NAFTA and U.S.-Mexican Beef Trade: Long-Run Implications for Changes in Trade Flows from Technology Transfers

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December, 1997
Staff Paper #294

Staff Papers Series
Department of Economics

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Abstract

This study examines potential long-term impacts on the U.S. and Mexican beef industries of the reduction in trade barriers under NAFTA and likely associated international technology transfers (of beef cattle, feeding methods, and meat packing) and foreign capital investments. The beef industry is represented as four subsectors: cow-calf production, post-weaning beef production, meat packing, and leather production. The analysis is accomplished through a multi-sector model of the U.S. and Mexican beef industries, estimation of key parameters, and simulation of long-run outcomes under three alternative scenarios. Our results show that Mexico will dramatically expand the size of its cow herd. The expanded supply and lower post-slaughter processing cost in Mexico give it a comparative advantage in beef production, despite most of the feed grain requirement being met from U.S. exports. Mexico is able to expand its exports of feeder calves significantly when technology is transferred and to become a beef exporter. Beef prices in both countries decrease in real terms. We conclude that U.S. beef producers cannot be optimistic about the long-run potential for beef exports to Mexico but much better prospects exist for U.S. feed grain exports.

Key words: North American Free Trade Agreement, beef industry, meat packing, technology transfer, tariffs, United States, Mexico

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Journal Paper J-________ of the Iowa Agriculture and Home Economics Experiment Station, Project No. 3175.

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This project was sponsored, in part, by a grant from the Cooperative State Research Service, USDA through a grant from the Midwest Agribusiness Trade Research and Information Center (MATRIC) under agreement 92-34285-7145. Any opinions, findings, conclusions, or recommendations expressed are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture. The authors are grateful to the members of the International Agricultural Trade Research Consortium (IATRC), WRCC67, WRCC177 and Tom Wahl who provided helpful comments on early versions of this paper that improved the final result.

NAFTA and U.S.-Mexican Beef Trade: Long-run Possibilities for Technology Transfers and Changes in Trade Flow

A major impetus for freer trade in North America occurred with the enactment of the North American Free Trade Agreement (NAFTA) and associated parallel agreements dealing with environmental and labor standards. Most sections of the NAFTA deal with trading goods, services, and foreign investment. For trade in goods, provisions exist for the elimination of trade barriers among the trading partners. All non-tariff trade barriers are eliminated immediately, but to ease the transition, some tariffs will be eliminated immediately and others will phase out over 5, 10, or 15 years.’ Removing trade barriers and harmonizing safety standards are expected to be major factors for increasing trade among the North American countries, including trade in agricultural commodities.

When we think of U.S. agricultural imports from Mexico, fresh fruits and vegetables, e.g., tomatoes, squash, melons, strawberries (and possibly fish and coffee), come to mind. However, in recent pre-NAFTA years, Mexico has also been exporting about 1 million head of beef feeder steers per year to the U.S. and importing 100,000 to 200,000 metric tons of beef, 1.5 to 2.5 million hides, and 1 to 2 million metric tons of grain per year from the U.S. Hence, U.S.-Mexican trade can be characterized by Mexico shipping feeder cattle to the U.S., then repurchasing about half of the resulting meat and all of the hides.

All other things being equal, the elimination of trade barriers should increase trade volume relative to the pre-existing direction. Hence, we would expect the U.S. to increase its imports of feeder cattle from Mexico and its exports of beef, hides, and grain to Mexico. The economies of Mexico and the U.S. are quite different -- suggesting potentially dramatic long-run changes in beef trade after NAFTA. For example, it has generally been agreed that Mexico’s lower wage rates (about one-sixth for similarly skilled labor) is an advantage to manufacturing labor-intensive goods. This seems to have little to do with trade in beef or most agricultural commodities (i.e., relatively little labor is required to produce a beef slaughter steer). However, considerable labor is required in post-slaughter phases of beef production and marketing. The wage divided by the marginal product of labor gives an estimate of unit costs, so labor productivity differences across countries are also an important dimension of international trade.

