determine levels for agricultural commodities. Elasticities are easily understood, are conveniently dimensionless, and can be directly measured as the parameters of a regression equation of purchases, outlays, and prices (Deaton and Muellbauer, 1980a). When Richard Stone first estimated a system of demand equations in 1954, consumer theory began to be used consistently to define and modify the demand equations to be applied to the data. Consumer behavior theory provides a complete set of demand equations obtained by maximizing the utility function for the consumer subject to a budget constraint. These demand functions relate quantities consumed to a set of commodity prices and income. A complete array of demand elasticities can be obtained from these relationships which may be numerous. A complete demand system specification is attractive because it satisfies basic restrictions from economic theory and reduces the number of parameters to estimate (Johnson, Hassan, and Green).

Agricultural economists have use single equation and the complete demand system approaches to test countless issues such as seasonality in consumer demand (Heien), parameter stability (Moschini and Meilke), structural change (Chavas, Nyankori and Miller), effects on income distribution (Hahn), separability (Eals and Unnevehr), dynamic adjustment in monthly consumer (Wohlgenant and Hahn), etc.

Complete demand specifications have been widely used in recent studies. Two venerable formulations of demand systems are the so-called Almost Ideal Demand System (AIDS) and the ROTTERDAM model. For meat, Wahl and Tsai used the AIDS model to estimate meat demand parameters for Japan and Taiwan, respectively. Capps *et al.* used the Rotterdam model to obtain estimates of demand parameters for meat products in the Pacific Rim countries. In Mexico, only a few studies have been related to meat demand behavior. Heien *et al.* used the Almost Ideal Demand System (AIDS) to analyze food consumption in Mexico with emphasis on protein-supplying goods. They focus on the effect of demographic factors and expenditures with no reference to price behavior. Mintert *et al.* also used the AIDS model to study meat demand in Mexico. Their results, however, are largely inconsistent with consumer theory. They found positive own-price elasticities for pork and lamb and several meat product complementarities. This study will compare both demand systems (AIDS and ROTTERDAM) and the single equation formulation in an effort to choose the most appropriate model of Mexican meat demand behavior. Historical simulation (i.e. ability to track historical data) and consistency with consumer theory will be used to evaluate the three specifications. A description of the three formulations to be used follows.

<u>The Almost Ideal Demand System (AIDS)</u>

The Almost Ideal Demand System (AIDS) was specified by Deaton and Muellbauer in 1980. They contend that the AIDS gives an arbitrary first order approximation to any demand system, satisfies the axioms of choice exactly, aggregates perfectly over consumers without invoking parallel linear Engel curves, has a functional form which is consistent with known household-budget data, is simple to estimate, largely avoiding the need for non-linear estimation, and can be used to test the restrictions of homogeneity and symmetry through linear restrictions on fixed parameters. Although the original model includes a non-linear specification for the price vector, a linear approximation suggested by Stone (1953) is often used.

The linear approximation of the AIDS (LA/AIDS) may be specified as:

(3.20) $w_{it} = \alpha_i + \Sigma_j \gamma_{ij} ln p_{jt} + \beta_i ln[Y_t/P_t^*] + \epsilon_{it}$

where w_{it} represents the expenditure share of product i; p_{jt} corresponds to the nominal price of product j; Y_t denotes expenditure on the set of products; ϵ is the disturbance term; α, γ, and β are the parameters to estimate; $P_t^* = w_{kt} ln p_{kt}$ represents Stone's linear approximation; *ln* means natural log; and each variable is subscripted with t to indicate the current time period. The classical restrictions required to satisfy the theoretical properties of adding up, homogeneity, and symmetry, which should be imposed, can be written as:

(3.21) Adding Up: $\Sigma_i \alpha_i = 1$, $\Sigma_i \gamma_{ij} = 0$, and $\Sigma_i \beta_i = 0$;
(3.22) Homogeneity: $\Sigma_j \gamma_{ij} = 0$;
(3.23) Symmetry: $\gamma_{ij} = \gamma_{ji}$.

The adding up restriction means that the estimated demand functions must add up to the total expenditures. The homogeneity restriction means that the estimated demand functions are homogeneous of degree 0 in prices and income taken together. The symmetry restriction implies that the estimated demand functions satisfy the Slutsky symmetry. The uncompensated (Marshallian) and compensated (Hicksian) price elasticities and expenditure elasticities can be calculated using the LA/AIDS coefficient estimates as follows:

(3.24) Uncompensated Price Elasticity: $-\delta_{ij} + \gamma_{ij}/w_i - \beta_i w_j/w_i$
(3.25) Compensated Price Elasticity: $-\delta_{ij} + w_j + \gamma_{ij}/w_i$
(3.26) Expenditure Elasticity: $1 + \beta_j/w_i$,

where δ is the Kronecker delta equal to one if i=j and equal to zero otherwise.

Equations [3.45] to [3.48] in Table 3.3 are the demand system relationships for the LA/AIDS used to estimate the Mexican meat demand parameters. Equation [3.45] is the Stone's linear approximation to the model. The log of the meat price index (*ln*MPI) is calculated as the summation of the budget shares of beef, pork, and chicken (BEES, POES, and CHES, respectively) multiplied by the log of the retail prices for beef, pork, and chicken (RPB, RPP, and RPCH, respectively).

The next three equations ([3.46] through [3.48] in Table 3.3) describe the relationship between the budget shares of each type of meat product and meat prices and expenditures. The budget share of each particular type of meat is specified to be a function of the log of its own price, the log of other meat prices, and the log of total meat expenditures deflated by the meat price index. The beef expenditure share (BEES) is specified as a function of the log of the prices of beef (*ln*RPB), pork (*ln*RPP), and chicken (*ln*RPCH) and the log of total meat expenditures divided by the meat price index (*ln*(TPEM/MPI)) in equation [3.46] in Table 3.3. Pork and chicken expenditure shares (POES and CHES, respectively) follow the same specification in equations [3.47] and [3.48] in Table 3.3, respectively.

When estimating a demand system one equation must be omitted to avoid singularity of the variance-covariance matrix of disturbances. In this case chicken, will be omitted because it has the smallest budget share of the three types of meat considered. The parameters associated with chicken can be recovered through the classical restrictions mentioned earlier.

<u>The Rotterdam Model</u>

Theil and Barten proposed the Rotterdam model in the mid-sixties. The absolute price version of the Rotterdam model may be specified as:

(3.27) $\hat{w}_i \, d\mathit{ln}\,(q_i) = \theta_i \, d\mathit{ln}\,(Q) + \Sigma_j^n \pi_{ij} \, d\mathit{ln}\,(p_j) + \epsilon_i$

where $d\mathit{ln}\,(Q) = \Sigma_i \hat{w}_i \, d\mathit{ln}\,(q_i)$ is the Divisia volume index.

Unlike the AIDS, $\hat{w}_i$ does not correspond to the expenditure share of a product in time period t but to an average of the budget share in the current and previous time periods. Equations [3.49] to [3.51] in Table 3.3 show the calculations for this particular term for beef, pork, and chicken, respectively. Per capita consumption of product I in time t is represented by q_i while p_j corresponds to the price of product j in time period t. The parameters θ and π are to be estimated and ϵ corresponds to the disturbance term. The expression d*ln* represents log differentials which are approximated by log differences in empirical estimation.

Classical restrictions are also needed to conform to theory as in the case of the AIDS model. These restrictions are depicted as follows:

(3.28) Adding Up $\Sigma_j \theta_j = 1$;
(3.29) Homogeneity $\Sigma_j \pi_{ij} = 0$;
(3.30) Symmetry $\pi_{ij} = \pi_{ji}$.

The set of elasticities for the Rotterdam model may be estimated using the following calculations:

(3.31) Uncompensated Price Elasticity: $1/\hat{w}_i(\pi_{ij} - \hat{w}j\theta_j)$;

(3.32) Compensated Price Elasticity: $\pi_{ij}/\hat{w}_i$;
(3.33) Expenditure Elasticity: $\theta_i/\hat{w}_i$.

As in the case of the AIDS model, chicken will be omitted to avoid singularity. The Rotterdam formulation used for Mexico is presented in equations [3.58] to [3.61] in Table 3.3. The Rotterdam model requires several manipulations of the variables in order to be able to estimate the parameters. First, d*ln* (Q), which is represented by Q in equation [3.58], is calculated as a summation of the product of $\hat{w}_i$ and d*ln* (q_i). The term d*ln* (q_i) is the log of the result of dividing the current by the lagged consumption of meat "I". Equations [3.52] to [3.54] in Table 3.3 provide the calculations used to obtain the respective d*ln* (q) (DQ_i) for beef, pork, and chicken, respectively. On the other hand, d*ln* (p_i) (DP_i) is the log of the result of dividing the current by the lagged price of the ith meat. This is shown in equations [3.55] to [3.57] in Table 3.3 for beef, pork, and chicken, respectively. Equation [3.59] presents the relationship for beef. DQBEEF, which is the corresponding $\hat{w}$ d*ln* (q) for beef, is specified as a function of Q and DPBEEF, DPPORK, and DPCHIC. Similar relationships for DQPORK and DQCHIC are presented in equations [3.60] and [3.61], respectively, in Table 3.3.

The Single Equation Model

The single equation specification does not comply with all the classical restrictions imposed by economic theory because it is not derived using utility theory. A single equation formulation considers the demand for each product in the system to be a unique relationship. Quantities consumed are modeled as a function of prices and income. Homogeneity is often employed by deflating prices and income by a common general price index. Other classical restrictions are normally ignored. Equations [3.62] to [3.64] in Table 3.3 are the single equation meat demand specifications. The demand for each of the three meat products follows a similar specification. In equation [3.62] per capita demand for beef (DPB) is a function of the price of beef (RPB), the price of pork (RPP), the price of chicken (RPCH), and per capita disposable income (RPI). Per capita demand for pork (DPP) and chicken (DPCH) (equations [3.63] and [3.64], respectively) have similar specifications. In this case, no equation has to be omitted because there is no risk of singularity nor can the parameters of any one equation be derived from those of the other estimated equations.

Linkages Between Supply and Demand

The type of demand formulation selected will affect the linkage between supply and demand in the model because the dependent variable utilized in every demand formulation is different. While the AIDS model uses the budget share as dependent variable (w_j), the Rotterdam model uses the more complicated term $\hat{w}_i$dln (q_i), and the single equation system uses simply per capita consumption. Tables 3.4, 3.5, and 3.6 integrate the livestock and meat supply component with the LA/AIDS, the ROTTERDAM, and the LINEAR specifications, respectively, for the meat demand component. Equations [3.1] to [3.17] in Tables 3.4, 3.5, and 3.6, taken from the livestock and meat supply component presented in Table 3.1, represent the livestock and meat supply component. Equations [3.38], [3.39], and [3.40] show the calculation of per capita consumption of beef, pork, and chicken, respectively, as presented in Table 3.3.

The integrated LA/AIDS specification for the meat demand is presented in Table 3.4. Equations [3.42], [3.43], and [3.44] in Table 3.4 calculate the budget shares for beef, pork, and chicken, respectively. Budget shares are specified to be functions of the log of the prices of beef, pork, and chicken and the log of total meat expenditures divided by the meat price index (equations [3.46] to [3.48] in Table 3.4).

Table 3.5 depicts the integrated model of livestock and meat supply and demand using the ROTTERDAM specification. Equations [3.38] to [3.44] and [3.49] to [3.61] in Table 3.5 show the calculations and the behavioral relationships for the ROTTERDAM specification as explained in the previous section. Equations [3.62], [3.63], and [3.64] in Table 3.6 are the behavioral relationships in the LINEAR meat demand specification. As discussed earlier, per capita demand of beef, pork, and chicken are specified as functions of the prices of beef, pork, and chicken and the per capita income. Finally, table 3.7 presents the definition of the variables used in this section.

Summary

This section has presented the conceptual model of the Mexican livestock, meat, and feedgrain sectors. First, the underlying assumptions of the model were presented. Then, the livestock and meat supply relationships were discussed.

The feed sector model was then developed. Three different model formulations, (AIDS, ROTTERDAM, and single equation) for meat demand and their description were presented. Finally, an integrated supply and demand model was presented for each of the meat demand specifications. The next section will present the estimation results of the three integrated models. Based on their performance in tracking historical data, one specification will be selected to analyze the simulation effects of trade liberalization in the Mexican livestock, meat, and feedgrain sectors.

Table 3.1. The Mexican Livestock and Meat Supply Model*

Cattle and Beef

[3.1] $EIBC = f_1(FPC/PPF, EIBC_{t-1}, EIBC_{t-2}, Z, Z_{t-1})$

[3.2] $CB = EIBC_{t-1} * CR$

[3.3] $EIFC = f_2(CB, CB_{t-1})$

[3.4] $SLTC = f_3(RPB, FPC, EIFC)$

[3.5] $CB + EIBC_{t-1} + EIFC_{t-1} + MCAT = SLTC + EIBC + EIFC + XCAT + LD$

[3.6] $TPB = SLTC * CACW$

[3.7] $TPB + MB = DB + XB$

Hogs and Pork

[3.8] $EIBS = f_4(FPH/PPF, EIBS_{t-1}, EIBS_{t-2}, Z, Z_{t-1})$

[3.9] $PB = EIBS * PR$

[3.10] $EIFP = f_5(PB, PB_{t-1})$

[3.11] $SLHG = f_6(FPH, RPP, EIFP)$

[3.12] $EIBS_{t-1} + EIFP_{t-1} + PB + MHOG = SLHG + EIBS + EIFP + XHOG + LD$

[3.13] $TPP = SLHG * HACW$

[3.14] $TPP + MP = DP + XP$

Chicken and Chicken Meat

[3.15] $SLCH = f_7(RPCH, PPF, Z)$

[3.16] $TPCH = SLCH * CHCW$

[3.17] $TPCH + MCH = DCH + XCH$

* Variable definitions are presented in the table on page 47.

Table 3.2. The Mexican Feed Supply and Demand Model

Sorghum

[3.18] APS = f_8(APS$_{t-1}$, PPS$_{t-1}$, Z)

[3.19] AHS = f_9(APS)

[3.20] TPS = AHS * SY

[3.21] FDS = f_{10}(GCA, PPS, PPC)

[3.22] MS + TPS = FDS + NFDS + XS

Soybean

[3.23] APSB = f_{11}(APSB$_{t-1}$, PPSB$_{t-1}$, Z)

[3.24] AHSB = f_{12}(APSB)

[3.25] TPSB = AHSB * SBY

[3.26] CDSB = f_{13}(PPSB, PPSM, CCSB$_{t-1}$, SSB)

[3.27] MSB + TPSB = CDSB + NCDSB

Soymeal

[3.28] TPSM = MYSB * CDSB

[3.29] DSM = f_{14}(GCA, PPSM)

[3.30] MSM + TPSM = DSM

Corn

[3.31] APC = f_{15}(APC$_{t-1}$, PPC$_{t-1}$ Z)

[3.32] AHC = f_{16}(APC)

[3.33] TPC = AHC*CY

[3.34] FDC = f_{17}(GCA, PPC, PPS)

[3.35] MCORN + TPC = FDC + NFDC + XCORN

Additional Indices

[3.36] GCA = EITC+p*EITH+ch*SLCH

[3.37] PPF = s*PPS+sm*PPSM+cn*PPC

Table 3.3. Mexican Meat Demand Models

GENERAL TERMS

[3.38] DPB = DB/POP

[3.39] DPP = DP/POP

[3.40] DPCH = DCH/POP

[3.41] TPEM = DPB*RPB + DPP*RPP + DPCH*RPCH

[3.42] BEES = DPB*RPB/TPEM

[3.43] POES = DPP*RPP/TPEM

[3.44] CHES = DPCH*RPCH/TPEM

LA/AIDS

[3.45] *ln*MPI = BEES**ln*(RPB) + POES**ln*(RPP) + CHES**ln*(RPCH)

[3.46] BEES = f_{18}(*ln*RPB, *ln*RPP, *ln*RPCH, *ln*(TPEM/MPI))

[3.47] POES = f_{19}(*ln*RPB, *ln*RPP, *ln*RPCH, *ln*(TPEM/MPI))

[3.48] CHES = f_{20}(*ln*RPB, *ln*RPP, *ln*RPCH, *ln*(TPEM/MPI))

Rotterdam

[3.49] WBEEF = (BEES + $BEES_{t-1}$)/2

[3.50] WPORK = (POES + $POES_{t-1}$)/2

[3.51] WCHIC = (CHES + $CHES_{t-1}$)/2

[3.52] DQBEEF = WBEEF**ln*(DPB/DPB_{t-1})

[3.53] DQPORK = WPORK**ln*(DPP/DPP_{t-1})

[3.54] DQCHIC = WCHIC**ln*(DPCH/$DPCH_{t-1}$)

[3.55] DPBEEF = *ln*(RPB/RPB_{t-1})

[3.56] DPPORK = *ln*(RPP/RPP_{t-1})

[3.57] DPCHIC = *ln*(RPCH/$RPCH_{t-1}$)

[3.58] Q = DQBEEF + DQPORK + DQCHIC

[3.59] DQBEEF = f_{21}(Q, DPBEEF, DPPORK, DPCHIC)

[3.60] DQPORK = f_{22}(Q, DPBEEF, DPPORK, DPCHIC)

[3.61] DQCHIC = f_{23}(Q, DPBEEF, DPPORK, DPCHIC)

Single Equation

[3.62] DPB = f_{24}(RPB, RPP, RPCH, RPI)

[3.63] DPP = f_{25}(RPB, RPP, RPCH, RPI)

[3.64] DPCH = f_{26}(RPB, RPP, RPCH, RPI)