U.S. beef packing has attributes that make a significant part of it transferable to Mexico in the long-run. It is labor intensive (accounting for about 50 percent of U.S. packing cost on a value added basis), it uses relatively low-skilled labor, and in the U.S. it remains significantly more unionized. Furthermore, the wage elasticity of packing labor is quite low, and although the capital investment for a new packing plant is large, capital service's cost share is small (see Melton and Huffman, 1995). Hence, there is a potential cost advantage to meat packing in Mexico relative to the U.S. and a relatively small capital cost is associated with such a transfer.

Cost advantages in beef packing could also be re-enforced by the Mexican leather industry. Whereas Mexico currently imports beef hides to support its leather industry, the U.S. leather industry has declined steadily for over 30 years (i.e., the proportion of hides domestically processed has fallen from about 80 percent in the mid-1960s to less than 30 percent by 1990). Locally available hides would bear less freight cost and thereby increase their relative value to domestic suppliers in Mexico.

Other studies of the NAFTA effects on U.S.-Mexican beef trade have focused primarily on the short-run effects of anticipated trade barrier reductions and growth in Mexican per capita real income (e.g., Brown; USDA-OE; Rosson, et al). This type of analysis leads only to an expansion of existing trends in U.S.-Mexican beef trade. Our study examines the possibility of major changes in existing trends by considering long-run effects of international technology transfers and foreign capital investment in the Mexican beef industry. These include transfers of modem beef genetics and management, expansions of modem high-energy, confined cattle-feeding operations and semi-automated beef packing plants, and vertical integration of cattle feeding and packing. This analysis is accomplished through the development of a multi-sector model of the U.S. and Mexican beef industries, estimation of key parameters of the model, and simulation of long-run outcomes under alternative assumptions regarding the broader Mexican and U.S. economies.

Background

Because of geographic proximity and other factors, the U.S., Mexico, and Canada have become increasingly linked in international migration, trade, capital investment, and technology transfer. Large differences in size and economic performance persist between Mexico and the U.S./Canada and little convergence has occurred during the past three decades. Recent liberalization of U.S. -Canadian trade (1988), U.S.-Mexican trade (NAFTA), and new GATT policies of the World Trade Organization will enhance the integration of the countries in North America. The new regional trade initiatives, however, do not deal directly with immigration, and although trade is somewhat a substitute for migration, international migration will continue to be an important issue in North America that will be inescapably linked with the trade and economic activity of each country.

Economic Activity and Growth

The U.S. has a significantly larger population and amount of economic activity than either Canada or Mexico. In 1960, the population of the U.S. was 4.5 times larger than that of Mexico.’ Although the rate of population growth has slowed, the net annual average population growth rate between 1960 and 1990 was 2.7 percent for Mexico but only 1.1 percent for the U.S. (table 1). Thus, the size of the U.S. population in 1990 was only 2.8 times that of Mexico. The volume of market economic activity in the U.S. is about 30 times larger than in Mexico (10 times larger than Canada), and per capita real output is about 10 times larger. Although Mexico had a rate of growth of aggregate real GDP higher than the U.S. between 1960 and 1980, the real growth rate of the U.S. was significantly better during the decade of the 1980s.

In Mexico, wage rates, converted to U.S. dollars at the official exchange rate, have also been much lower. During this period average wage rates for production workers in manufacturing were 7 to 11 times larger in the U.S. than in Mexico. Seasonal agricultural workers in the U.S. received wage rates that were 4 to 6 times larger than in Mexico (see Huffman 1986). Some of these differences are associated with relatively low capital-labor ratios in Mexico, leading to lower labor productivity in Mexico, and Mexican born natives complete about **50** percent less schooling than U.S.-born natives.

In Mexico, the agricultural sector accounts for a much larger share of GDP, labor force, and the rural population than in the U.S. (see table 1). In 1990, the agricultural sector's share of GDP was 9 percent in Mexico compared to 2 percent in the U.S. Agriculture also accounted for 3 1 percent of labor and 29.2 percent of the population in Mexico, compared to 1.7 percent and 2.2 percent, respectively, in the U.S. In both countries, the agricultural sector's share is shrinking (see table 1).