Table 3.4. Integration of the Livestock and Meat Supply and Demand: LA/AIDS

Cattle and Beef

[3.1] EIBC $= f_1(FPC, EIBC_{t-1}, PPF,)$

[3.2] EIFC $= f_2(CB, CB_{t-1})$

[3.3] CB $= EIBC_{t-1} * CR$

[3.4] SLTC $= f_3(RPB, FPC, EIFC)$

[3.5] $CB + EITC_{t-1} + MCAT = SLTC + EITC + XCAT + CALD$

[3.6] TPB = SLTC * CACW

[3.7] DB = TPB + MB - XB

[3.38] DPB = DB/POP

[3.42] BEES = DPB*RPB/TPEM

[3.46] BEES $= f_{18}(ln RPB, ln RPP, ln RPCH, ln(TPEM/MPI))$

Hogs and Pork

[3.8] EIBS $= f_4(FPH, EIBS_{t-1}, PPF,)$

[3.9] EIFP $= f_5(PB, PB_{t-1})$

[3.10] PB = EIBS * PR

[3.11] SLHG $= f_6(FPH, RPP, EIFP)$

[3.12] $EITH_{t-1} + PB + MHOGS = EITH + SLHG + HOLD$

[3.13] TPP = SLHG * HACW

[3.14] DP = TPP + MP - XP

[3.39] DPP = DP/POP

[3.43] POES = DPP*RPP/TPEM

[3.47] POES $= f_{19}(ln RPB, ln RPP, ln RPCH, ln(TPEM/MPI))$

Chicken and Chicken Meat

[3.15] SLCH $= f_7(RPCH, SLCH_{t-1}, T, PPF)$

[3.16] TPCH = SLCH * CHCW

[3.17] DCH = TPCH + MCH - XCH

[3.40] DPCH = DCH/POP

[3.44] CHES = DPCH*RPCH/TPEM

[3.48] CHES $= f_{20}(ln RPB, ln RPP, ln RPCH, ln(TPEM/MPI))$

Identities

[3.41] TPEM = DPB*RPB + DPP*RPP + DPCH*RPCH

[3.55] $ln MPI = BEES*ln(RPB) + POES*ln(RPP) + CHES*ln(RPCH)$

Table 3.5. Integration of the Livestock and Meat Supply and Demand: ROTTERDAM

Cattle and Beef

[3.1] EIBC $= f_1(FPC, EIBC_{t-1}, PPF,)$

[3.2] EIFC $= f_2(CB, CB_{t-1})$

[3.3] CB $= EIBC_{t-1} * CR$

[3.4] SLTC $= f_3(RPB, FPC, EIFC)$

[3.5] $CB + EITC_{t-1} + MCAT = SLTC + EITC + XCAT + CALD$

[3.6] TPB = SLTC * CACW

[3.7] DB = TPB + MB - XB

[3.38] DPB = DB/POP

[3.42] BEES = DPB*RPB/TPEM

[3.49] WBEEF $= (BEES + BEES_{t-1})/2$

[3.52] DQBEEF $= WBEEF*\mathit{ln}(DPB/DPB_{t-1})$

[3.55] DPBEEF $= \mathit{ln}(RPB/RPB_{t-1})$

[3.59] DQBEEF $= f_{21}(Q, DPBEEF, DPPORK, DPCHIC)$

Hogs and Pork

[3.8] EIBS $= f_4(FPH, EIBS_{t-1}, PPF,)$

[3.9] EIFP $= f_5(PB, PB_{t-1})$

[3.10] PB = EIBS * PR

[3.11] SLHG $= f_6(FPH, RPP, EIFP)$

[3.12] $EITH_{t-1} + PB + MHOGS = EITH + SLHG + HOLD$

[3.13] TPP = SLHG * HACW

[3.14] DP = TPP + MP - XP

[3.39] DPP = DP/POP

[3.43] POES = DPP*RPP/TPEM

[3.50] WPORK $= (POES + POES_{t-1})/2$

[3.53] DQPORK $= WPORK*\mathit{ln}(DPP/DPP_{t-1})$

[3.56] DPPORK $= \mathit{ln}(RPP/RPP_{t-1})$

(continued on next page)

Table 3.5. Continued

[3.60] DQPORK = f_{22}(Q, DPBEEF, DPPORK, DPCHIC)

Chicken and Chicken Meat

[3.15] SLCH = f_7(RPCH, $SLCH_{t-1}$, T, PPF)

[3.16] TPCH = SLCH * CHCW

[3.17] DCH = TPCH + MCH - XCH

[3.40] DPCH = DCH/POP

[3.44] CHES = DPCH*RPCH/TPEM

[3.51] WCHIC = (CHES + $CHES_{t-1}$)/2

[3.54] DQCHIC = WCHIC**ln*(DPCH/$DPCH_{t-1}$)

[3.57] DPCHIC = *ln*(RPCH/$RPCH_{t-1}$)

[3.61] DQCHIC = f_{23}(Q, DPBEEF, DPPORK, DPCHIC)

Identities

[3.58] Q = DQBEEF + DQPORK + DQCHI

[3.41] TPEM = DPB*RPB + DPP*RPP + DPCH*RPCH

Table 3.6. Integration of the Livestock and Meat Supply and Demand: Single Equation

Cattle and Beef

[3.1] EIBC $= f_1(FPC, EIBC_{t-1}, PPF,)$

[3.2] EIFC $= f_2(CB, CB_{t-1})$

[3.3] CB $= EIBC_{t-1} * CR$

[3.4] SLTC $= f_3(RPB, FPC, EIFC)$

[3.5] $CB + EITC_{t-1} + MCAT = SLTC + EITC + XCAT + CALD$

[3.6] TPB $= SLTC * CACW$

[3.38] DPB $= DB/POP$

[3.62] DPB $= f_{24}(RPB, RPP, RPCH, RPI)$

Hogs and Pork

[3.8] EIBS $= f_4(FPH, EIBS_{t-1}, PPF,)$

[3.9] EIFP $= f_5(PB, PB_{t-1})$

[3.10] PB $= EIBS * PR$

[3.11] SLHG $= f_6(FPH, RPP, EIFP)$

[3.12] $EITH_{t-1} + PB + MHOGS = EITH + SLHG + HOLD$

[3.13] TPP $= SLHG * HACW$

[3.14] DP $= TPP + MP - XP$

[3.39] DPP $= DP/POP$

[3.63] DPP $= f_{25}(RPB, RPP, RPCH, RPI)$

Chicken and Chicken Meat

[3.15] SLCH $= f_7(RPCH, SLCH_{t-1}, T, PPF)$

[3.16] TPCH $= SLCH * CHCW$

[3.17] DCH $= TPCH + MCH - XCH$

[3.40] DPCH $= DCH/POP$

[3.64] DPCH $= f_{26}(RPB, RPP, RPCH, RPI)$

Table 3.7. Definition of Variables for Model Section

Jointly Determined Variables

AHC	= Area Harvested of Corn
AHS	= Area Harvested of Sorghum
AHSB	= Area Harvested of Soybean
APC	= Area Planted of Corn
APS	= Area Planted of Sorghum
APSB	= Area Planted of Soybean
BEES	= Beef Expenditure Share
CB	= Calves Born
CDSB	= Crush Demand for Soybean
CHES	= Chicken Expenditure Share
DB	= Demand for Beef
DCH	= Demand for Chicken
DP	= Demand for Pork
DPB	= Demand Per-capita of Beef
DPCH	= Demand Per-capita of Chicken
DPP	= Demand Per-capita of Pork
DSM	= Demand for Soymeal
EIBC	= Ending Inv. of Breeding Cattle
EIBS	= Ending Inventory of Breeding Sows
EIFC	= Ending Inv. of Feeder Cattle
EIFP	= Ending Inventory of Feeder Pigs
EITC	= Ending Inv. of Total Cattle
EITH	= Ending Inventory of Total Hogs
FDC	= Feed Demand of Corn
FDS	= Feed Demand for Sorghum
FPC	= Farm Price of Cattle
FPH	= Farm Price of Hogs
GCA	= Grain Consuming Animals
MPI	= Meat Price Index
PB	= Piglets Born

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Table 3.7. Continued

POES	= Pork Expenditure Share
PPC	= Producer Price of Corn
PPF	= Producer Price of Feed
PPS	= Producer Price of Sorghum
PPSB	= Producer Price of Soybean
PPSM	= Producer Price of Soymeal
RPB	= Retail Price of Beef
RPCH	= Retail Price of Chicken
RPP	= Retail Price of Pork
SLCH	= Slaughter of Chicken
SLHG	= Slaughter of Hogs
SLHG	= Slaughter of Hogs
SLTC	= Slaughter of Total Cattle
TPB	= Total Production of Beef
TPC	= Total Production of Corn
TPCH	= Total Production of Chicken
TPEM	= Total Per capita Expenditures on Meat
TPP	= Total Production of Pork
TPS	= Total Production of Sorghum
TPSB	= Total Production of Soybean
TPSM	= Total Production of Soymeal
Exogenous Variables	
c	= Corn Weight in a Feed mix
CACW	= Cattle Average Carcass Weight
CALD	= Cattle Lost and Dead
ch	= Prop. of Feed Consumed by Chicken Relative to Cattle
CHCW	= Chicken Average Carcass Weight
CR	= Calving Rate
CRED	= Availability for Farm Credit
CY	= Corn Yield
HACW	= Hogs Average Carcass Weight

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Table 3.7. Continued

HOLD	= Hogs Lost and Dead
MB	= Imports of Beef
MC	= Imports of Corn
MCAT	= Imports of Total Cattle
MCH	= Imports of Chicken
MHOGS	= Imports of Total Hogs
MP	= Imports of Pork
MS	= Imports of Sorghum
MSB	= Imports of Soybean
MSM	= Imports of Soymeal
MYSB	= Meal Yield of Soybean
NCDSB	= Non-crush Demand for Soybean
NFDC	= Non-feed Demand for Corn
NFDS	= Non-feed Demand for Sorghum
p	= Prop. of Feed Consumed by Hogs Relative to Cattle
Pop	= Total Mexican Population
PR	= Piglets Bearing Rate
RPI	= Real Per capita Income
s	= Sorghum Weight in a Feed mix
SBY	= Soybean Yield
SEED	= Input Costs in Farming
sm	= Soymeal Weight in a Feed mix
SY	= Sorghum Yield
T	= Technological Change
XB	= Exports of Beef
XCAT	= Exports of Total Cattle
XCH	= Exports of Chicken
XP	= Exports of Pork
XS	= Exports of Sorghum

EMPIRICAL ANALYSIS

This section presents the results of the empirical analysis performed using the model presented in the previous section. First, some data considerations are discussed. Then, the estimation procedures are reviewed and some econometric considerations are discussed. The meat demand model is tested for structural change and for price endogeneity. The results of the empirical estimation are presented and discussed. Historical simulation is then performed to evaluate and select among the three alternative model specifications presented in the previous section. The best specification will then be selected for the simulation presented in the next section.

Data Sources and Considerations

As discussed earlier, reliability has been a problem for official Mexican data. Only recently, has the Mexican government taken measures to develop a credible and consistent data base of the Mexican economy. The Instituto Nacional de Estadistica, Geografia e Informatica (INEGI) (National Institute of Statistics, Geography, and Information) was recently created to coordinate the collection, organization, and dissemination of information in Mexico. In the past, several agencies would collect and distribute data to only a select number of organizations. Two or more agencies would sometimes collect the same data with different methodologies with widely different results. Lack of consistency in the organization of the Federal Administration has also been a problem. In the last three Federal periods (of six years each), several government ministries have been created and disappeared.

Data used for this study came mainly from the annual Mexican Presidential Report to the Congress. The report contains the most complete data set available in Mexico. The report compiles information from all the different official Federal agencies. Data used for this analysis range from 1972 to 1991. Complete series for some variables in the conceptual model presented in the previous section were not available. Consequently, some modifications were made to the model. Data for information about macroeconomic variables, crop area harvested, crop prices, livestock inventories, meat and crop production, imports and exports, production credit, and input costs were all taken from the Presidential Report. Data for Mexican meat and livestock prices were provided by the Colegio de Posgraduados in Chapingo, Mexico. Data on soymeal was obtained from the National Transformation Industry Association (CANACINTRA). The proportions used to estimate the number of grain consuming animal units were taken also from several issues of Agricultural Statistics (USDA) since no equivalent information is available in Mexico. Weights used to estimate the average producer price of feed were taken from the literature (Perez-Espejo).

Estimation Procedures

As mentioned in the background section, after the 1982 economic crisis, expenditures on meat consumption in Mexico suffered a setback. As depicted in figure 4.1, total per capita expenditures on meat reached a high in 1982 and fell almost 50% by 1991. Also, after the trade liberalization trend started in 1986 in Mexico, beef imports began to appear and per capita beef consumption jumped from 12.6 kg in 1985 to 15.7 kg in 1986. On the other hand, pork consumption decreased from 16.6 kg to 12.1 kg over the same period (Figure 4.2). This pattern indicates the possibility of structural change in meat consumption in Mexico. Several studies (Moschini and Meilke, Eales and Unnevehr, Chavas (83), Braschler, Nyankori and Miller, Garcia Vega, Tsai) test or discuss the issue of structural change in meat consumption. In most cases, parameter instability has been used to demonstrate the evidence of structural change. However, Chavas (89) affirms that the simple change in parameters over the years may not be enough to affirm that structural change has occurred. Chavas defines structural change as a change in the basic hypotheses used in the analysis of economic behavior. He contends that model specification and period selection might influence the results obtained.

Given the changes in the Mexican economy that have occurred, particularly since 1982, a test for structural change in Mexican meat consumption would be necessary. To avoid the problem of unique specification and period selection discussed by Chavas, three specifications (AIDS, ROTTERDAM, and LINEAR) and two period selections will be used to test for structural change in the Mexican meat consumption behavior. The selection of the two time periods was based on the discussion in the background section. The first period (1983-91) represents the years after the 1982 economic crisis in Mexico. The second period (1986-91) refers to the years since Mexico began the process of unilateral trade liberalization. The results of the three specifications for each period will be compared to draw conclusions about structural change in Mexican meat consumption patterns.

In demand systems estimation, supply is generally assumed to be perfectly elastic. In the AIDS model, prices are assumed to be fixed, this is, exogenously determined. Deaton and Muellbauer derived the AIDS model from an expenditure function representing the PIGLOG (Price independent, generalized linearity) class of preferences. This permits perfect aggregation over consumers and results in representative demand functions that are correctly estimated using market level data. The demand functions maintain the fixed price assumption, however. Previous studies have shown that endogeneity may be present with respect to the prices of a demand model (Wahl, Tsai). Also, when a meat demand system is integrated into a larger supply and demand system, price endogeneity has been shown to lead to improved demand parameter estimation results (Tsai). In this study, once the evidence of structural change has been accepted or rejected, a test for price endogeneity on the demand model will be performed. The test to be used (Hausman specification test) will be discussed later.

After endogeneity is accepted or rejected for each demand model, each demand specification will be integrated into the livestock and feedgrain models. A sensitivity test will be performed to analyze the effects of a 20% increase in cattle exports. The magnitude and direction of the changes in the endogenous variables will then be compared. The model specification that tracks the historical data better and performs better in the sensitivity analysis according to standard simulation statistics will then be used for the simulation of the effects of US-Mexico trade liberalization in the next section.

Econometric Considerations

In many cases, Ordinary Least Squares (OLS) is the most appropriate estimation procedure for single equation models (Pindyck and Rubinfeld). However, multiple equation models include several endogenous variables which are simultaneously determined. Simultaneity can cause OLS parameters estimators to be inconsistent. In simultaneous equation models, endogenous variables in one equation are used as explanatory variables in other equations. Hence, the error terms may be correlated with the endogenous variables. Consequently, OLS estimation would be both biased and inconsistent. Instrumental variables estimation is reasonable in the context of simultaneous equation models because the exogenous and predetermined variables in the model serve as excellent instrumental variables. Indirect least squares (ILS) can be used to obtain consistent parameter estimates. However, in some cases it is not possible to use ILS and, in cases of overidentified equations, ILS leads to several distinct estimators.

Two Stage Least Squares (2SLS) provides a useful estimation procedure for obtaining the values of structural parameters in overidentified equations. The 2SLS estimator uses the information available from the specification of an equation system to obtain a unique estimate for each structural parameter.

Although 2SLS yields consistent parameter estimates when equation systems are simultaneous, as a general rule 2SLS estimates are inefficient because they apply only to a single equation within the system of equations (Pindyck and Rubinfeld). The problem of lost of efficiency can be resolved by using a method of estimating system of equations in which parameters for all equations are determined in a single procedure. When there is no simultaneity in a system of equations but the errors are correlated, then the Seemingly Unrelated Regression (SUR) technique may be employed. The SUR method involves generalized least-squares estimation and achieves an improvement in efficiency by taking into explicit account the fact that cross-equation error correlation may not be zero. The natural extension of the SUR estimation for a simultaneous equation model is the Three Stage Least Square technique (3SLS). The 3SLS procedure involves the application of generalized least-squares estimation to the system of equations, each of which has first been estimated using 2SLS.

SUR estimation has been generally used to estimate demand systems like the AIDS and the ROTTERDAM because of the assumption of price exogeneity. In this study, SUR estimation will be used to test for structural change in Mexican meat demand. After the evidence of structural change has been accepted or rejected, the three alternative specifications will be estimated using both SUR and 3SLS. As mentioned earlier, SUR accounts for the fact that cross-equation error correlation might not be zero but does not consider simultaneity. 3SLS does consider simultaneity among equations but may be inefficient if the prices are in fact exogenous.

The Hausman specification test (Hausman) will be performed to test for endogeneity of prices in the meat demand system. Consider the null hypothesis that the prices on the right-hand side of a demand system are exogenous. Under the null hypothesis, SUR estimation is consistent and asymptotically efficient but inconsistent under the alternative hypothesis. 3SLS is consistent under both the null and the alternative hypotheses but inefficient under the null hypothesis. This inefficiency may be relatively small, however, and the loss in efficiency may be offset by the gain in simulation performance. Accounting for endogeneity of some variables may bring more consistent parameter estimates and may capture some information that could be lost by considering those variables as exogenous. As Tsai stated, when the meat demand model is combined with a livestock and feedgrain models, the parameter estimates may be improved. Both techniques SUR and 3SLS will be tested by the simulation performance once the model is fully integrated with the meat, livestock, and feedgrain sectors.

Using SUR and 3SLS, the Hausman specification test consists of determining how large the difference is between the two set of parameters in relation to its variance. Let b be a vector of coefficient estimates of a demand system using SUR. Let b^* be a vector of coefficient estimates of the same demand system obtained using 3SLS. Let var (b) be the parameter variance-covariance matrix from the SUR estimation and var (b^*) be the parameter variance-covariance matrix from the 3SLS estimation. The test for misspecification is:

[4.1] $m = q' M(q)^{-1} q$,

where $q=b-b^*$, $M(q)=var(b)-var(b^*)$, m has a chi-squared distribution with n degrees of freedom, and n is the number of parameters in b that are directly affected by the correction for endogeneity. If m is greater than the chi-square value, then the null hypothesis of price exogeneity is rejected and the alternative hypothesis of endogeneity is accepted. The larger the difference between the set of parameters ($b-b^*$), the more likely that the alternative hypothesis of endogeneity is accepted.

After the endogeneity hypothesis has been tested, the three demand specifications will be integrated to the livestock and feedgrain components to simulate historical data. Simulation statistics like the root mean square and the Theil simulation statistics will be used to evaluate which model performs better in tracking historical data.

Structural Change in Mexican Meat Consumption Behavior

Table 4.1 shows the results obtained for the three demand specifications when an intercept shifter is added. A dummy variable (equal to zero from 1972 to 1982, equal to one from 1982 to 1991) was included in every equation to capture any possible change in the behavior of meat consumption in Mexico between the two periods. Testing the hypothesis that several coefficients are jointly equal to zero in the context of a multiple regression model can be performed by using the *F* distribution. However, when the hypothesis is that a single regression coefficient is equal to zero, the *F* test is reduced to a *t* test. Since only intercept shifters were included, the *t* test will be used to test for structural change in meat consumption in Mexico.

R-Squares for the nine equations are over the 90% level except for the beef and chicken equations in the ROTTERDAM specification (Table 4.1). Both the ROTTERDAM and the AIDS specifications showed evidence of serial correlation and were corrected for serial correlation. The resulting rho values are presented in table 4.1. The Durbin-Watson (D-W) statistic indicates the absence of serial correlation in all cases except possibly for beef on the linear specification, which falls into the inconclusive region. As the t-values show, out of nine estimated parameters for the 1982-91 dummy, only one (beef equation in the linear specification) was significant at the 10% level and none was at the 5% level.

Table 4.2 shows the results of the analysis for structural change when a different period (1986-91) is considered. Again, a dummy equal to zero from 1972 to 1985 and equal to one for the rest of the sample was included as an intercept shifter. R-Squares are similar to those from the period 1983-1991 except that they are lower for the three equations using the ROTTERDAM specification. The D-W statistic values are also generally less conclusive. There is however, an improvement in the number of significant parameters. Out of nine parameters estimated related to the structural change test, five were significant at the 5% level.

The results of neither period, however, are conclusive. When the first period (1983-91) was considered, the AIDS and the ROTTERDAM models resulted in a negative but insignificant coefficient for pork consumption and a positive but insignificant coefficients for beef and chicken. The linear specification resulted in negative coefficients for all three types of meats. Only the beef equation had a significant parameter at the 10% level. Using the second period (1986-91) to analyze structural change, pork consumption in all three specifications resulted in negative and significant (5% level) coefficients. However, beef was affected negatively under the AIDS specification but positively under the ROTTERDAM and the LINEAR specifications. Chicken was positively affected under the AIDS and the ROTTERDAM specifications, but negatively under the LINEAR specification. The dummy parameter is significant for chicken in the AIDS model and for beef in the ROTTERDAM model. Hence, the results using the second period fail to demonstrate evidence of a structural change occurred in Mexican meat consumption behavior following trade liberalization. Because little was found during any period or for any specification, the hypothesis of structural change in meat demand in Mexico is rejected.

Parameter Estimation for the Demand Model and Endogeneity Results

Tables 4.3, 4.4, and 4.5 show the results of model parameter estimation using 3SLS and SUR for the AIDS specification. Parameter values, the corresponding t values, and summary statistics for both 3SLS and SUR techniques are shown in Table 4.3. As discussed before, one equation (chicken) had to be dropped to avoid singularity of the variance-covariance matrix of disturbances. The parameters relative to this equation were recovered using the classical restrictions of homogeneity, symmetry, and adding-up.

Most of the estimated parameters are significant under both techniques (3SLS, and SUR) except for the chicken equations, where only half of the eight recovered parameters are significant. The magnitudes of those parameters under both estimation techniques are very similar. Using the Hausman specification test, the m statistic for the AIDS specification is -0.25. The corresponding Chi-square distribution 5% cut-off point with eight degrees of freedom is 15.51. Therefore, consistency of the SUR estimates cannot be rejected, implying that prices may be treated as exogenous when using the AIDS specification to estimate meat demand parameters in Mexico.

Table 4.4 provides the estimated elasticities for the AIDS model when using 3SLS estimation. The expenditure elasticity is quite large for pork while negative for chicken. Both the Marshallian and the Hicksian own price elasticities are negative for the three types of meat. Some of the cross price effects are somewhat inconsistent with prior expectations, however. The Marshallian elasticities for pork and chicken indicate reciprocal complementarity with beef and substitutability between them. The Hicksian elasticities also indicate net complementarity between chicken and beef. Table 4.5 provides the resulting elasticities for the AIDS specification using the SUR estimation technique. Estimated elasticities look very similar under the 3SLS and SUR estimation techniques. Complementarity is also present in this case.

Table 4.6 shows the parameters estimates obtained using the ROTTERDAM specification and the 3SLS and SUR estimation techniques. R-squares and parameter significance are lower than in the AIDS specification. Of the twelve estimated and recovered parameters for each estimation technique, only two are significant at the 5% level. The similarity of the parameters under both techniques is still quite high. The m statistic of the Hausman test for the ROTTERDAM specification is 0.71 which again implies rejection of the alternative hypothesis of inconsistency of the SUR estimates (the Chi-square distribution value at the 5% level of significance with six degrees of freedom is 12.59).

Tables 4.7 and 4.8 provide the estimated elasticities for both the 3SLS and the SUR techniques, respectively, using the ROTTERDAM specification. Pork still has a large expenditure elasticity. The chicken expenditure elasticity is positive, however, in contrast to the AIDS model. Marshallian and Hicksian elasticities show complementarity problems as in the AIDS case and even beef and pork exhibit positive own-price elasticities in the Hicksian sense.

Table 4.9 shows the parameter estimates for the LINEAR specification using both the 3SLS and the SUR techniques. As mentioned earlier, no equation had to be dropped under this specification. R-square for the three equations in both cases are above 90%. The D-W statistic results do not provide conclusive evidence of serial correlation in any case. Parameter significance under the LINEAR specification is better than the ROTTERDAM but not as good as the AIDS specification. Again, the parameters are quite similar under both the 3SLS and SUR estimation. The m statistic for the Hausman specification test is 1.53. The corresponding value of the Chi-square distribution at the 5% level with 15 degrees of freedom is 25. Hence, the null hypothesis of consistency of the SUR estimation again cannot be rejected.

Elasticities for the LINEAR specification for both estimation techniques are provided in table 4.10 and 4.11, respectively. Pork shows again the largest income effect and chicken has a negative income effect as in the case of the AIDS specification. Marshallian and Hicksian elasticities have the expected signs consistent with prior expectations in both the 3SLS and SUR models except for the Hicksian elasticity for chicken on the beef equation, likely as a result of the negative income effect for chicken. Magnitude of the elasticities for both techniques are quite similar as expected due to the similarity of the estimated parameters.

In summary, six models were estimated: three different specifications and two estimation techniques. R-squares for the AIDS and the LINEAR specifications were over 95% in most cases. In the ROTTERDAM specification, the R-squares were somewhat lower. The D-W statistics did not show conclusive evidence of serial correlation in any case. The best parameter significance was found under the AIDS specification and the worst in the ROTTERDAM model. The elasticities indicated many cases of complementarity in the AIDS and the ROTTERDAM specifications but not for the LINEAR model. Complementarity has been a common problem among researchers when estimating demand systems. The response has generally been to note the problem and to try to formulate a reasonable justification for the counter-intuitive results. In simulation, however, counter-intuitive complementarity can produce counter-intuitive results and inappropriate policy recommendations.

The chicken income elasticity was negative in the AIDS and the LINEAR specifications. A negative income elasticity for chicken implies that Mexicans consume more chicken as income decreases. This appears to be consistent with historical behavior in Mexico. As discussed in the background section, as per capita income dropped following the economic crisis of 1982, chicken consumption increased steadily. Income elasticity for pork was shown to be larger than that of beef in all six models estimated. The main factors that contribute to this behavior may be prices and meat processing. As shown in table 2.6, pork prices have been consistently higher than those of beef. In addition, ham, bacon, and other pork derivatives are quite expensive in Mexico and only high income consumer are able to purchase them regularly.

The endogeneity test performed on the three specifications failed to reject the null hypothesis of SUR estimation consistency. Prices for the demand system could be treated as exogenous using the SUR estimation technique when demand estimation is performed independently. However, as discussed by Tsai, when simultaneity of meat and livestock supply and demand is present, 3SLS has proven to provide a better performance. Therefore, 3SLS will be used to estimate the fully integrated Mexican meat, livestock, and feedgrain model.

Mexican Meat Demand Simulation

The three model specifications were integrated with the livestock supply and feedgrain supply and demand components to simulate historical data in Mexico. Unfortunately, the AIDS specification converged only for 3 observations and the ROTTERDAM specification did not converge in simulation over the historical period. Complementarity among meat products within the AIDS and the ROTTERDAM specifications combined with a large expenditure elasticity for pork could have caused the no-convergence.

The LINEAR specification was the only one to converge. Theil statistics indicate a small bias and a reasonably good ability to track historical data. The LINEAR specification for the Mexican meat demand model will then be used for a sensitivity test in the next section.

The Fully Integrated Mexican Livestock, Meat, and Feedgrain Model

The livestock and meat supply and the feedgrain supply and demand models were integrated with the linear specification to perform a sensitivity analysis. The original intention was to do the same with the AIDS and the ROTTERDAM models to compare the results. But since those models would not converge, only the linear specification was used. A change of 20% in cattle exports was used to measure the magnitude and the direction of the impact on the endogenous variables. First, the resulting parameters of the fully integrated model are presented in Table 4.12. Definition of the variables is described in Table 4.13.

Several modifications were made to the models as presented in Tables 3.1 and 3.2. First, data differentiating feeder from breeding cattle inventories were not available for Mexico. Only data for cattle inventories were available. Second, the original inventory equations included two lag periods for inventories and exogenous factors with one lag. However, inventory lagged two periods and lagged exogenous variables were not significant and dropped from the livestock inventory equations. The profit representation for the livestock equation, defined by farm price divided by the price of feed, was decomposed into farm prices of livestock and the producer price of feed, both deflated by the wholesale price index to separately capture the effect of those variables. In the feedgrain model, incomplete series were found for area planted. Consequently, area harvested was used to estimate supply behavior. Demand for feedgrains was estimated as total demand because no separate data were available for feed and non-feed demand for grains. Due to the high rates of inflation that have existed in Mexico during the last 20 years, all prices were deflated. Meat prices and per capita income were deflated by the consumer price index while feedgrain and livestock prices were deflated by the wholesale price index. Finally, lagged per capita consumption was added to each equation in the meat demand model.

Table 4.12 presents the results of the parameter estimation. Quantities in parentheses are the t-values while quantities in brackets represent the elasticities, ceteris paribus. Since the model is simultaneous, net effects can only be obtained by using the analytical derived reduced form. In this section, the term elasticity will be used to indicate the gross effect between two variables multiplied by the ratio of their means.

Equations (4.1) to (4.8) in Table 4.12 are the equations for the cattle and beef supply and demand models. Equation (4.1) is the cattle inventory equation. The high estimated parameter for lagged ending inventory indicates that beginning inventories determine a big percentage of ending cattle inventories (eitc). The estimated results indicate that eitc increases with an increase in farm price of cattle (fpc) and decreases if the price of feed (ppf) rises. The corresponding short run elasticities are quite small, 0.02 for fpc and -0.01 for ppf. The long run elasticities are only slightly larger, 0.15 and -0.08, respectively. This may be an indication that, because of beef price controls in Mexico, cattle producers have been quite unresponsive to changes in cattle prices. The low elasticity of the price of feed is not surprising because of the low percentage of cattle fed with feedgrains in Mexico.

The behavior of slaughter of cattle (sltc) is presented in equation (4.2) in Table 4.12. The availability of cattle represented by beginning inventories of cattle ($eitc_{t-1}$) has a large elasticity (7.08). That is for a one percent change in beginning cattle inventories slaughter is expected to change by seven percent. The cattle slaughter input price (fpc) has the expected negative effect on slaughter and an elasticity equal to -0.68. The output price (retail price of beef (rpb)) has a low elasticity of 0.10. Calves born (cb) are calculated as the product of beginning inventories of total cattle times the calving rate (cr) (equation (4.3)). Equation (4.4) is the market clearing equation for live cattle as explained previously in chapter III.

Total production of beef (tpb) is specified in equation (4.5) as the product of cattle slaughtered and the average cattle carcass weight (cacw). Equation (4.6) is the market clearing equation for beef. Equation (4.7) estimates per capita consumption of beef (qb) by dividing total demand for beef (db) by population (pop). Finally, equation (4.8) shows the per capita beef demand relationship previously explained with only slight changes in parameters due to the inclusion of lagged per capita consumption. Long run elasticities for price of beef (rpb), price of pork (rpp), price of chicken (rpch), and per capita income (rpci) are estimated to be -0.42, 0.17, 0.16, and 0.75 respectively.

Hog and pork behavioral equations are presented in equations (4.9) to (4.15). Similar to cattle, ending inventories of total hogs (eith) vary positively with respect to farm price of hogs (fph) and negatively with respect to price of feed (ppf). Also, lagged inventories are a strong determinant of ending inventories as shown by the estimated coefficient (0.83) and its t value (14.6). Elasticities for fph and ppf are small but somewhat larger than the corresponding elasticities for cattle. Long run elasticities for fph and ppf are 0.29 and -0.47, respectively. Slaughter of hogs (slhg) is specified as a function of retail price of pork (rpp), farm price of hogs (fph), and lagged inventories of hogs. Although smaller than in the case of cattle, elasticity of available hogs for slaughter is relative high (1.32). Magnitude of the elasticities for rpp and fph indicate that hog slaughter is not very responsive to changes in prices.

Equation (4.11) in Table 4.12 specifies the number of piglets born (pb) in a year to be the product of beginning inventories and the piglets bearing rate (pr). Equation (4.12) is the market clearing equation for live hogs. Total production of pork is specified in equation (4.13) as the product of hogs slaughtered and the average carcass weight of hogs (hacw). The market clearing condition for pork is presented in equation (4.14). Per capita consumption for pork (qp) is estimated by dividing total demand for pork (dp) by population in equation (4.15). Equation (4.16) presents the pork demand relationship described earlier with the addition of the lagged per capita consumption for pork. Long-run elasticities for the price of beef (rpb), the price of pork (rpp), the price of chicken (rpch), and per capita income (rpci) are 0.61, -1.06, 0.57, and 1.62. Own-price and income elasticity seem considerably high compared to cross-price elasticities. As discussed before, high own-price and income elasticities may be due to the fact that pork has generally been the most expensive but also the most preferred meat in Mexico during the past 20 years.

The chicken and chicken meat sector is presented in equations (4.17) to (4.21) in Table 4.12. Equation (4.17) explains the behavior of chicken slaughter (slch). The slaughter of chicken in Mexico is affected positively by the retail price of chicken (rpch) and negatively by the price of feed (ppf), as expected. Elasticity for the price of feed is not as small as in the case of hogs and cattle reflecting the fact that the chicken industry is the major consumer of feedgrains in Mexico. Equations (4.18) specifies chicken meat production as the product of chicken slaughter and the average chicken carcass weight (chcw) in Mexico. Equation (4.19) is the market clearing condition for chicken meat. Equation (4.20) converts total chicken consumed to per capita consumption (qch). Finally, equation (4.21) shows the chicken meat consumption relationship as explained before except that lagged dependent variable shows a very large coefficient (1.02).

The sorghum sector behavior is captured by equations (4.22) to (4.25) in Table 4.12. As mentioned earlier, data for area planted were incomplete so that area harvested became the dependent variable for feedgrain supply in equation (4.22). The lagged dependent variable, lagged price of sorghum (pps), and the amount of available credit (sorgcr) affect positively the amount of area harvested of sorghum. As expected, the price of an input like sorghum seed (sorgps) has a negative effect on the area harvested of sorghum. Short run elasticities are not large except for the lagged dependent variable. Long run elasticities for lagged price of sorghum, sorghum credit, and sorghum price of seed, are 0.38, 0.38, and -0.07, respectively. Equations (4.23) explains total production of sorghum as the product of area harvested and yield. Equation (4.24) is the market clearing condition for sorghum. The total demand for sorghum (ds) is equation (4.25) in Table 4.12. Note the huge elasticity estimated for grain consuming animal units (gca) (8.11). This means that for a one percent change on the number of grain consuming animals there is an 8.11 percent change in the demand for sorghum. The change as large as 1% on the number of grain consuming animals, however, has not been very common over the last 20 years in Mexico. The own-price elasticity for sorghum is -0.28 and the cross-price elasticity with corn is 0.10 which implies a weak relationship of substitutability explained basically by the limits on corn consumption as an animal feed established by the Mexican government.

Equations (4.26) to (4.32) describe the soybean and soymeal sector. The area harvested of soybeans is explained in equation (4.26) as a function of lagged price of soybean (ppsb) and three exogenous variables: (1) the amount of rain (rain), (2) the price of soybean seed (soybps), and (3) the available credit for soybeans (soybcr). The lagged dependent variable did not perform well (wrong sign and a very low significance) and was dropped from the equation. The amount of rain is a strong factor for the area harvested of soybeans. Mexican agriculture still depends to a large extent on climatic conditions which is captured by the large elasticity for rain (0.89) in the area harvested of soybeans equation. Equations (4.27) specifies total production of soybeans as the product of harvested area and yield. Equation (4.28) is the market clearing condition for soybeans.