In combination, these changes resulted in growth rates of real per capita aggregate output of 59 percent in the U.S. and -15 percent in Mexico between 1960 and 1990. Thus, during this period, differences in real income per capita did not converge. Furthermore, divergent growth in U.S.-Mexican per capita income also occurred during the 1980s (table 1). By 1990, GDP per capita in the U.S. was about 10 times larger than in Mexico. These differences have contributed to trade and legal and illegal migration pressure from Mexico to the United States.

Trade and Immigration

International trade flows between the U.S. and Mexico have been relatively similar in spite of the large economic size differences (table 1), but net immigration flows have been heavy from Mexico to the United States. The U.S. and Mexico have each pursued agricultural commodity and trade policies that affect incentives for trade and welfare. The U.S. has used a national price support-deficiency payment plan for basic agricultural commodities (i.e., feed grain, wheat, rice, cotton, and (recently) soybeans).' With program participation, farmers have been eligible for income deficiency payments that typically apply to less than total marketings of a covered crop. The U.S. had a relatively low pre-NAFTA trade-weighted tariff on agricultural imports from Mexico of about 5.7 percent in 1988 (Burfisher, et al., 1992). However, wide variances across agricultural commodities existed. The U.S. has tended to apply high seasonal tariffs (tariff rates that are high only during the season for marketing by U.S. producers of a commodity, e.g., a seasonal rate of 35 percent for dried onions, garlic, fresh cantaloupes, and melons). Many fresh vegetables that compete with U.S. production have been subject to a 25 percent tariff, including brussel sprouts and seasonal asparagus, but the tariff on fresh tomatoes is quite low and there is no tariff **on coffee** from Mexico. Most horticultural items have been subject to a tariff of 17.5 percent.

The U.S. has also maintained import quotas on dairy products, sugar, some meats, and a few other farm commodities. The U.S. has limited meat imports under the Meat Import Law, which applies to fresh, chilled, and frozen beef, veal, mutton, and goat. Less than 1 percent of U.S. agricultural imports from Mexico have been under quota in recent pre-NAFTA years.

Relatively large net Mexican emigration flows to the United States have been occurring; some accommodated by U.S. immigration policy which has gone through major changes since 1965. U.S. policies have had a large effect on availability, nationality (see Gabbard and Mines 1995), and wage rates of low-skilled U.S. labor (see Martin and Taylor 1995; Huffman 1995; Borjas, Freeman, and Katz 1992). In particular, the Immigration Reform and Control Act of 1986 (IRCA) caused both temporary and long-term growth in the U.S. available supply of low-skilled labor for agriculture and food processing (Martin 1995; Huffman 1995).

The primary effect of IRCA on wage rates was to reduce U.S. wage rates -- both farm and nonfarm -- for low-skilled labor from what they would otherwise have been (Martin and Taylor, 1995; Huffman, 1995). This improved the international competitiveness of U.S. industries using low-skilled labor, like meat packing, and it caused some temporary locally depressing effects on agricultural wage rates which might affect the location of processing plants.

Beef Industry Structure

Although the U.S. has about 40 million cows and 650 million acres of pasture and range, low grain prices cause the U.S. beef industry to be a predominantly grain-fed industry. Although most calves are born on forage pastures and range, they are moved into concentrated feedlots at an early age. They are then fed high grain rations until ready to slaughter at less than 24 months of age and about 1200 pounds. As a result, the U.S. produces about 26 million head of grain-fed slaughter animals per year yielding about 19 billion pounds of carcass beef (USDA).

Mexico, however, has feed grain shortages and a production system dominated by grass-fed beef (which is a different quality than U.S. grain-fed beef). Calves in Mexico are typically maintained on grass or high roughage diets until 3-4 years of age and slaughtered at about 70 to 80 percent of U.S. slaughter weights. The grazing areas of Northern Mexico receive less annual precipitation than U.S. grazing areas. Also, Mexican beef and grain pricing policies of the past have undoubtedly affected cow herd size. As a result, Mexico has only about 10 million cows on 370 million acres of pasture and range (about half the average stocking rate of the U.S.). Furthermore, although Northern Mexico has been using largely European-origin cattle for some time, weaning rates (calves weaned per cow exposed) are lower in Mexico than in the U.S. Thus, substantially fewer pounds of beef are produced per acre in Mexico than in the U.S. If, however, cow management were improved and calves were removed from pasture earlier, the potential exists to increase beef production -- including the release of considerable forage to support an expanded cow herd.

Similar differences in post-slaughter processing and marketing exist between Mexico and the U.S. The majority of U.S. grain-fed beef is slaughtered and processed to primal or sub-primal cuts in large modern packing plants of 2500 head per day capacity or more. Furthermore, considerable market concentration exists in these plants which are largely owned by one of three major meat packing companies (ConAgra-Monfort, IBP, and &gill-Excel). The big-three account for over 70 percent of the commercial fed-beef slaughter in the U.S. (Kimle and Hayenga).

Mexico does not have the same degree of market concentration in beef packing and processing, although it does have about 12 modem packing plants, of various sixes, that could potentially pass USDA inspection. The majority of beef animals in Mexico are still slaughtered in small unautomated packing plants (10 to 200 head daily capacity) employing old technology similar to a U.S. locker plant. Furthermore, the majority of beef is sold as carcass beef sides to local butchers who perform the balance of the cutting and processing functions. This results in considerable beef (meat) waste relative to the U.S. system.[4] It further results in pricing that does not reflect the relative value of the various beef cuts to consumers, and consumers in Mexico pay essentially the same price regardless of the beefs quality.' As a result, the average retail beef price in Mexico is approximately equal to that in the U.S., but price differences across cuts are much smaller in Mexico. Lack of significant retail beef price differences, coupled with income differences, help explain why annual per capita beef consumption in Mexico is less than half of what it is in the U.S. (Hall and Livas-Hemandez, 1990).

The **Beef Industry Model**

For purposes of modeling the beef industry in Mexico and the U.S., we define the industry in terms of multiple production phases: 1. Cow-calf or pre-weaning production; 2. Post-weaning or slaughter animal production; 3. Packing and post-slaughter beef processing and marketing; and 4. Leather production. Figure 1 presents a flow diagram for our multi-sector domestic beef industry.[6]

Value-added aggregate cost functions must be obtained for each phase of beef production in both countries. From these cost functions, domestic supply functions can be derived for fed beef, non-fed beef, and leather along with derived demand functions for the intermediate product (the animal) connecting these phases. Derived demand functions for the major inputs of beef production and processing, including grain, labor, packing materials, and capital services can also be derived from cost functions.

In most cases, beef production represents a small share of national input use. We translate this to mean that the domestic supply functions for most inputs used in beef production can reasonably be assumed to be perfectly elastic. Grain and pasture are exceptions. The current analysis proceeds under the simplifying assumption that national grain and pasture supply functions are perfectly inelastic.'

Aggregate consumer (domestic) demand exists for three products: retail beef, beef by-products, and leather. Trade in leather and beef by-products are not, however, the primary focus of this study. Hence, leather prices are assumed to be fixed and beef by-products are ignored.

Domestic supply and demand functions are linked by identities that recognize the possibility of bilateral trade between Mexico and the U.S. in retail beef, beef feeder animals (weighing about 400 pounds), hides, and feed grain on a corn equivalent basis (i.e., the quantity supplied, net of trade, must equal the quantity demanded in each country). In our beef industry there are two final products: hides and retail beef (see figure 1). The estimates of our beef industry model are summarized in the following sections.