The crush demand for soybeans (cdsb) is presented as equation (4.29) in Table 4.12. As discussed in the model section, soybean crush demand is affected by the price of soybeans as an input (ppsb), the price of soymeal as an output (ppsm), and the availability of soybeans. Soybean imports are used as a proxy for soybean supply because they represent a large part of the available supply of soybeans. Estimated parameters for price of soybeans and soymeal have the expected sign. The elasticity of soybean imports is larger than both price elasticities indicating that crush is more responsive to changes in available supply than to changes in prices. Total production of soymeal and the market clearing equation for soymeal are specified in equations (4.30) and (4.31), respectively. The demand for soymeal is presented in equation (4.32). The elasticity of soymeal demand with respect to grain consuming animals again is quite large (7.92). The own-price effect is not large nor significant.

The corn sector is described in equations (4.33) to (4.36) in Table 4.12. As explained in the previous section, the area harvested of corn is specified as a function of the lagged price of corn (ppc), and some exogenous variables, including the price of seed corn (cornps) and available credit for corn (corncr). Although the signs are as expected, the magnitude of the elasticities indicates that none of the variables affects the area harvested of corn strongly. Area harvested of corn has not varied too much in the last 20 years, hence the difficulty finding significant explanatory variables. Government intervention via subsidies, production for subsistence, and cultural factors may be the reasons behind the stability in the amount of area harvested of corn. Total production of corn (tpc) and the market clearing condition for corn are specified in equations (4.34) and (4.35), respectively. In the total demand for corn (dc) (equation (4.36)) grain consuming animal units also has a large elasticity (4.80). The price of corn and price of sorghum reflect expected signs although their respective elasticities are small as in the case of demand for sorghum.

Finally, equations (4.37) and (4.38) in Table 4.12 show the calculations used to obtain the number of grain consuming animal units (gca) and the average producer price of feed (ppf). The number of grain consuming animals, as discussed in the previous section, is an aggregated of the inventories of cattle and hogs and the number of chickens slaughtered during each period. The aggregation factors (mcow, pork, and chi) indicate the dry-weight quantity of a feed consumed by an animal during a base period and were obtained from several issues of the USDA agricultural statistical yearbook. Although corn is not consumed as an animal feed in the same proportion as sorghum, people interviewed stated that with a lower price, corn would substitute sorghum in any feed mix.

Model Validation

Validation of the structural model was conducted through historical simulation. Root mean squared percentage error (RMS% error), Theil forecast error statistics, and sensitive analysis were used to evaluate the performance of the model. These results are shown on Tables 4.14 and 4.15.

The RMS% error is a measure of the deviation of the simulated variable from its actual time path in percentage terms. Low RMS% errors are one desirable measure of simulation fit (Pindyck and Rubinfeld). Another useful simulation statistic applied to the evaluation of historical simulations is Theil's inequality coefficient (U). Low values of U represent a good performance of the model. When U=0, then the model has a perfect fit while if U=1 the performance of the model is as bad as it possibly could be. Theil's inequality coefficient can be decomposed in three proportions: U^m, U^s, and U^c called the bias, the variance, and the covariance proportions, respectively. U^m is an indication of systematic error. It measures the extent to which the average values of the simulated and actual series deviate from each other. The variance proportion U^s indicates the ability of the model to replicate the degree of variability in the variable of interest. A large U^s indicates that the actual series has fluctuated considerably while the simulated series show little fluctuation or vice versa. The last measure (U^c) indicates unsystematic error which is the remaining error after deviations from average values have been accounted for. Theil's inequality coefficient can also be decomposed into three other components: U^m, U^r, and U^d. The first term (U^m) is as described before while the second and third are called the regression proportion and disturbance proportion. These statistics are also presented in Table 4.14. The RMS% error looks relatively small except for those variables representing prices. This is to be expected since the variation in prices in the model is the result of the variation over a number of supply and demand variables. None of the endogenous variables show a systematic error (bias) but the same tendency for prices to vary is shown in the corresponding variance and covariance proportions and the regression and disturbance proportions.

Table 4.15 provides the dynamic multipliers and the dynamic elasticities for selected variables calculated after an increase of 20% on cattle exports was simulated for the year 1972. The multipliers indicate that the model is stable because all the variables return to equilibrium and the direction of the changes is expected. Cattle slaughter, for example, is reduced in the first period as expected due to the increase in cattle exports. The magnitude of the multipliers, however, is small which means that a 20% change in cattle exports does not impact substantially the endogenous variables of the model.

Dynamic elasticities represent a relative measure of the impact of a change in an exogenous variable. Long run multiplier for beef, for example, was not large but the elasticity for beef relative to a change of 20% in cattle exports (1.58) is the largest among the variables analyzed.

Summary

This section has presented the results of the empirical estimation performed on the Mexican livestock, meat, and feedgrain model developed in the previous section. Data issues were addressed first. Reliability has been a problem for official Mexican data. Estimation procedures were considered after. Structural change and endogeneity of the prices in the demand model were discussed. Then, econometric considerations were presented. The differences among several estimation techniques like the OLS, ILS, 2SLS, SUR, and 3SLS were discussed. Three alternative model specifications (AIDS, ROTTERDAM, and LINEAR) for the Mexican meat demand were used to test for structural change. The results obtained did not show strong evidence that a structural change has occurred in the Mexican meat demand behavior due to the 1982 economic crisis or to the trade liberalization that started in 1986.

Parameters for the three model specifications were estimated using both SUR and 3SLS. Complementarity problems among meat products were found under the AIDS and the ROTTERDAM specifications. The income and expenditure elasticity for pork was found to be relatively large (over 1). Income elasticity in the LINEAR specification and expenditure elasticity in the AIDS specification for chicken was negative. The Mexican meat demand model was also tested for price endogeneity using the Hausman specification test. The results of the Hausman test indicate that the parameters obtained by using SUR estimation are consistent and prices in the Mexican meat demand model may treated as exogenous when the demand model is estimated independently. However, when estimation of livestock and meat supply and demand is required, 3SLS estimation technique is encouraged.

The three alternative model specifications for meat demand were then integrated to the livestock and feedgrain components of the model. A failed attempt was made to simulate the AIDS and the ROTTERDAM specifications. Unfortunately, neither of the two converged for simulation due possibly to the existence of complementarities among meat products and the large income elasticity for pork. The LINEAR specification was then used to estimate the parameters of the integrated Mexican livestock, meat, and feedgrain model.

Estimated parameters for the Mexican livestock, meat, and feedgrain model were presented. Summary statistics showed a good estimation performance of the model. Among the principal results drawn from the empirical estimation are the following:

1. Cattle inventories response to changes in cattle and feed prices is very small which may indicate that, due to meat price controls in Mexico, farmers are quite unresponsive to changes in cattle prices.

2. Slaughter of cattle is highly determined by cattle supply, although cattle and beef prices affect negatively and positively, respectively, the amount of cattle slaughter.

3. Hog inventories responses to hog and feed prices are somewhat higher than the corresponding responses for cattle. Hog slaughter is not highly affected by hog and pork prices but by available hog supply.

4. Per capita consumption of beef and pork are directly affected by changes on per capita income while the effect on chicken per capita consumption is negative.

5. Changes on feed prices seem not to affect significantly the amount of area harvested of the feed crops. Guaranteed prices and the Mexican government trade policy have caused the low response of farmers to changes on feed prices.

After discussing every component of the model, the model was validated using historical simulation. Simulation statistics like the RMS% error and the Theil's statistics showed an overall good performance for all the endogenous variables, except for prices. This variation was expected, however, because the variation in prices in the model is the result of the variation over a number of supply and demand variables. Dynamic multipliers and dynamic elasticities were also presented. The multipliers and elasticities indicate that the model is stable because all the variables return to equilibrium after a shock and the direction of the changes is as expected.

Table 4.1. Mexico: Structural Change Analysis for Meat Demand (Period 1983-91)

LA/AIDS MODEL

	Beef	Pork	Chicken

Dummy After 1982	0.017 (1.65)	-0.003 (-0.34)	0.008 (0.73)
Rho	0.611 (4.53)		
R-Square	0.94	0.97	0.94
D-W Stat.	2.17	2.25	1.69

ROTTERDAM MODEL

	Beef	Pork	Chicken
Dummy After 1982	0.007 (1.27)	-0.008 (-1.42)	0.003 (1.52)
Rho	0.069 (0.47)		
R-Square	0.91	0.97	0.83
D-W Stat.	1.90	1.98	2.03

LINEAR MODEL

	Beef	Pork	Chicken
Dummy After 1982	-0.505 (-2.07)	-0.066 (-0.10)	-0.274 (-0.86)
R-Square	0.95	0.96	0.98
D-W Stat.	1.57	2.30	1.92

Note: t values are in parentheses.

Table 4.2. Mexico: Structural Change Analysis for Meat Demand (Period 1986-91)

LA/AIDS MODEL

	Beef	Pork	Chicken
Dummy for 1986 to 1991	-0.003 (-0.27)	-0.076 (-3.72)	0.057 (6.13)
Rho	0.360 (2.39)		
R-Square	0.96	0.98	0.88
D-W Stat.	2.46	1.74	1.47

ROTTERDAM MODEL

	Beef	Pork	Chicken
Dummy for 1986 to 1991	0.018 (2.57)	-0.018 (-2.41)	0.003 (1.60)
Rho	0.170 (0.94)		
R-Square	0.81	0.93	0.82
D-W Stat.	1.91	1.87	1.47

LINEAR MODEL

	Beef	Pork	Chicken
Dummy for 1986 to 1991	0.076 (0.23)	-3.782 (-4.74)	-0.632 (-1.21)
R-Square	0.94	0.98	0.98
D-W Stat.	1.71	1.51	1.58

Note: t values are in parentheses.

Table 4.3. Mexico: 3SLS and SUR Meat Demand Parameter Estimates: LA/AIDS Model

3SLS EQUATIONS

	Beef	Pork	Chicken*
Intercept	0.785 (5.63)	-0.392 (-1.99)	0.607 (2.22)
Price of Beef	0.224 (14.81)	-0.160 (-11.28)	-0.064 (-3.48)
Price of Pork	-0.160 (-11.28)	0.113 (5.02)	0.047 (1.83)
Price of Chicken	-0.064 (-3.48)	0.047 (1.83)	0.017 (0.46)
Y/P	-0.113 (-2.88)	0.253 (4.57)	-0.140 (-1.06)
Rho	0.429 (3.47)		
R-Square	0.95	0.95	*
D-W Statistic	2.58	1.83	*

SUR EQUATIONS

	Beef	Pork	Chicken
Intercept	0.795 (5.92)	-0.387 (-2.01)	0.592 (2.28)
Price of Beef	0.222 (8.25)	-0.162 (-11.69)	-0.060 (-3.45)
Price of Pork	-0.162 (-11.69)	0.108 (4.88)	0.054 (2.16)
Price of Chicken	-0.060 (-3.45)	0.054 (2.16)	0.006 (0.17)
Y/P	-0.114 (-3.03)	0.253 (4.66)	-0.139 (-1.13)
Rho	0.404 (3.24)		
R-Square	0.95	0.95	*
D-W Statistic	2.55	1.80	*

* The chicken equation was omitted as discussed in the text. Parameters for this equation were recovered using the classical restrictions.

Table 4.4. Mexico: 3SLS Meat Demand Elasticities: LA/AIDS Model*

Expenditure Elasticities

	Beef	Pork	Chicken
	0.732 (18.75)	1.546 (27.91)	-0.190 (-2.48)

Marshallian Elasticities

	Beef	Pork	Chicken
Beef	-0.353 (-6.44)	-0.258 (-6.70)	-0.121 (-2.73)
Pork	-0.574 (-14.92)	-1.009 (-13.69)	0.037 (5.52)
Chicken	-0.044 (-0.27)	0.949 (4.29)	-0.716 (-2.21)

Hicksian Elasticities

	Beef	Pork	Chicken
Beef	-0.046 (-1.21)	0.081 (2.39)	-0.035 (-0.79)
Pork	0.073 (2.39)	-0.293 (-6.04)	0.220 (3.95)
Chicken	-0.123 (-0.79)	0.861 (3.95)	-0.738 (-2.35)

* t values are in parentheses.

Table 4.5. Mexico: SUR Meat Demand Elasticities: LA/AIDS Model*

Expenditure Elasticities

	Beef	Pork	Chicken
	0.728 (19.31)	1.546 (28.51)	-0.178 (-2.41)

Marshallian Elasticities

	Beef	Pork	Chicken
Beef	-0.356 (-6.64)	-0.261 (-6.96)	-0.111 (-2.66)
Pork	-0.579 (-15.38)	-1.020 (-14.01)	0.052 (7.94)
Chicken	-0.015 (-0.10)	1.003 (4.68)	-0.810 (-2.51)

Hicksian Elasticities

	Beef	Pork	Chicken
Beef	-0.051 (-1.34)	0.076 (2.30)	-0.025 (-0.61)
Pork	0.069 (2.30)	-0.304 (-6.26)	0.235 (4.35)
Chicken	-0.089 (-0.61)	0.921 (4.35)	-0.831 (-2.65)

* t values are in parentheses

Table 4.6. Mexico: 3SLS and SUR Meat Demand Parameter Estimates: ROTTERDAM Model

3SLS EQUATIONS

	Beef	Pork	Chicken*
Price of Beef	0.003 (0.11)	-0.022 (-0.80)	0.019 (1.16)
Price of Pork	-0.22 (-0.80)	0.035 (1.03)	-0.013 (-0.67)
Price of Chicken	0.019 (1.16)	-0.013 (-0.67)	-0.006 (-0.32)
Q	0.289 (3.28)	0.618 (6.54)	0.093 (1.48)
Rho	0.097 (0.52)		
R-Square	0.71	0.89	*
D-W Statistic	1.91	1.85	*

SUR EQUATIONS

	Beef	Pork	Chicken
Price of Beef	0.004 (0.15)	-0.026 (-0.95)	0.021 (1.40)
Price of Pork	-0.026 (-0.95)	0.042 (1.31)	-0.016 (-0.94)
Price of Chicken	0.021 (1.40)	-0.016 (-0.94)	-0.005 (-0.30)
Q	0.302 (3.36)	0.599 (6.33)	0.099 (1.59)
Rho	0.127 (0.72)		
R-Square	0.71	0.89	*
D-W Statistic	1.92	1.83	*

* The chicken equation was omitted as discussed in the text. Parameters for this equation were recovered using the classical restrictions.

Table 4.7. Mexico: 3SLS Meat Demand Elasticities: ROTTERDAM Model*

Expenditure Elasticities

	Beef	Pork	Chicken
	0.690 (3.27)	1.335 (6.53)	0.690 (0.54)

Marshallian Elasticities

	Beef	Pork	Chicken
Beef	-0.281 (-4.38)	-0.735 (-11.3)	0.018 (0.47)
Pork	-0.309 (-4.38)	-0.543 (-7.45)	-0.051 (-1.24)
Chicken	-0.869 (-5.24)	-2.532 (-15.7)	-0.143 (-0.90)

Hicksian Elasticities

	Beef	Pork	Chicken
Beef	-0.008 (-0.07)	-0.052 (-0.42)	0.044 (0.72)
Pork	-0.047 (-0.47)	0.075 (0.62)	-0.027 (-0.45)
Chicken	0.158 (0.46)	-0.108 (-0.26)	-0.050 (-0.31)

* t values are in parentheses.

Table 4.8. Mexico: SUR Meat Demand Elasticities: ROTTERDAM Model*

Expenditure Elasticities

	Beef	Pork	Chicken
	0.720 (3.36)	1.294 (6.32)	0.842 (0.57)

Marshallian Elasticities

	Beef	Pork	Chicken
Beef	-0.292 (-4.51)	-0.723 (-11.3)	0.023 (0.63)
Pork	-0.328 (-5.67)	-0.509 (-7.36)	-0.060 (-1.61)
Chicken	-0.890 (-6.85)	-2.488 (-16.9)	-0.143 (-1.01)

Hicksian Elasticities

	Beef	Pork	Chicken
Beef	0.010 (0.09)	-0.061 (-0.49)	0.051 (0.83)
Pork	-0.055 (-0.55)	0.090 (0.77)	-0.035 (-0.60)
Chicken	0.181 (0.52)	-0.137 (-0.34)	-0.044 (-0.31)

* t values are in parentheses.

Table 4.9. 3SLS and SUR Meat Demand Parameter Estimates: LINEAR Model

3SLS EQUATIONS

	Beef	Pork	Chicken*
Intercept	4.297 (1.62)	-5.345 (-0.98)	2.876 (1.86)
Price of Beef	-0.063 (-6.02)	0.019 (1.80)	0.044 (2.05)
Price of Pork	0.040 (1.61)	-0.071 (-3.83)	0.057 (1.46)
Price of Chicken	0.005 (0.50)	0.010 (1.58)	-0.038 (-3.07)
Per capita Income	0.164 (3.26)	0.209 (2.48)	-0.036 (-1.56)
R-Square	0.94	0.96	0.98
D-W Statistic	1.82	2.44	1.68

SUR EQUATIONS

	Beef	Pork	Chicken
Intercept	4.492 (1.73)	-5.266 (-0.97)	2.957 (1.92)
Price of Beef	-0.061 (-6.02)	0.019 (1.82)	0.042 (1.99)
Price of Pork	0.038 (1.57)	-0.071 (-3.86)	0.057 (1.47)
Price of Chicken	0.005 (0.52)	0.010 (1.57)	-0.039 (-3.17)
Per capita Income	0.151 (3.12)	0.211 (2.53)	-0.038 (-1.62)
R-Square	0.93	0.96	0.98
D-W Statistic	1.71	2.49	1.69

* The chicken equation was not omitted in this case.

Table 4.10. Mexico: 3SLS Meat Demand Elasticities: LINEAR Model*

Income Elasticities

	Beef	Pork	Chicken
	0.698 (3.26)	0.879 (2.48)	-0.334 (-1.56)

Marshallian Elasticities

	Beef	Pork	Chicken
Beef	-0.418 (-6.02)	0.145 (1.80)	0.180 (2.05)
Pork	0.267 (1.61)	-0.542 (-3.83)	0.229 (1.46)
Chicken	0.072 (0.50)	0.164 (1.58)	-0.335 (-3.07)

Hicksian Elasticities

	Beef	Pork	Chicken
Beef	-0.126 (-1.10)	0.468 (4.09)	-0.262 (-1.53)
Pork	0.635 (2.62)	-0.135 (-0.65)	0.332 (1.00)
Chicken	-0.069 (-0.54)	0.009 (0.08)	-0.375 (-2.65)

* t values are in parentheses.

Table 4.11. Mexico: SUR Meat Demand Elasticities: LINEAR Model*

Income Elasticities

	Beef	Pork	Chicken
	0.642 (3.12)	0.888 (2.53)	-0.346 (-1.62)

Marshallian Elasticities

	Beef	Pork	Chicken
Beef	-0.411 (-6.02)	0.147 (1.82)	0.171 (1.99)
Pork	0.253 (1.57)	-0.542 (-3.86)	0.230 (1.47)
Chicken	0.073 (0.52)	0.162 (1.57)	-0.342 (-3.17)

Hicksian Elasticities

	Beef	Pork	Chicken
Beef	-0.142 (-1.29)	0.444 (4.04)	0.247 (1.49)
Pork	0.626 (2.63)	-0.131 (-0.64)	0.335 (1.02)
Chicken	-0.072 (-0.57)	0.002 (0.02)	-0.3.83 (-2.72)

* t values are in parentheses.

Table 4.12. Structural Equations of the Mexican Livestock, Meat, and Feedgrain Model[*]

<u>Cattle and Beef Sector</u>	
(4.1) $eitc = 2744 + 8.30*fpc + 0.87*eitc_{t-1} - 0.05*ppf$	R-sq.= 0.98
(3.59) (3.53) (27.1) (-1.94)	D-h = 1.49
[0.02] [0.87] [-0.01]	
(4.2) $sltc = -26417 + 5.23*rpb - 61.25*fpc + 1.52*eitc_{t-1}$	R-sq.= 0.81
(-9.11) (0.85) (-3.24) (12.5)	D-W = 1.56
[0.10] [-0.68] [7.08]	
(4.3) $cb = eitc_{t-1}*cr$	
(4.4) $sltc = eitc_{t-1} + cb + mcat - eitc - xcat - catld$	
(4.5) $tpb = sltc*cacw$	
(4.7) $qb = db/pop$	
(4.8) $qb = 4.56 - 0.06*rpb + 0.02*rpp + 0.04*rpch + 0.16*rpci + 0.07*qb_{t-1}$	R-sq. = 0.92
(2.59) (-8.18) (3.14) (2.85) (5.05) (1.27)	D-h = 0.02
[-0.40] [0.16] [0.15] [0.70] [0.07]	
<u>Hogs and Pork Sector</u>	
(4.9) $eith = 2834 + 9.87*fph + 0.83*eith_{t-1} - 0.20*ppf$	R-sq.= 0.95
(3.17) (1.09) (14.6) (-1.75)	D-h = 1.01
[0.05] [0.83] [-0.08]	
(4.10) $slhg = -2263 + 12.48*rpp - 51.36*fph + 1.40*eith_{t-1}$	R-sq.= 0.94
(-1.52) (2.07) (-2.73) (12.5)	D-W = 1.65
[0.10] [-0.25] [1.32]	
(4.11) $pb = eith_{t-1}*pr$	
(4.12) $slhg = eith_{t-1} + pb + mhog - eith - hogld$	
(4.13) $tpp = slhg*hacw$	
(4.14) $dp = tpp + mp - xp$	
(4.15) $qp = dp/pop$	

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Table 4.12. Continued

(4.16) $qp = -3.63 + 0.04*rpb - 0.06*rpp + 0.06*rpch + 0.16*rpci + 0.59*qp_{t-1}$ R-sq.= 0.95

(-1.03) (2.34) (-4.92) (2.43) (2.91) (10.9) D-h = 0.02

[0.25] [-0.43] [0.23] [0.66] [0.60]

Chicken and Chicken Meat Sector

(4.17) $slch = 274 + 18.93*rpch + 0.98*slch_{t-1} - 0.21*ppf$ R-sq. = 0.97

(0.37) (2.64) (16.6) (-2.75) D-h = 0.92

[0.38] [0.94] [-0.38]

(4.18) $tpch = slch*chcw$

(4.19) $dch = tpch + mch - xch$

(4.20) $qch = dch/pop$

(4.21) $qch = 2.76 + .003*rpb + 0.01*rpp - 0.04*rpch - 0.03*rpci + 1.02*qch_{t-1}$ R-sq. = 0.98

(2.34) (0.37) (1.64) (-3.91) (-1.60) (17.1) D-h = 0.18

[0.04] [0.12] [-0.31] [-0.26] [0.99]

Sorghum Sector

(4.22) $ahs = 167 + 0.71*ahs_{t-1} + 0.05*(pps)_{t-1} - .001*sorgps + .0007*sorgcr$ R-sq. = 0.92

(1.12) (10.5) (1.43) (-0.52) (4.32) D-h = 0.63

[0.71] [0.11] [-0.02] [0.11]

(4.23) $tps = ahs*sy$

(4.24) $ds = tps + ms - xs$

(4.25) $ds = -41904 + 2.08*gca - 0.54*(pps) + 0.14*(ppc)$ R-sq. = 0.96

(-14.5) (17.4) (-3.69) (0.96) D-W = 1.84

[8.11] [-0.28] [0.10]

Soybean and Soymeal Sector

(4.26) $ahsb = -13.3 + .003*(ppsb)_{t-1+} + .0\ 1*rain - .004*soybps + .001*soybcr$ R-sq. = 0.96

(-0.35) (1.04) (10.3) (-3.36) (12.4) D-W = 1.92

[-0.09] [0.89] [-0.43] [0.32]

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Table 4.12. Continued

(4.27) tpsb = ahsb*sby					
(4.28) cdsb = tpsb + msb					
(4.29) cdsb = 627 + 0.04*(ppsm) - 0.07*(ppsb) + 1.26*msb					R-sq. = 0.97
(4.96)	(2.51)	(-3.17)	(27.7)		D-W = 2.07
	[0.20]	[-0.41]	[0.68]		
(4.30) tpsm = cdsb*mysb					
(4.31) dsm = tpsm + msm					
(4.32) dsm = -7195 + 0.34*gca - .006*(ppsm) + 0.28*dsm_{t-1}					R-sq. = 0.87
(-4.52)	(5.08)	(-0.43)	(2.86)		D-h = 0.77
	[7.92]	[-0.04]	[0.27]		
Corn Sector					
(4.33) ahc = 7578 + 0.07*$(ppc)_{t-1}$ - .026*sorgps + .0009*sorgcr					R-sq. = 0.79
(15.2)	(0.66)	(-2.80)	(4.37)		D-W = 1.88
	[0.05]	[-0.09]	[0.08]		
(4.34) tpc = ahc*cy					
(4.35) dc = tpc + mc - xc					
(4.36) dc = -49086 + 2.68*gca - 0.61*(ppc) + 0.29*(pps)					R-sq. = 0.93
(-6.60)	(9.44)	(-3.23)	(0.96)		D-W = 2.31
	[4.80]	[-0.19]	[0.07]		
Identities					
(4.37) gca = eitc + eith*(hog/mcow) + slch*(chi/mcow)					
(4.38) ppf = .4*(pps) + .4*(ppc) + .2*(ppsm)					

[*] t values are in parentheses and gross effect elasticities are in brackets.

Table 4.13. Definition of Variables for Empirical Analysis Section

Jointly Determined Variables

ahc= Area Harvested of Corn

ahs = Area Harvested of Sorghum

ahs = Area Harvested of Soybean

cb = Calves Born

cdsb = Crush Demand for Soybean

db = Demand for Beef

dch = Demand for Chicken

dp = Demand for Pork

ds = Demand for Sorghum

dsm = Demand for Soymeal

eitc = Ending Inventories of Total Cattle

eith = Ending Inventory of Total Hogs

fpc = Farm Price of Cattle

fph = Farm Price of Hogs

gca = Grain Consuming Animal Units

pb = Piglets Born

ppc = Producer Price of Corn

ppf = Producer Price of Feed

pps = Producer Price of Sorghum

ppsb = Producer Price of Soybean

ppsm = Producer Price of Soymeal

qb = Per Capita Consumption of Beef

qch = Per Capita Consumption of Chicken

qp = Per Capita Consumption of Pork

rpb = Retail Price of Beef

rpch = Retail Price of Chicken

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Table 4.13. Continued

rpp = Retail Price of Pork

slch = Slaughter of Chicken

slhg = Slaughter of Hogs

sltc = Slaughter of Cattle

tpb = Total Production of Beef

tpc = Total Production of Corn

tpch = Total Production of Chicken

tpp = Total Production of Pork

tps = Total Production of Sorghum

tpsb = Total Production of Soybean

tpsm = Total Production of Soymeal

Exogenous Variables

cacw = Cattle Average Carcass Weight

catld = Cattle Lost and Dead

chcw = Chicken Average Carcass Weight

chi = Average Feed Consumed by a Chicken in a Year

corncr = Credit Availability for Corn

cornps = Price of Corn Seed

cr = Calving Rate

cy = Corn Yield

hacw = Hogs Average Carcass Weight

hog = Average Feed Consumed by a Hog in a Year

hogld = Hogs Lost and Dead

mb = Imports of Beef

mc = Imports of Corn

mcat = Imports of Cattle

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Table 4.13. Continued

mch = Imports of Chicken

mcow = Average Feed Consumed by a Milk Cow in a Year

mhog = Imports of Hogs

mp = Imports of Pork

ms = Imports of Sorghum

msb = Imports of Soybean

msm = Imports of Soymeal

mysb = Meal Yield of Soybean

pop = Total Mexican Population

pr = Piglets Bearing Rate

rain = Rainfall

rpci = Real Per capita Income

sby = Soybean Yield

sorgcr = Credit Availability for Sorghum

sorgps = Price of Sorghum Seed

soybcr = Credit Availability for Soybean

soybps = Price of Soybean Seed

sy = Sorghum Yield

xb = Exports of Beef

xc = Exports of Corn

xcat = Exports of Total Cattle

xch = Exports of Chicken

xp = Exports of Pork

xs = Exports of Sorghum

Table 4.14. Model Simulation Validation Statistics

	MSE Decomposition Proportions

Variable	Bias (UM)	Reg (UR)	Dist (UD)	Var (US)	Covar (UC)	RMS% Error	Theil's U
EITC	0.000	0.121	0.879	0.040	0.960	0.895	0.004
FPC	0.000	0.377	0.623	0.002	0.998	15.490	0.073
EITH	0.002	0.043	0.955	0.039	0.959	9.861	0.047
FPH	0.000	0.956	0.043	0.627	0.373	82.274	0.352
TPCH	0.126	0.493	0.380	0.398	0.475	15.506	0.065
AHS	0.042	0.002	0.956	0.018	0.940	5.585	0.027
PPS	0.036	0.616	0.348	0.471	0.493	35.989	0.202
AHSB	0.000	0.004	0.996	0.025	0.975	21.165	0.062
PPSB	0.042	0.699	0.259	0.134	0.824	128.95	0.672
PPSM	0.036	0.917	0.048	0.435	0.529	244.51	0.860
AHC	0.002	0.024	0.975	0.014	0.985	4.335	0.020
PPC	0.000	0.196	0.804	0.108	0.892	32.981	0.116
CB	0.015	0.000	0.985	0.001	0.984	0.819	0.004
PB	0.016	0.108	0.876	0.000	0.984	8.829	0.042
SLTC	0.006	0.142	0.852	0.034	0.960	7.126	0.033
TPB	0.006	0.127	0.867	0.034	0.961	7.126	0.033
SLHG	0.010	0.205	0.786	0.018	0.972	18.779	0.089
TPP	0.011	0.176	0.813	0.013	0.976	18.779	0.089
TPS	0.038	0.000	0.962	0.021	0.941	5.585	0.028
DS	0.038	0.146	0.817	0.196	0.767	4.472	0.021
TPSB	0.000	0.001	0.999	0.028	0.972	21.165	0.061
CDSB	0.000	0.006	0.994	0.021	0.979	7.410	0.026
TPSM	0.000	0.008	0.991	0.028	0.972	7.410	0.028
DSM	0.000	0.010	0.990	0.027	0.972	6.758	0.025
TPC	0.004	0.001	0.995	0.018	0.978	4.335	0.021
TDC	0.004	0.008	0.988	0.026	0.970	3.738	0.017

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Table 4.14. Continued

MSE Decomposition Proportions

Variable	Bias (UM)	Reg (UR)	Dist (UD)	Var (US)	Covar (UC)	RMS% Error	Theil's U
GCA	0.020	0.017	0.963	0.000	0.980	0.822	0.004
SLCH	0.111	0.512	0.377	0.404	0.485	15.506	0.067
PPF	0.006	0.974	0.021	0.768	0.226	85.343	0.365
RPB	0.000	0.945	0.054	0.602	0.398	48.010	0.225
RPP	0.000	0.952	0.048	0.621	0.379	88.349	0.358
RPCH	0.004	0.887	0.109	0.539	0.457	44.132	0.207
QBEEF	0.004	0.363	0.633	0.130	0.866	7.222	0.034
QPORK	0.009	0.237	0.754	0.031	0.960	18.570	0.090
QCHIC	0.088	0.537	0.375	0.402	0.509	15.176	0.066
DB	0.006	0.098	0.896	0.024	0.971	7.222	0.033
DP	0.011	0.181	0.808	0.014	0.975	18.570	0.088
DCH	0.126	0.486	0.388	0.396	0.478	15.176	0.063

Table 4.15. Dynamic Multipliers and Dynamic Elasticities for Selected Variables From a 20% Increase in Mexican Cattle Exports

DYNAMIC MULTIPLIERS

Period	EITC	SLTC	FPC	RPB	GCA	PPF	DS	DSM
1	0.1123	-1.122	0.0301	0.1309	0.1531	2.5460	0.0000	0.0000
2	0.1105	0.0405	0.0025	0.0014	0.0764	0.3467	0.1158	0.0206
3	0.0673	0.0693	0.0019	0.0029	0.0527	0.8977	0.1123	0.0002
4	0.0785	0.0112	0.0021	0.0072	0.0225	-0.037	0.0833	0.0086
5	0.0536	0.0514	0.0010	-0.0005	0.0263	0.4770	0.0585	-0.001
6	0.0600	0.0120	0.0015	0.0039	0.0126	-0.014	0.0437	0.0043
7	0.0469	0.0341	0.0009	0.0003	0.0150	0.2699	0.0269	-0.0005
8	0.0495	0.0142	0.0011	0.0024	0.0088	0.0224	0.0266	0.0023
9	0.0388	0.0292	0.0008	0.0003	0.0131	0.2199	0.0154	-0.000
10	0.0380	0.0154	0.0008	0.0016	0.0083	0.0622	0.0203	0.0000
Long Run Multiplier	0.62	-0.86	0.04	0.15	0.38	4.73	0.48	0.03

DYNAMIC ELASTICITIES

Period	EITC	SLTC	FPC	RPB	GCA	PPF	DS	DSM
1	0.0055	-0.3203	0.6695	1.3926	0.0066	0.4974	0.0000	0.0000
2	0.0049	0.0105	0.0521	0.0135	0.0033	0.0539	0.0341	0.0360
3	0.0030	0.0172	0.0336	0.0304	0.0022	0.1455	0.0310	0.0003
4	0.0035	0.0027	0.0432	0.0775	0.0009	-0.005	0.0195	0.0182
5	0.0023	0.0118	0.0210	-0.006	0.0011	0.0749	0.0140	-0.002
6	0.0026	0.0026	0.0277	0.0439	0.0005	-0.002	0.0097	0.0045
7	0.0021	0.0073	0.0187	0.0031	0.0006	0.0537	0.0062	-0.001
8	0.0021	0.0028	0.0201	0.0218	0.0003	0.0046	0.0064	0.0021
9	0.0016	0.0053	0.0137	0.0030	0.0005	0.0406	0.0031	-0.000
10	0.0016	0.0026	0.0131	0.0167	0.0003	0.0011	0.0032	0.0000
Long Run Elasticity	0.03	-0.26	0.90	1.58	0.02	0.86	0.12	0.00

SIMULATION ANALYSIS

This section presents the results of using the Mexican livestock, meat, and feedgrain model and empirical estimates as presented in the previous model and empirical analysis sections to analyze the effects of the unilateral liberalization of Mexican trade which began in the mid-1980s on the Mexican livestock, meat, and feedgrain sectors. Because a complete, consistent series of data for those sectors is not yet available for the period since NAFTA took effect in January of 1994, this analysis considers only the pre-NAFTA period of Mexican unilateral liberalization. The results, however, should provide important insights into the effects of liberalization under NAFTA for the Mexican livestock, meat, and feedgrain sectors. In order to isolate the specific effects of liberalization of trade in each of those sectors as well as the aggregate overall effects of liberalization on all sectors, the results of 5 different simulation scenarios will be considered:

- Liberalization of only cattle exports from Mexico;
- Liberalization of only cattle imports by Mexico;
- Liberalization of only meat imports by Mexico;
- Liberalization of only feed imports by Mexico; and,
- Liberalization of exports and imports of cattle, meat, and feed simultaneously.

Trade liberalization involves the elimination of tariffs and other trade barriers to facilitate trade. Whether trade subsequently grows, however, depends on the pre-liberalization level of protection and changes in the economic conditions in the trading countries. That is, the lowering of tariffs will have little impact if the tariffs are low to begin with or if economic conditions in the trading countries change. Thus, while lower tariffs can boost trade, an economic downturn in the importing country can reduce demand and offset the import effects of liberalization. In many ways, trade liberalization largely opens the door of a country like Mexico to increased export and import opportunities. The rate of economic growth in that country, however, will have a significant effect on the extent of the growth in trade as a result of liberalization. Consequently, this section also reports the analysis of the effects of changes in Mexican per capita incomes during the period of unilateral liberalization on Mexican exports and imports of livestock, meat, and feedgrains.