Retail Beef Demand Functions

The quantity of retail beef demanded depends on its own price, the prices of substitutes and complements, and the level of income. Although beef demand functions have traditionally been estimated in partial demand systems that include only close substitutes (other meats), we doubt that weak separability of consumer preferences exists for national aggregate demand. For example, at low income levels, vegetable proteins may substitute for meat in household consumption. However, as income increases, vegetable products may complement meats in a "balanced" diet meal. Similar relationships seem likely to exist between meats and non-food consumer goods, especially in light of the small share of expenditures represented by all food in more affluent economies. Hence, we specify a full expenditure AID system in which potential beef substitutes and complements include non-food items and the following food items: pork, chicken, other meat products (dominated by dairy products), and plant products.

The price of vegetable products is computed as an index of the quantity weighted prices of specific vegetable products (e.g., fresh fruits and nuts, beans, green vegetables, tomatoes, potatoes, breads and cereals, sugars, etc.). To further generalize the index, the prices used in the index are estimated hedonically from the nutrient yields (e.g., carbohydrate, fat, protein, vitamins and minerals, etc.) of the vegetable products (Rapor and Rourke, 1992).

Other animal products are dominated by dairy products, but include fish and limited amounts of other animal products (lamb, wild game, etc.). The price index of other animal products is similarly computed from quantity weighted prices of specific animal foods (e.g., milk, butter, eggs, fish, etc.) where the other animal prices used are also estimated hedonically based on the nutrient yields of the other animal products.

Non-food expenditures are estimated residually, where the total expenditure (income) is defined as per capita GDP, and the non-food CPI is defined to be its price. To account for changes in taste and preference not otherwise reflected in the system, we include a trend term in our AID system equations.

The demand system is fitted using annual U.S. data for the period 1%3-87. Although our two-country trade model uses the fitted demand equations rather than elasticities, the price and income elasticities of the AID system computed at the sample mean for the U.S. provide a convenient way to summarize them.[8] All own-price elasticities are of the expected sign (table 2) and most are statistically significant. These new results suggest that beef may be more own-price inelastic (-.31) and inferior good in a high income country (-. 10), which is different than reported by previous studies (see, for example, Huang, 1985).[9] Furthermore, beef substitutes for all other U.S. goods consumed except plant products. This finding supports one belief that at higher income levels beef and plant products may be more nearly viewed as components in a meal or diet than alternative food choices. Finally, there does not appear to be a significant trend toward lower beef consumption in the U.S. Declines in per capita beef consumption since 1976 are largely explained by changes in relative prices and income. Changes in consumer taste and preference seem to have had essentially no effect on beef consumption (as reflected by the insignificant trend term).

Although average food prices and quantities are reported for selected years in various sources, consistent time-series data for Mexican consumption are limited. Thus, it is impossible to estimate a comparable system of demand equations using Mexican data. To proceed, we assume that Mexican tastes and preferences for the aggregate commodities in our demand system are similar to those of U.S. consumers once adjusted for income and price levels. Differences between U.S. and Mexican consumption are then reflected by differences in the mix of foods consumed in the indexes, relative prices, and income at a point in time.

To illustrate, recall that in the AID system the elasticities of demand (either price or income) depend on the estimated coefficients and the expenditure shares of each good considered, i.e.,

$$\varepsilon_{ii} = -1 + \frac{\beta_{ii}}{S_i} + S_i, \varepsilon_{ij} = \frac{\beta_{ij}}{S_i} + S_j, \text{ and } \eta_i = 1 + \frac{\beta_{iI}}{S_i}$$

where ε and η are the price and income elasticities, β_{ij} is the coefficient of taste and preference relating changes in the consumption of the *ith* good to changes in the *jth* price (or I=income), and S_i is the share spent on the *ith* good. Differences in demand (elasticities) may then reflect differences in either parameters of the AIDS or expenditure shares.

Despite often lower prices, the significantly lower per capita income levels in Mexico causes expenditures on food to represent a larger share of GDP than in the U.S. For example, during the base period (1987-90), Mexicans consumed approximately 30 pounds of beef per capita compared to about 100 pounds per capita in the U.S. However, because of lower annual income levels ($1,730 in Mexico versus $22,290 per capita in the U.S.), beef's expenditure share in Mexico was nearly four times that of the U.S. (about 4.8 percent in Mexico compared to about 1.3 percent in the U.S.). As a result, beef demand in Mexico is substantially more own-price elastic (-.739) than the U.S. estimate (-.201) for the same period. Similarly, the estimated Mexican income elasticity of beef demand for the base period is considerably greater than the U.S. estimate for the same period (.653 in Mexico versus -.287 in the U.S.).

Our estimates exhibit larger expenditure shares and more own-price elastic demand functions for all aggregate food items in Mexico than in the U.S. over the base period. The income elasticity of demand in Mexico is also greater for all food items except Other Animal Products. Non-food demand in Mexico is similarly more own-price and income elastic (about -.37 and 1.15, respectively) than in the U.S., despite its significantly smaller share over the base period.[10]

Leather Production and Beef Hide Demand Functions

The second major product of beef production is the hide. The derived demand for hides arises from the leather manufacturing process. Because of its good properties, including flexibility (see Diewert), a translog cost function is chosen to describe the leather industry. Data for fitting input derived demand functions for the U.S. leather industry are taken from Jorgenson, Gollop, and Fraumeni. Inputs of labor, capital, energy, and hides are differentiated, and the system is fitted by SUR.

Our estimates of the U.S. leather industry's derived demand functions are also summarized in elasticities evaluated at the U.S. sample means (table 3). The own-price elasticities are of the expected sign and statistically significant. Capital tends to be a complement to both labor and energy in leather manufacturing, although neither the estimated elasticity nor its t-value is large. Labor is a major cost component (83 percent on a value-added basis) of leather manufacturing and relatively own-price inelastic (-.61). This finding may help explain why most U.S. leather manufacturing has re-located to areas of lower wage rates such as Mexico, Korea, and Taiwan in the last 30 years.

U.S. Beef Industry Supply and Input Demand Functions

Inputs are demanded to supply these joint outputs of beef production. For convenience, we represent the beef production process in three phases. The first, or cow-calf, phase produces an original product (the calf). The next two phases are represented as value-added processes in which additional production and/or processing is performed on the basic animal (calf or slaughter cow) produced in the first phase (see figure 1).

Phase 1: Pre-weaning. The pre-weaning or cow-calf phase of beef production is a multi-period reproductive process and the interconnections between inventory (herd size) and product flows (calves and cull cows sold) are dynamic. In particular, a beef cow typically produces calves in more than one year.

Furthermore, one of those calves may be her own replacement, which is not sold but retained for breeding in the future. To the extent that cows produce more than one replacement, the herd size expands and vice-a-versa. Hence, the cow-calf phase of beef production takes on characteristics of both investment and production.

Nerlove, Grether, and Carvalho have approached the problem of cow-calf production from a distinctly marketing viewpoint summarized as a quasi-rational expectations (QRE) model. In essence they argue that changes in calf production in any time period are a result of producer expectations about future prices that are, in turn, based in large part on past price patterns. Others have approached the problem in an asset replacement-investment framework (e.g., see Melton or Trapp). The number of calves available for sale and slaughter depends on the size of the cow herd -- which is an investment decision. Neither of these alternatives is entirely satisfying. We chose to combine the best parts of the two approaches.

In an optimal asset replacement-investment approach, heifers are added to the herd when their investment cost (the foregone opportunity of a current sale plus added rearing cost to reproductive age) is less than the present value of their residual annual earnings in production. Cows currently in production are similarly culled when their current market price (Ib=cull value) is greater than the discounted value of their future production (i.e., NPV<0). Hence, in any time period the number of cow replacements added and the number of cows culled depends on their net present value. With a simplifying assumption of constant returns to scale, these NPV relationships can be represented on a per acre of range and pasture (A) basis as:

$$\text{Replacements/Acre} = \frac{R_t}{A} = n(P_t, w_t, I_t, r) \text{ and Culls/Acre} = \frac{C_t}{A} = c(P_t, w_t, I_t, r)$$

where P_t is a vector of current and future beef prices in time period t, w_t is a matrix of current and future input prices, and I_t is a vector of current sales prices (by animal type).[11]

The beef cow herd size or inventory at a point in time (H) can be expressed in terms of changes that arise from replacements added, cows culled, and death losses (D):[12]

$$H_t = A\left[\frac{H_{t-1} + \Delta H_t}{A}\right] = A\left[\frac{H_{t-1} + R_{t-1} - C_{t-1} - D_{t-1}}{A}\right].$$

If more heifers are added for replacement than the number of cows culled (either voluntarily or by death loss), herd size expands and vice-a-versa.