Mexican Unilateral Trade Liberalization Simulations

The Mexican government began the process of opening its markets to international trade in 1986 (see background section for a detailed discussion). This process led to rapid growth in Mexican trade in livestock, meat, and grains. Cattle exports grew particularly rapidly (Fig. 5.1). Cattle imports also increased after 1987 although to considerably less extent than was the case for cattle exports (Fig. 5.2). Beef imports began growing consistently after 1987 (Fig. 5.3). Pork and chicken meat imports also experienced similar increases (Fig. 5.4 and 5.5). As discussed in the background section, CONASUPO used to subsidize feed and livestock producers by selling feedgrains at lower prices than those paid by CONASUPO. However, Mexican imports of grain generally declined after CONASUPO eliminated the sorghum subsidy in 1985. Feed and livestock producers faced world market prices for feedgrains and reduced the demand for feedgrains. However, following the 1986 Mexican trade liberalization, sorghum imports jumped to record levels by 1991(Fig. 5.6). Feed and livestock producers also face a soybean and soybean meal subsidy reduction in the late eighties which lowered soybean and soybean meal imports. However, liberalization allowed soybean and soybean meal imports to increase from 1987 to 1991 (Fig. 5.7 and 5.8). The strict Mexican corn import controls have never been lifted. Consequently, corn imports have not demonstrated a similar upward trend since the mid- 1980s (Fig. 5.9). Although NAFTA provides for the elimination of Mexican corn import controls, liberalization is scheduled to take place slowly over 15 years with protections against import surges.

To analyze the effects of the unilateral liberalization of Mexican trade that began in the mid-1980s, the Mexican livestock, meat, and feedgrain model presented in the previous section was simulated assuming that Mexican exports and imports of livestock, meat, and feedgrains continued under government control after 1986. For each of the 5 scenarios listed earlier, the model was simulated assuming the year to year change in the respective trade variable or variables over the 1986 to 1991 period of unilateral liberalization was equal to the average annual percent change in those variables over the pre-liberalization period of 1976 to 1985. Then, the changes in the model variables from their baseline levels were taken as measures of the effects of liberalization.

For the simulation of the effects of changes in per capita income on the results of the unilateral liberalization, annual changes in the level of per capita income during the 1986 to 1991 period were set one standard deviation above and below the historical levels. The results of simulating the model under these two assumptions were compared to the baseline to measure the extent to which the change in income during the period of unilateral liberalization affected the levels of trade in livestock, meat, and feedgrains that occurred during that period.

Simulation of Mexican Cattle Export Liberalization

For this simulation, only cattle exports were assumed to have remained under government control during the 1986 to 1991 period. To that end, cattle exports were assumed to have changed by an annual average of only -1.1% between 1986 and 1991 which was the average annual change experienced during the preceding 10 year period (Fig. 5.1). Thus, liberalization implied an average annual increase of 55% in Mexican cattle exports between 1986 and 1991. Changes in the model variables under these assumptions were taken as measures of the effects of the liberalization of cattle exports that began in 1986.

The simulation results indicated that if Mexican exports of cattle had continued to increase over the 1986 to 1991 period at the rate allowed by the government over the preceding years, Mexican cattle inventories would have been lower and slaughter higher than actually occurred as a result of the elimination of Mexican cattle export controls. The simulation results suggested that liberalization of Mexican cattle exports over the 1986 to 1991 period led to a building of Mexican cattle inventories specifically for export. Because exports increased more rapidly than herds could be built, Mexican cattle slaughter and the domestic beef supply was also negatively affected by the liberalization of Mexican cattle exports. The simulation results indicated that the liberalization of Mexican cattle exports beginning in 1986 led to a 0.2% increase in Mexican cattle inventories and a 6.6% decline in cattle slaughter in the first year and an average change of 0.9% and -9.3% in cattle inventories and slaughter over the 1986 to 1991 period (Table 5.1, Fig. 5.10d and Fig. 5.10a).

The lower cattle slaughter resulting from cattle export liberalization also led to a lower beef supply and higher beef and cattle prices (Table 5.1 and Fig 5.10i, Fig. 5.10b, and Fig. 5.10c, respectively). The retail price of beef and the farm price of cattle averaged 61% and 45% higher, respectively, as a result of the liberalization of Mexican cattle exports than otherwise would have been the case over the 1986 to 1991 period (Table 5.1, Fig. 5.10b, and Fig. 5.10c). This result implies a retail beef price flexibility in Mexico of about 6.5. The increase in cattle prices in each year motivated farmers to hold cattle in inventory to profit from higher cattle prices in subsequent years.

The increase in cattle inventories increased the number of grain consuming animal units by an average of 0.5% during the 1986 to 1991 period (Table 5.1 and Fig. 5.10e). As a result, the demand for feed increased by an average of 0.7% over the same period (Table 5.1 and Fig. 5.10f). The small average increase in feed demand (0.7%) led to a large increase in feed prices by an average 26% over the 1986 to 1991 period implying a price flexibility of feed demand in Mexico of about 37. The increase in feed prices motivated farmers to produce more feed although the magnitude of the feed production effect was quite small (0.9% on average) (Table 5.1 and Fig. 5.10h).

Simulation of Mexican Cattle Import Liberalization

The effects of the liberalization of cattle imports on Mexican livestock, meat, and feedgrain markets were obviously opposite of those of the liberalization of cattle exports. Because the magnitude of cattle imports during the 1986-1991 period was fairly modest compared to the level of cattle exports during the same period, the effects of liberalizing cattle imports were smaller than those of liberalizing cattle exports. For this simulation, only cattle imports were assumed to have remained under government control during the 1987 to 1991 period. To that end, cattle imports were assumed to have changed by an annual average of only 8% between 1987 and 1991 which was the average annual change experienced during the preceding 10 year period (Fig. 5.2). Thus, liberalization implied an average annual increase of 50% in Mexican cattle imports between 1987 and 1991. Changes in the model variables under these assumptions were taken as measures of the effects of the liberalization of cattle imports that began in 1988.

The increase in cattle imports that occurred during 1987 to 1991 led to a 2% higher level of slaughter on average over the period than otherwise would have been the case (Table 5.2 and Fig. 5.11a). The higher cattle slaughter increased the domestic beef supply, pushing cattle and beef prices down by an average of 10% and 12%, respectively, over the period (Table 5.2 and Fig. 5.11b and 5.11c).

Despite the increase in cattle supplies from imports, the lower prices of cattle resulted in small net reductions in cattle inventories (0.1%), grain consuming animal units (0.1%), total feed consumption (0.1%), producer price of feed (5.3%), and total feed production (0.1%) (Table 5.2 and Fig. 5.11d to 5.11h). Finally, the increased slaughter of cattle resulted in increases in meat production by an average of 1.3% over the period (Table 5.2 and Fig. 5.11i).

Simulation of Mexican Beef, Pork, and Chicken Meat Import Liberalization

Mexican import restriction on various meat products began to be eliminated in 1988 (see Figures 5.3 to 5.5 and the discussion in the background section). At the time, Mexican meat imports, as was the case for cattle imports, were not very high. For this simulation, only meat imports were assumed to have remained under government control during the 1988 to 1991 period. To that end, imports of beef, pork, and chicken meat were assumed to have changed by annual averages of only 12%, 13%, and 20%, respectively, between 1988 and 1991 which were the average annual changes experienced during the preceding 10 year period (Fig. 5.3 to 5.5). Thus, liberalization implied an average annual increase of 55%, 51%, and 29%, respectively, in Mexican imports of beef, pork, and chicken meat between 1988 and 1991. Changes in the model variables under these assumptions were taken as measures of the effects of the liberalization of meat imports that began in 1988.

The easing of Mexican government controls on meat imports during the 1988 to 1991 period increased the domestic Mexican supply of meat and pushed meat prices down. The average drop in the retail price of meat over the 1988 to 1991 period due to the increase in meat imports was 12%, 6.5%, and 0.8%, for beef, pork, and chicken, respectively (Table 5.3 and Fig. 5.12a to 5.12c). The change in the retail price of chicken meat was negative as expected in the first year (1988). In subsequent years, however, the negative effect of the price reduction on chicken meat production was about the same as the increase in chicken meat imports resulting in little change in the chicken meat price. Adjustments in beef and pork supply were less rapid so that prices of both were lower on average over the period as a result of imports than otherwise would have been the case.

Lower prices of meat led to decreases in livestock and chicken prices and only small declines in cattle and hog ending inventories (0.02% and 0.3% on average, respectively) (Table 5.3 and Fig. 5.12d and 5.12e). As a result, neither grain consuming animal units nor the producer price of feed was much affected by the increase in meat imports. The average effect on grain consuming animal units and producer price of feed was -0.03% and -1.75%, respectively, over the 1988-1991 period (Table 5.3 and Fig. 5.12g and 5.12h). Finally, meat consumption was about 2% higher each year on average as a result of the liberalization of meat imports than otherwise would have been the case (Table 5.3 and Fig 5.12i).

Simulation of Mexican Feedgrain Import Liberalization

Feedgrain import controls began to be eliminated in about 1987 (see Figures 5.6 to 5.8 and discussion in the background section). To simulate the effects of the feed import liberalization, imports of corn, sorghum, and soybeans and soybean meal were assumed to have remained under government control during the 1987 to 1991 period. To that end, imports of sorghum, soybeans, and soybean meal were assumed to have changed by annual averages of only 21%, 9%, and 12%, respectively, between 1987 and 1991 which were the average annual changes experienced during the preceding 10 year period (Fig. 5.6 to 5.8). Thus, liberalization implied average annual increases of 29%, 11%, and 48% in sorghum, soybean, and soybean meal imports, respectively, between 1987 and 1991. Corn exports were left at their historical levels since corn import barriers were not eased during this period. Changes in the model variables under these assumptions were taken as measures of the effects of the liberalization of feedgrain imports that began in 1987.

Mexican feed trade liberalization could have brought several different results to the Mexican feedgrain markets due to the interrelationships among feedgrains. For example, while an increase in sorghum imports might decrease sorghum prices and discourage farmers to plant sorghum, low sorghum prices may boost corn production because of the substitutability between sorghum and corn. Hence, the net effect of an increase in sorghum imports on total grain production will depend on the weighted average effects on sorghum and corn. According to the simulation results, the liberalization of Mexican feedgrain imports increased the supply of feed and held the average Mexican farm price of feed lower by an annual average of 23% during the 1987-1991 period while feed production experienced a small but positive annual average change of 0.8% (Table 5.4 and Fig. 5.13a and 5.13b). Lower feed prices in the first year stimulated greater Mexican holdings of cattle and hogs (1% and 7.1%, respectively) and, consequently, a lower number of cattle and hogs available for slaughter in that year (-0.7% and -1.9%, respectively) (Table 5.4, Fig. 5.13c, and Fig 5.13d). In contrast, the lower cost of feed led to a net increase in chicken slaughter during that year (Table 5.4 and Fig. 5.13e). Over time, the increased number of cattle and hogs in inventory led to larger slaughter of both livestock types. The rather large drop in the farm price of feed in 1991, however, as a result of a large increase in feedgrain imports, stimulated additional expectations by Mexican livestock producers of increased profits and led to a large jump in inventories of both cattle and hogs and some reduction again in the number of each livestock type available for slaughter.

The average annual increase in ending inventories of cattle was less than 1% over the period while that of hogs and slaughter of chicken were 7.1% and 7%, respectively (Table 5.4 and Fig. 5.13c, Fig. 5.13d, and 5.13e). The larger effect of changes in feed prices on hog inventories and slaughter of chicken on average over the period compared to the effect on cattle inventories reflects the relatively lower incidence of feeding in the Mexican cattle industry (see discussion in the background section).

Increases in livestock inventories and chicken slaughter increased the number of grain consuming animal units and the amount of feed consumed over time. Grain consuming animal units increased 1.3% annually on average over the 1986-1991 period while total feed consumption increased 5.4% on average over the same period (Table 5.4 and Fig. 5.13f and 5.13g). The eventually larger supplies of livestock ready for slaughter as the result of lower feed prices generated average increases in Mexican farm price of cattle and meat production of 11% and 2.2%, respectively, over the period (Table 5.4 and Fig. 5.13h and 5.13i).

Simulation of Total Liberalization

For this simulation, Mexican imports and exports of cattle, meat, and feedgrains together were assumed to have remained under government control during the 1986 to 1991 period. Consequently, Mexican cattle, meat, and feedgrain exports and imports were simultaneously set at the levels assumed for each in their preceding individual simulations and the model was once again simulated over the 1986 to 1991 period. Simulated changes in the model variables under these assumptions were taken as measures of the net effects of the simultaneous unilateral liberalization of Mexican cattle, meat, and feedgrain trade that began in 1986.

The simulation results clearly indicate that the Mexican unilateral liberalization benefited both the livestock and feedgrain sectors in Mexico. Even though increased imports of feedgrains had a negative effect on feed prices in Mexico, feed production experienced a positive change. Furthermore, the increased demand for livestock as the result of freer trade generated an increase in demand for feed that more than offset the negative effects for the feedgrain sector. Thus, even though feedgrain import liberalization alone would have reduced Mexican feedgrain prices over the 1986 to 1991 period by an annual average of 23%, and the increase in feed production would have been only of 0.8% (see Table 5.4), increased demand for feed as the result of the liberalization of livestock and meat trade boosted both and resulted in net average annual increases in total production (1.8%) and in the farm price of feed (0.3%).

The simulation results also indicated that the unilateral liberalization benefited the Mexican meat processing industry. Even though liberalization reduced meat production by an annual average of 2.6% over the period, the inelastic nature of beef demand in Mexico resulted in a much larger 33% increase in the real retail price of beef so that revenues to the beef processing industry actually increased as a result of liberalization (Table 5.5 and Fig 5.14b and Fig. 5.14i).

Increased feed imports reduced the cost of feeding and stimulated livestock slaughter over the period as shown in Table 5.4. Nevertheless, the strong increase in cattle exports over the same period reduced slaughter by more than enough to offset the positive effects of the increased feed imports on slaughter (Table 5.5 and Fig. 5.14a). Even so, the net negative effect of liberalizing all markets on cattle slaughter (an average annual reduction of 7.7%) was not as large as in the case of liberalizing only cattle exports (an average annual reduction of 9.3%). That is, liberalizing cattle exports and feedgrain imports in tandem resulted in a smaller reduction in slaughter than if only cattle exports had been liberalized.

The smaller production of meat as a result of liberalization pushed up meat prices and reduced meat consumption (Table 5.5 and Fig. 5.14b). The simulated 33% annual average increase in the retail price of beef was about half the simulated annual increase (61%) from liberalizing only cattle exports. The farm price of cattle also increased (42.5% average annual increase) as larger cattle exports reduced the number of cattle available for slaughter (Table 5.5 and Fig. 5.14c).

Larger inventories of livestock generated a larger number of grain consuming animal units in Mexico (Table 5.5 and Fig. 5.14c) which stimulated consumption of feed by an average of 5.2% over the period (Table 5.5 and Fig. 5.14f). The increase in feed consumption was facilitated primarily by the increased feedgrain imports along with a small increase in domestic feedgrain production (1.8% average annual increase) (Table 5.5 and Fig. 5.14h).

An increase in feed demand normally would be expected to push feed prices up. However, the positive price effects of an increase in feed demand from increased cattle inventories were largely offset by the negative price effects of an increase in feed imports as a result of the unilateral liberalization (Table 5.5 and Fig. 5.14g). Even though the average net change in the producer price of feed was only 0.26%, the annual year-to-year fluctuations in feed price were quite high. Given the rather low price elasticity of feed production (as discussed in empirical analysis section), however, the price fluctuations generated only a small response in total feed production as mentioned earlier.

Simulated Effects of Changes in Real Per Capita Income

Real per capita income in Mexico varied widely around a generally upward trend during the 1970s and the 1980s (Fig. 5.15). Mexican real per capita income increased annually by an average 3.7% between 1972 and 1981 only to fall by almost 10% over the following two years as a result of a severe economic downturn. Following a slight increase in 1984 and 1985, the second economic crisis of the decade again pushed Mexican real per capita income down by more than 6% in 1986. Although real GDP increased somewhat in 1987 and 1988, real per capita income decreased slightly because population growth out paced real GDP growth. Real per capita income increased by almost 1% annually on average from 1988 through 1991 coinciding with the Mexican unilateral trade liberalization policy. In the foregoing simulations of trade liberalization, the level of per capita income was assumed to be that actually achieved during the 1988 to 1991 period of liberalization. Obviously, the final effects of liberalization are dependent to some extent on the level of income growth during the period of liberalization. To determine the extent to which the simulated effects of the unilateral trade liberalization were dependent on the level of income achieved during the period, the total liberalization simulation scenario (i.e., simulation of simultaneous liberalization of all livestock, meat, and feedgrain trade) was run again under different per capita income assumptions.

Over the 1971 to 1991 period, the annual change in Mexican real per capita income was as high as 6.2% and as low as -6.7% (Fig. 5.16). The standard deviation in annual real per capita income over that period was 3.6%. Consequently, for the analysis of the effects of per capita income on Mexican livestock, meat, and feedgrain trade, the total simulation scenario was re-run twice over the period 1986 to 1991 assuming first that per capita income was one standard deviation higher than the level actually achieved (the "High Income" scenario) and then assuming per capita income was one standard deviation lower than the level actually achieved during that period (the "Low Income" scenario). Figure 5.17 shows the historical and the assumed high and low levels of real per capita income during the 1986 to 1991 period of unilateral trade liberalization.

In general, a higher real per capita income in Mexico would be expected to increase meat consumption which would increase meat prices and encourage meat imports (Table 5.6). On the other hand, the higher meat prices would also tend to encourage an increase in livestock inventories, livestock slaughter, and domestic meat production and discourage both meat imports and cattle exports. The larger livestock inventories and slaughter would tend to increase grain consuming animal units, and boost feed consumption, production, and imports. The net effects will depend on the behavioral characteristics of the livestock, meat, and feedgrain markets as represented in the model developed for this study.

Figure 5.18 illustrates the simulated effects of different levels of real per capita income on meat imports over the 1986 to 1991 period of Mexican unilateral trade liberalization. Under the "High Income" (HIGH) assumption, simulation of the model indicated that Mexican meat imports would have been 65,000 mt (411%) higher than actually achieved through the policy of trade liberalization (i.e., TL in Fig. 5.18) in the first year and 107,000 mt (233%) higher annually on average over the six-year period of 1986 to 1991. On the other hand, under the "Low Income" (LOW) assumption, the simulation results indicate that Mexican meat imports would likely not have been simply lower than actually occurred following the liberalization of trade but would likely have been negative. That is, if Mexican per capita income would have been only 1 standard deviation lower than was actually the case during the 1986 to 1991 period of unilateral trade liberalization, Mexican meat demand would have dropped enough to eliminate meat imports altogether and created excess Mexican supplies of meat for export (Fig. 5.18 and Table 5.7).

The higher beef consumption from a higher level of per capita income would have also led to a higher beef and cattle prices, stimulating an increase in cattle inventories and slaughter and a decrease in cattle available for export. This negative effect of income on cattle exports, however, would have been rather small for 2 main reasons. First, since the effect of an increase of real per capita income on meat demand is relatively low (0.3% on average, Table 5.6), meat imports fill a large part of the increased meat demand so that relatively few cattle would have needed to be diverted from exports to meet the increased meat demand. Second, the higher prices of cattle and beef stimulate increased inventories and cattle available for slaughter, further easing the pressure to divert cattle from exports to meet the higher domestic demand for meat. The simulated negative, net average annual impact of the assumed changes in real per capita income on Mexican cattle exports from the level that actually occurred under the trade liberalization policy was just over ±4% for the six-year period (Fig. 5.19 and Table 5.8).

Also, the simulation results indicated that imports of both Mexican cattle and feedgrains were positively associated with changes in income in Mexico. Given the small assumed change (±3.6%) in the level of Mexican real per capita income over the 1986 to 1991 period of Mexican unilateral trade liberalization, Mexican cattle imports would have changed by an average ±41,000 head (±45.8%) in the same direction from the level actually achieved during that period (Table 5.9 and Fig. 5.20). As with meat imports, cattle imports would likely have completely disappeared if real per capita income had declined despite the unilateral opening of Mexican markets between 1986 and 1991.

Because of a change in income would have affected the level of meat demand and livestock inventories and slaughter, the demand for feed would have also been higher leading to an increase in feedgrain imports. The model simulation results suggested that the assumed ±3.6% annual average change in real per capita income would have led to an annual average ±4% change in Mexican feed imports in the same direction (Table 5.10 and Fig. 5.21).

Conclusions and Implications for Policy

The trade liberalization simulation results presented in this section provide insight on the consequences of more open Mexican markets for the Mexican livestock, meat, and feedgrain markets particularly during the 1986 to 1991 period of unilateral trade liberalization by Mexico. In general, the analysis indicates that the Mexican policy shift to more open markets substantially impacted Mexican livestock, meat, and feedgrain trade. The results also clearly indicate that the effects of liberalizing Mexican livestock, meat, and feedgrain trade are highly dependent on the level and direction of change in per capita income during the period of liberalization. These results lead to a number of key implications for policy.

First, the Mexican comparative advantage is in the production of feeder cattle for export rather than for domestic feeding and slaughter. In simulating the effects of the Mexican unilateral liberalization during the period of 1986 to 1991, the resulting changes in meat and feedgrain trade were completely overwhelmed by the effects of a relatively large increase in cattle exports.

Second, liberalization of Mexican markets benefits both the livestock and feedgrain sectors in Mexico. Even though increased imports of feedgrains had a negative effect on feed prices in Mexico in the simulation of the liberalization of Mexican livestock, meat, and feedgrain markets over the 1986 to 1991 period, the resulting increased demand for livestock generated an increase in demand for feed that more than offset those negative effects for the feedgrain sector.

Third, liberalization of Mexican markets also benefits the Mexican meat processing industry. Even though the simulation of the simultaneous liberalization of Mexican livestock, meat, and feedgrains indicated that meat production was lower on average over the period than would have been the case, the inelastic nature of beef demand in Mexico resulted in a much larger percentage increase in the real retail price of beef. Consequently, the simulation results indicated that the unilateral liberalization of the 1986 to 1991 period indicated that revenues to the Mexican beef processing industry actually increased during the period as a result.

Fourth, liberalization of Mexican livestock, meat, and feedgrain markets generates little effect on the Mexican feedgrain sector because the positive price effects of an increase in feed demand from increased cattle inventories are largely offset by the negative price effects of an increase in feed imports.

Fifth, changes in real per capita income in Mexico are an important factor in determining the likely consequences of trade liberalization on Mexican meat import imports. If Mexican per capita income had been only 1 standard deviation lower than was actually the case during the 1986 to 1991 period of unilateral trade liberalization, the model simulation results indicate that Mexican meat demand would have dropped enough to eliminate meat imports altogether possibly even creating excess Mexican supplies of meat for export. On the other hand, the simulation results also indicate that a higher level of per capita income during the period of liberalization than actually occurred would have boosted Mexican meat consumption and led to higher beef and cattle prices, stimulating an increase in cattle inventories and slaughter and a relatively small net decrease in cattle available for export.

Sixth, imports of both Mexican cattle and feedgrains are positively associated with changes in income in Mexico. Given the small assumed change (±3.6%) in the level of Mexican per capita income over the 1986 to 1991 period of Mexican unilateral trade liberalization, the model simulation results reveal that Mexican cattle imports would have changed by an average ±45.8% in the same direction from the level actually achieved during that period. Because a change in income would have affected the level of meat demand and livestock inventories and slaughter, the demand for feed would have also been higher leading to a small annual average ±4% change in Mexican feed imports in the same direction.

Seventh, even though feed prices are positively affected by trade liberalization in the meat, livestock, and feedgrain markets, Mexican feed production responds little to those changes. Mexican farmers respond more to other variables such as the cost and availability of credit, the cost of other inputs, and government farm policies.

Table 5.1. Mexico: Effects of Cattle Exports Liberalization on Selected Variables, 1986-1991

	Slaughter of Cattle			Retail Price of Beef			Farm Price of Cattle		
Year	GCL[1]	Change		GCL	Change		GCL	Change	
	ThH	ThH	%	MxP	MxP	%	MxP	MxP	%
1986	6773	-451	-6.6	42	26	62	55	9	17
1987	6724	-603	-8.9	50	37	73	48	14	29
1988	6098	-523	-8.5	80	34	42	46	14	31
1989	6074	-464	-7.6	94	33	35	45	14	31
1990	5748	-920	-16.0	62	58	93	24	24	99
1991	6061	-506	-8.3	68	42	62	29	18	63

	Cattle Inventories			Grain Cons. An. Units			Feed Consumption		
Year	GCL	Change		GCL	Change		GCL	Change	
	ThH	ThH	%	ThU	ThU	%	TMT	TMT	%
1986	23128	53	0.2	24395	45	0.2	20277	0	0.0
1987	22962	117	0.5	24220	94	0.4	23659	83	0.3
1988	22853	160	0.7	23786	124	0.5	21653	165	0.7
1989	22799	192	0.8	23753	142	0.6	21774	221	1.0
1990	22778	276	1.2	23763	200	0.8	27198	288	1.0
1991	22660	300	1.3	23500	210	0.9	22698	391	1.7

	Producer Price of Feed			Feed Production			Meat Consumption		
Year	GCL	Change		GCL	Change		GCL	Change	
	MxP	MxP	%	TMT	TMT	%	TMT	TMT	%
1986	7606	493	6.4	17716	0	0.0	3143	-101	-3.2
1987	6804	886	13.0	19250	83	0.4	3038	-159	-5.2
1988	5868	1076	18.3	17376	165	0.9	2784	-167	-6.0
1989	4419	1171	26.5	16948	221	1.3	2538	-186	-7.3
1990	2703	1722	63.7	21683	288	1.3	2700	-313	-11
1991	5907	1647	27.8	19586	391	1.9	3009	-282	-9.3

[1] GCL= Simulated level under continued government cattle exports control assumption
ThH= Thousand heads MxP= 1980 Mexican pesos ThU= Thousand units TMT= Thousand metric tons

Table 5.2. Mexico: Effects of Cattle Imports Liberalization on Selected Variables, 1986-1991

	Slaughter of Cattle			Retail Price of Beef			Farm Price of Cattle		
Year	GCL[1]	Change		GCL	Change		GCL	Change	
	ThH	ThH	%	MxP	MxP	%	MxP	MxP	%
1986	6773	9	0.1	42	-0.5	-1.2	55	-0.2	-0.3
1987	6724	6	0.1	50	-0.3	-0.7	48	-0.2	-0.3
1988	6098	198	3.2	80	-11.5	-14.4	46	-4.2	-9.3
1989	6074	49	0.8	94	-3.4	-3.6	45	-1.7	-3.7
1990	5748	328	5.7	62	-19.1	-30.4	24	-7.6	-30
1991	6061	157	2.6	68	-11.2	-16.5	29	-5.1	-17

	Cattle Inventories			Grain Cons. An. Units			Feed Consumption		
Year	GCL	Change		GCL	Change		GCL	Change	
	ThH	ThH	%	ThU	ThU	%	TMT	TMT	%
1986	23128	-1.1	-0.0	24395	-0.9	-0.0	20277	0.0	-0.0
1987	22962	-1.6	-0.0	24220	-1.2	-0.0	23659	-1.6	-0.0
1988	22853	-24	-0.1	23786	-21	-0.1	21653	-2.2	-0.0
1989	22799	-26	-0.1	23753	-20	-0.1	21774	-37	-0.2
1990	22778	-61	-0.2	23763	-48	-0.2	27198	-39	-0.1
1991	22660	-71	-0.3	23500	-53	-0.2	22698	-94	-0.4

	Producer Price of Feed			Feed Production			Meat Consumption		
Year	GCL	Change		GCL	Change		GCL	Change	
	MxP	MxP	%	TMT	TMT	%	TMT	TMT	%
1986	7606	-9.9	-0.1	17716	0.0	-0.0	3143	2.0	0.0
1987	6804	-11	-0.1	19250	-1.6	-0.0	3038	1.8	0.0
1988	5868	-224	-3.8	17376	-2.2	-0.0	2784	46	1.6
1989	4419	-158	-3.5	16948	-37	-0.2	2538	20	0.8
1990	2703	-461	-17	21683	-39	-0.2	2700	87	3.2
1991	5907	-418	-7.1	19586	-94	-0.4	3009	66	2.2

[1] GCL= Simulated level under continued government cattle imports control assumption
ThH= Thousand heads MxP= 1980 Mexican pesos ThU= Thousand units TMT= Thousand metric tons

Table 5.3. Mexico: Effects of Meat Imports Liberalization on Selected Variables, 1986-1991

	Retail Price of Beef			Retail Price of Pork			Retail Price of Chicken		

Year	GCL[1]	Change		GCL	Change		GCL	Change	
	MxP	MxP	%	MxP	MxP	%	MxP	MxP	%
1986	42	0.0	-0.0	61	0.0	-0.0	58	0.0	0.0
1987	50	0.0	-0.0	117	0.0	-0.0	72	0.0	0.0
1988	80	-10	-13	139	-14	-9	76	-5	-6.2
1989	94	-9	-10	137	-8	-5	63	0.2	0.4
1990	62	-6	-9	91	-4	-4	44	0.7	1.5
1991	68	-11	-16	89	-9	-9	51	0.6	1.2

	Cattle Inventories			Hog Inventories			Slaughter of Chicken		
Year	GCL	Change		GCL	Change		GCL	Change	
	ThH	ThH	%	ThH	ThH	%	HTH	HTH	%
1986	23128	0.0	0.0	13857	0.0	0.0	35837	0.0	0.0
1987	22962	0.00	0.0	13614	0.0	0.0	3502	0.0	0.0
1988	22853	-3.6	-0.01	11172	-35	-0.3	3639	-79	-2.1
1989	22799	-5.9	-0.02	11401	-36	-0.3	3560	-58	-1.6
1990	22778	-6.3	-0.02	11083	-26	-0.2	4910	-31	-0.6
1991	22660	-8.6	-0.03	9493	-29	-0.3	5180	-1	-0.0

	Grain Cons. An. Units			Producer Price of Feed			Meat Consumption		
Year	GCL	Change		GCL	Change		GCL	Change	
	ThU	ThU	%	MxP	MxP	%	TMT	TMT	%
1986	24395	0.0	0.0	7606	0.0	0.0	3143	0.0	0.0
1987	24220	0.0	0.0	6804	0.0	0.0	3038	0.0	0.0
1988	23786	-6.5	-0.02	5868	-70	-1.2	2784	41	1.5
1989	23753	-9.0	-0.03	4419	-77	-1.7	2538	65	2.5
1990	23763	-8.6	-0.03	2703	-66	-2.4	2700	50	1.8
1991	23500	-11	-0.04	5907	-95	-1.6	3009	72	2.4

[1] GCL= Simulated level under continued government meat imports control assumption HTH= Hund. thous. heads
ThH= Thousand heads MxP= 1980 Mexican pesos ThU= Thousand units TMT= Thousand metric tons

Table 5.4. Mexico: Effects of Feed Imports Liberalization on Selected Variables, 1986-1991

	Producer Price of Feed			Feed Production			Cattle Inventories		
Year	GCL[1]	Change		GCL	Change		GCL	Change	

	MxP	MxP	%	TMT	TMT	%	ThH	ThH	%
1986	7606	0.0	0.0	17716	0	0.0	23128	0.0	0.0
1987	6804	-734	-10	19250	99	0.5	22962	52	0.2
1988	5868	-2311	-39	17376	199	1.1	22853	216	0.9
1989	4419	-440	-9	16948	379	2.2	22799	236	1.0
1990	2703	7.3	0.2	21683	-151	-0.7	22778	236	1.0
1991	5907	-3373	-57	19586	180	0.9	22660	478	2.1

	Hog Inventories			Slaughter of Chicken			Grain Cons. An. Units		
Year	GCL	Change		GCL	Change		GCL	Change	
	ThH	ThH	%	HTH	HTH	%	ThU	ThU	%
1986	13857	0.0	0.0	35837	0.0	0.0	24395	0.0	0.0
1987	13614	230	1.6	3502	74	2.1	24220	74	0.3
1988	11172	881	7.8	3639	306	8.4	23786	290	1.2
1989	11401	717	6.2	3560	291	8.1	23753	297	1.2
1990	11083	570	5.1	4910	254	5.1	23763	287	1.2
1991	9493	1466	15	5180	589	11	23500	607	2.5

	Feed Consumption			Farm Price of Cattle			Meat Production		
Year	GCL	Change		GCL	Change		GCL	Change	
	TMT	TMT	%	MxP	MxP	%	TMT	TMT	%
1986	20277	0.0	0.0	55	0	0.0	3128	0.0	0.0
1987	23659	99	0.4	48	1	1.8	3020	-14	-0.5
1988	21653	697	3.2	46	3	7.0	2755	-6	-0.2
1989	21774	2102	9.6	45	2	5.7	2508	141	5.5
1990	27198	1449	5.3	24	4	14.8	2665	120	4.4
1991	22698	1931	8.5	29	7	25	2970	51	1.7

[1] GCL= Simulated level under continued government feed imports control assumption HTH= Hund. thous. heads
ThH= Thousand heads MxP= 1980 Mexican pesos ThU= Thousand units TMT= Thousand metric tons

Table 5.5. Mexico: Effects of Total Liberalization on Selected Variables, 1986-1991

	Slaughter of Cattle			Retail Price of Beef			Farm Price of Cattle		
Year	GCL[1]	Change		GCL	Change		GCL	Change	
	ThH	ThH	%	MxP	MxP	%	MxP	MxP	%

1986	6773	-451	-6.6	42	26	62	55	9	17
1987	6724	-656	-9.7	50	37	73	48	15	31
1988	6098	-461	-7.5	80	6	8	46	12	27
1989	6074	-344	-5.6	94	0.5	0.5	45	14	31
1990	5748	-500	-8.7	62	25	40	24	20	81
1991	6061	-493	-8.1	68	10	15	29	20	68

	Cattle Inventories			Grain Cons. An. Units			Feed Consumption		
Year	GCL	Change		GCL	Change		GCL	Change	
	ThH	ThH	%	ThU	ThU	%	TMT	TMT	%
1986	23128	53	0.2	24395	45	0.2	20277	0.0	0.0
1987	22962	170	0.7	24220	169	0.7	23659	183	0.7
1988	22853	349	1.5	23786	387	1.6	21653	862	3.9
1989	22799	397	1.7	23753	410	1.7	21774	2276	10
1990	22778	445	1.9	23763	431	1.8	27198	1683	6.1
1991	22660	699	3.1	23500	754	3.2	22698	2213	9.7

	Producer Price of Feed			Feed Production			Meat Consumption		
Year	GCL	Change		GCL	Change		GCL	Change	
	MxP	MxP	%	TMT	TMT	%	TMT	TMT	%
1986	7606	493	6.4	17716	0	0.0	3143	-101	-3.2
1987	6804	152	2.2	19250	183	0.9	3038	-174	-5.7
1988	5868	-1523	-25	17376	364	2.1	2784	-85	-3.1
1989	4419	498	11	16948	553	3.2	2538	40	1.6
1990	2703	1204	44	21683	82	0.3	2700	-55	-2.0
1991	5907	-2238	-37	19586	462	2.3	3009	-92	-3.1

[1] GCL= Simulated level under continued government complete trade control assumption
ThH= Thousand heads MxP= 1980 Mexican pesos ThU= Thousand units TMT= Thousand metric tons

Table 5.6. Mexico: Effects of a 3.6% Increase in Real Per Capita Income on Selected Variables

	Meat Consumption			Retail Price of Beef			Retail Price of Pork		
Year	TL[1]	Change		TL	Change		TL	Change	
	TMT	TMT	%	MxP	MxP	%	MxP	MxP	%

1986	2893	1	0.1	79	13.4	16	92	17.5	19
1987	2876	5	0.2	77	12.3	16	114	15.5	13
1988	2786	8	0.2	79	12.4	15	132	15.8	12
1989	2607	11	0.4	96	12.3	13	130	15.5	12
1990	2714	12	0.4	83	12.8	15	105	16.4	16
1991	2971	14	0.5	78	12.7	16	110	15.8	14

	Retail Price of Chicken			Cattle Inventories			Slaughter of Cattle		
Year	TL	Change		TL	Change		TL	Change	
	MxP	MxP	%	ThH	ThH	%	ThH	ThH	%
1986	50	1.7	3.3	23046	5	0.01	6030	-4.6	-0.07
1987	63	1.6	2.5	23089	7	0.03	5919	-0.4	-0.00
1988	69	1.7	2.4	23118	8	0.03	5660	1.5	0.02
1989	60	1.6	2.7	23162	9	0.04	5644	2.5	0.04
1990	49	1.8	3.6	23170	10	0.04	5254	3.0	0.05
1991	44	1.7	3.8	23271	10	0.04	5580	3.4	0.06

	Grain Cons. An. Units			Feed Consumption			Feed Production		
Year	TL	Change		TL	Change		TL	Change	
	ThU	ThU	%	TMT	TMT	%	TMT	TMT	%
1986	24342	8	0.03	20326	0	0.0	17765	0	0.0
1987	24409	13	0.05	23471	15	0.06	19062	15	0.07
1988	24120	15	0.06	22193	22	0.09	17418	22	0.12
1989	24174	16	0.06	24029	27	0.11	17480	27	0.15
1990	24172	18	0.07	28714	33	0.11	21598	33	0.15
1991	24178	18	0.07	24901	35	0.14	20038	35	0.17

[1] TL= Historical level after 1986 trade liberalization
ThH= Thousand heads MxP= 1980 Mexican pesos ThU= Thousand units TMT= Thousand metric tons

Table 5.7. Mexico: Impact of Changes in Real Per Capita Income on Meat Imports

	Meat Imports		Trade Lib. (High Income)		Trade Lib. (Low Income)	
Year	GCL[1]	TL	Change		Change	
	Thous. Metric Tons		TMT	%	TMT	%
1986	16	16	65	411	-65	-411

1987	18	18	91	510	-91	-510
1988	29	81	107	132	-107	-132
1989	33	112	118	105	-118	-105
1990	40	99	127	128	-127	-127
1991	47	122	135	110	-135	-110

Table 5.8. Mexico: Impact of Changes in Real Per Capita Income on Cattle Exports

	Cattle Exports		Trade Lib. (High Income)		Trade Lib. (Low Income)	
Year	GCL	TL	Change		Change	
	Thousand Heads		ThH	%	ThH	%
1986	462	860	-47	-5.5	47	5.5
1987	457	1019	-42	-4.1	42	4.1
1988	451	981	-41	-4.2	41	4.2
1989	446	945	-39	-4.1	39	4.1
1990	440	1351	-40	-2.9	40	2.9
1991	435	1030	-37	-3.6	37	3.6

[1] GCL= Assumed variable level under continued government control TL= Historical level after 1986 trade liberalization ThH= Thousand heads TMT= Thousand metric tons

Table 5.9. Mexico: Impact of Changes in Real Per Capita Income on Cattle Imports

Year	Cattle Imports		Trade Lib. (High Income)		Trade Lib. (Low Income)	
	GCL[1]	TL	Change		Change	
	Thousand Heads		ThH	%	ThH	%
1986	57	57	47	83	-47	-83
1987	39	39	42	109	-42	-109
1988	42	218	41	19	-41	-19
1989	46	104	39	37	-39	-37
1990	50	354	40	11	-40	-11
1991	54	227	37	16	-37	-16

Table 5.10. Mexico: Impact of Changes in Real Per Capita Income on Feed Imports

Year	Feed Imports		Trade Lib. (High Income)		Trade Lib. (Low Income)	
	GCL	TL	Change		Change	
	Thous. Metric Tons		TMT	%	TMT	%
1986	3392	3392	88	2.6	-88	-2.6
1987	5317	5479	161	2.9	-161	-2.9
1988	5263	5879	226	3.8	-226	-3.8
1989	5895	7660	287	3.7	-287	-3.7
1990	6382	8017	361	4.5	-361	-4.5
1991	4067	6368	416	6.5	416	6.5

[1] GCL= Assumed variable level under continued government control TL= Historical level after 1986 trade liberalization ThH= Thousand heads TMT= Thousand metric tons

SUMMARY AND CONCLUSIONS

A number of countries have formed or are negotiating the terms for trade associations of various types to stimulate their economies. Trade associations or agreements that reduce tariff and non-tariff barriers among countries allow freer trade and increase the size of the market for goods and services of the participant countries. In North America, the U.S., Canada, and Mexico launched an experiment in regional free trade when the North American Free Trade Agreement (NAFTA) entered into force at the beginning of 1994.

This study provided a comprehensive, consistent assessment of the potential impacts of freer U.S.-Mexico agricultural trade on the Mexican livestock, meat, and feedgrain industries. Several research objectives were pursued in this study, including the following: (1) a qualitative assessment of the economic structure and government policy intervention in the Mexican livestock, meat, and feedgrain industry; (2) the development of an econometric model to measure and analyze the key parameters affecting the behavior of the demand, supply, prices, trade, and other relevant variables in the Mexican livestock, meat, and feedgrain markets; (3) validation of the econometric model for use in historical simulation analysis of Mexican markets for livestock, meat, and feedgrains; and (4) the analysis of the likely effects of freer U.S.-Mexico trade through model simulation analyses under several different scenarios.

The first objective was achieved in the background section by presenting the characteristics of the Mexican livestock, meat, and feedgrain sectors and by providing the basis for the hypothetical model subsequently defined. Among the main conclusions of the qualitative assessment of the Mexican livestock, meat, and feedgrain industries found in the background section are the following:

1. The growth and development of the Mexican meat and livestock industries prompted the development and expansion of the Mexican feedgrain industry during the 1970s. This expansion was slowed by the 1982 economic crisis in Mexico.

2. Although beef had been the meat traditionally consumed by Mexicans, pork became the most consumed meat during the 1970s and 1980s fostered by the rapid development of the Mexican hog industry during the 1970s and 1980s. Following the 1982 economic crisis, however, chicken emerged as a cheap and increasingly popular meat alternative in Mexico.

3. Mexican government domestic and trade policies prior to the unilateral opening of Mexican markets restricted the trade meat and livestock as well as of feedgrains in order to maintain low meat prices or to enforce the "guaranteed price" policy for feedgrains.

4. The main components of balanced animal feed rations in Mexico are sorghum and soymeal. Corn is the major staple food in Mexico so that corn is not commonly used in feed formulations.

5. PROCAMPO is the latest program of the Mexican government intervention in agriculture. This program intends to gradually eliminate the guaranteed price scheme and to bring Mexican agricultural prices to a world level.

The model section achieved the second objective and presented a conceptual model of the Mexican livestock, meat, and feedgrain sectors. The underlying assumptions of the model were presented first and then the livestock and meat supply relationships were discussed. The supply and demand model for the feedgrain sector was also presented. The results of three meat demand model formulations (LA/AIDS, ROTTERDAM, and single equation) for the Mexican meat sector were then presented and compared. Finally, an integrated supply and demand model for each of the meat demand specifications was presented.

The empirical analysis section focused on the third objective of the study and presented the results of the empirical estimation of the alternative conceptual models of the Mexican livestock, meat, and feedgrain industries presented in the previous chapter. Data issues were addressed first focusing on the lack of reliability of official Mexican data. Issues and procedures for econometric estimation of the coefficients of the alternative models were then considered, especially the issues of structural change and endogeneity of the prices in the demand models. Econometric considerations, including the differences among several estimation techniques such as OLS, ILS, 2SLS, SUR, and 3SLS, were discussed. The three alternative models for Mexican meat demand as formulated conceptually in the previous chapter were used to test for structural change. The results failed to provide strong evidence of structural change in Mexican meat demand behavior due to the 1982 economic crisis or to the trade liberalization that began in 1986.

Parameters for the three model specifications were estimated using both SUR and 3SLS. Problems of gross complementarity among the different types of meat plagued both the AIDS and the ROTTERDAM results. The Mexican meat demand model was also tested for price endogeneity using the Hausman specification test.The results of the Hausman test indicate that the parameters obtained by using SUR estimation are consistent and prices in the Mexican meat demand model may treated as exogenous when the demand model is estimated independently. However, when estimation of livestock and meat supply and demand is required, 3SLS estimation technique is encouraged.

The three alternative model specifications for meat demand were then integrated into the livestock and meat supply and feedgrain components of the model. The plan was to simulate all three models over the historical period and conduct sensitivity analyses as a means of selecting among the models for use in the subsequent simulation analysis. Unfortunately, both the model with the AIDS meat demand system formulation and the model with the ROTTERDAM meat demand formulation failed to converge in simulation. The cause of the failure to converge was primarily the high degree of complementarities among meats in the demand systems which forced a number of the endogenous variables like meat prices away from rather than towards an equilibrium solution. Only the model with the single equation LINEAR meat demand system specification converged and simulated over the entire period of the data and, thus, by default was selected for use in the subsequent simulation analysis.

Among the principal results drawn from the empirical estimation of the coefficients of the model with the single equation meat demand system were the following:

1. Mexican cattle inventories have been highly unresponsive to changes in Mexican cattle and feed prices reflecting the effects of Mexican meat price and trade controls.

2. The slaughter of cattle in Mexico is primarily determined by cattle supply although Mexican cattle and beef prices have had some affect on cattle slaughter in Mexico over time.

3. The response of Mexican hog inventories to Mexican hog and feed prices have been somewhat higher than the corresponding response of cattle inventories. Mexican price and trade controls on hog and pork have been less extensive than for cattle and beef. Also, the estimation results indicate that hog slaughter in Mexico has been determined primarily by the supply available for slaughter.

4. The per capita consumption of beef and pork in Mexico are positively affected by changes in per capita income. The gross income elasticity for beef is 0.7 while that of pork is 2.91. The higher income response of pork is explained by the fact that higher pork prices, especially of those of bacon, ham, and other derivatives may be purchased only by those high-income consumers.

5. Changes in feed prices have had little effect on the area harvested of the feedgrains in Mexico. Again, Mexican policies, including guaranteed prices and import restrictions, have reduced the historical importance of price changes in acreage decision of farmers.

Simulation statistics, including the RMS% error and the Theil coefficients, indicated a good performance of the model in tracking the historical data for prices. Sensitivity analysis indicated that the model is highly stable.

The fourth and final objective of the study was achieved in the simulation analysis section in which the results of using the Mexican livestock, meat, and feedgrain model to simulate the effects of trade liberalization in Mexico were presented. Because a complete, consistent series of data for those sectors is not yet available for the period since NAFTA took effect in January of 1994, the analysis considered only the pre-NAFTA period of Mexican unilateral liberalization. The results, however, provided important insights into the effects of liberalization under NAFTA for the Mexican livestock, meat, and feedgrain sectors. In order to isolate the specific effects of liberalization of trade in each of those sectors as well as the aggregate overall effects of liberalization on all sectors, the results of 5 different simulation scenarios were presented: (1) liberalization of only cattle exports from Mexico; (2) liberalization of only cattle imports by Mexico; (3) liberalization of only meat imports by Mexico; (4) liberalization of only feed imports by Mexico; and, (5) liberalization of exports and imports of cattle, meat, and feed simultaneously.

In general, the analysis indicated that the Mexican policy shift to more open markets substantially impacted Mexican livestock, meat, and feedgrain trade. The results also clearly indicated that the effects of liberalizing Mexican livestock, meat, and feedgrain trade were highly dependent on the level and direction of change in per capita income during the period of liberalization. More specifically, the simulation results indicated the following:

1. The Mexican comparative advantage is in the production of feeder cattle for export rather than for domestic feeding and slaughter.

2. Liberalization of Mexican markets benefits both the livestock and feedgrain sectors in Mexico.

3. Liberalization of Mexican markets also benefits the Mexican meat processing industry.

4. Liberalization of Mexican livestock, meat, and feedgrain markets generates little effect on the Mexican feedgrain sector because the positive price effects of an increase in feed demand from increased cattle inventories are largely offset by the negative price effects of an increase in feed imports.

5. Changes in real per capita income in Mexico are an important factor in determining the likely consequences of trade liberalization on Mexican meat import imports. For example, if Mexican per capita income had been only 1 standard deviation lower than was actually the case during the 1986 to 1991 period of unilateral trade liberalization, the model simulation results indicate that Mexican meat demand would have dropped enough to eliminate meat imports altogether possibly even creating excess Mexican supplies of meat for export.

6. Imports of both Mexican cattle and feedgrains are positively associated with changes in income in Mexico.

7. Even though feed prices are positively affected by trade liberalization in the meat, livestock, and feedgrain markets, Mexican feed production responds more to variables such as the cost and availability of credit, the cost of other inputs, and government farm policies than to prices.

Limitations of the Study

Modelling the livestock and agricultural sectors in Mexico is a difficult process. Lack of literature, lack of reliable data, and the inability and unwillingness of Mexican government officials to cooperate makes such a study a nearly impossible task. Several limitations or shortcomings of this study should be noted.

First, Mexico suffered several economic crises between 1971 and 1991 which were accompanied by huge devaluations of the Mexican peso and high rates of inflation. These two factors caused serious, although usually temporary, trade distortions. Trade policy changes in 1986 also brought changes in agricultural trade levels. The test conducted for structural change was intended to determine if those events affected Mexican meat consumption behavior. Although no evidence of structural change was found in the analysis, the test was limited to measuring parameter stability by using intercept and/or slope shifters due to the small number of observations (20). A larger number of observations would have allowed the use of more sophisticated techniques to test for structural change.

Second, several modifications were made to the conceptual model presented in the model section for the empirical estimation reported in the empirical analysis section as a result of the unavailability of needed data series. For example, breeding, feeder, and fed cattle inventories could not be separately identified. Consequently, only one "cattle inventory" behavioral equation was estimated. Also, data for area planted and feed and non-feed demand of the different crops were not available or incomplete. Although corn has been in animal feed rations in Mexico, no data is available on the feeding of corn. Data for the number of grass-fed versus grain-fed cattle in Mexico are also largely unavailable or unreliable.

Third, price data were obtained from several sources causing a degree of inconsistency. Meat and livestock prices were supplied by the Colegio de Posgraduados in Chapingo while most feed prices were estimated by dividing data on crop value and crop production appeared in the Mexican Presidential Report. Also, due to the high rates of inflation that existed in Mexico during the sample period (1971 to 1991), prices had to be deflated. Meat prices were deflated using a general consumer price index while livestock and feed prices were deflated using a general wholesale price index.

Fourth, the empirical model used for the simulation analyses was selected by default since two of the three alternative models failed to converge in simulation. Consequently, a comparison of the simulation performance of models of the Mexican livestock, meat, and feedgrain industries that included complete meat demand systems against the model including a single equation meat demand formulation was not possible.

Fifth, the low estimated price response of livestock inventories, livestock slaughter, and feedgrain area harvested reflects the effects of government policies that existed during the period of the data. Given the recent changes in government policy, including elimination of CONASUPO and production input subsidies, the implementation of PROCAMPO, the privatization of agricultural institutions, and the further liberalization of trade under NAFTA, among other things, the responsiveness of market agents to price signals has likely changed since the late 1980s and early 1990s. Unfortunately, data is available only with long lags in Mexico. When a reliable set of complete data becomes available for a more recent period, tests for such changes in behavioral parameters will need to be done.

Sixth, development of the livestock and the feed production models included the assumption of adaptive expectations in livestock production and naive expectations in feedgrain production consistent with similar studies for other countries. The performance of these expectations models against other possible models was not tested.

Seventh, for simplicity, the model developed assumed that several variables such as macroeconomic variables and technologically derived yields were exogenous. A more extensive model with an endogenous macroeconomic component would have provided the ability to conduct more extensive tests of the relationship between the Mexican macroeconomy and Mexican livestock, meat, and feedgrain trade.

Eighth, weights developed by the U.S. Department of Agriculture to calculate the number of U.S. grain-consuming animal units from data on U.S. livestock inventories were used to calculate Mexican grain-consuming animal units. The relevance of those weights for Mexico is not clear. Also, the weights used to calculate the producer price of feed were considered to be fixed over the entire sample.

Ninth, the effects of trade liberalization were analyzed against assumptions regarding what the level of livestock, meat, and feedgrain trade would have been in the absence of the policy of unilateral trade liberalization during 1986 through 1991. Although the assumptions were based on past performance of trade before liberalization, in the end, the simulated results are as arbitrary as the assumptions made. However, only the magnitudes and not the directions of change are dependent on those assumptions.

Finally, a dearth of previous quantitative studies on the Mexican livestock, meat, and feedgrain industries prevented a comparison of the results found in this study. Consequently, this study might be considered a benchmark for future analyses of those industries and of the effects of freer trade.

Suggestions for Further Research

The qualitative and empirical analyses presented in this study provide a more complete understanding of the behavior of the Mexican livestock, meat, and feedgrain markets. The research also presented an in depth analysis of the possible consequences of trade liberalization and changes in per capita income on those markets. The limitations of the study provide a starting point for future research efforts. Some other areas, including the following, might also prove fruitful for future research.

First, a more complete and consistent data series is needed for the Mexican agricultural sector in general. A combination of efforts by Mexican federal and state government agencies, crop producer associations, and livestock and meat federations is needed. Otherwise, poor data on Mexican agricultural markets will continue to hamper research efforts and limit confidence in analytical results using the available data.

Second, although agricultural trade is expected to intensify under NAFTA, the effects will be highly dependent on the performance of the Mexican economy as suggested in this study. Given the severe economic conditions of 1995 in Mexico, an updated study using more recent data will be needed to separate the trade effects of NAFTA and those of the Mexican economy.

Third, additional scenarios could be simulated to analyze the effects of specific tariff or trade barrier reductions, changes in the value of the peso, and other relevant issues affecting Mexican livestock, meat, and feedgrain trade.

Fourth, a more in depth analysis of the Mexican meat demand system in Mexico is needed. The use of other tests for structural change, variations in the complete demand system specifications, and disaggregation of meat consumption by geographical region, economic level, and demographic factors could provide a better explanation of the meat consumption behavior in Mexico.

Finally, a natural extension of this research would be the application of similar techniques used in this study to other agricultural products such as fruits and vegetables which are important part of U.S.-Mexico agricultural trade.

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