The majority of analyses employing asset replacement principles have assumed future prices are constant and known with certainty.[13] We believe that a more realistic assumption is that current cow investment decisions depend on current prices of cattle and beef sector inputs and expectations about future prices. In this QRE approach, we incorporate those expectations into the model by replacing future prices with price expectations (forecasts) derived from a time-series analyses of past prices. However, unlike most QRE analyses, we specify all prices in real terms. As a result, we are able to express the asset replacement criterion and the current cow herd inventory in terms of current real prices and the QREs of future real prices.

Real price QREs of the cow-calf sector are derived from annual U.S. data (1960-90) for cull cows, calves, grain, hay, and capital (proxied by real interest rates) using a Box-Jenkins procedure (table 5).[14] Y, G, and X (subscripted by the lag) are the annual autoregressive, seasonal autoregressive, and annual moving average parameters, respectively, of the time-series process. The estimated coefficients are statistically significant ($p < .05$), and the large F-test values and R^2s ($R^2 > .90$) indicate high explanatory power (see table 5). The Durbin-Watson (D-W) statistics associated with the transformed data are approximately 2.0. Although we cannot be certain how individual producers form price expectations, these forecasting equations perform well in terms of forecasting real price changes using data on past prices and are thus used as instruments for our QREs of future prices.

The decision to expand a herd requires an investment (in terms of additional calves retained at weaning) that reduces the current number of calves marketed and increases calf prices. However, that investment will be recaptured though the cow's productivity which first increases then declines over her reproductive life -- usually until 10 to 12 years. This tends to expand the future supply of beef calves and thereby reduce their price in a regular and predictable fashion. Hence, we believe that annual prices observed in a given phase of the biological cycle (e.g., first year of expansion or contraction) are correlated, and this cycle is reflected in our QREs.[15]

Biological, political, and managerial factors may also cause real feed (corn and hay) prices to exhibit cyclical patterns, which are of shorter duration (5-7 years) and lesser amplitude than cattle cycles. These factors include U.S. farm programs (major revisions at five year intervals), the productive life of a hay field (five to seven years), and the capital investment required to substantially change cropping patterns (e.g., combine, baler, etc.). Cyclical patterns in real capital prices (indicated to be about 7 years in duration) are more difficult to explain, but may be related to business cycles in the overall economy and the "average" capital investment recovery period -- including those specified by IRS tax code.

To complete the beef cow herd inventory section of the model, we recognize that irrigation and the alternative uses for hay (e.g., dairy, etc.) may cause the hay price to be less than perfectly correlated with the value of grazed forages, such as range. To reflect this aspect, we include an index of forage condition in the cow-calf phase of the model.

Phase 2: Post-weaning. The intermediate phase of the beef industry is the post-weaning phase (figure 1), which includes both extensive and intensive production practices. Upon weaning, many calves are moved to pasture, including wheat, for a growing period before being moved into a feedlot for finishing. Other calves are moved directly into the feedlot when weaned. The post-weaning cost function is defined on a value-added basis with weight gain per head and number of slaughter head as the output dimensions. Labor, grain, pasture, and capital are the primary inputs. The value-added cost function is then assumed to be translog in functional form (including trend terms). The cost and input demand functions are fitted by methods of 3SLS in which the wage rate for labor is endogenous and related to the U.S. average manufacturing wage rate.

Elasticities of input demand in post-weaning beef production, evaluated at the sample mean, highlight labor's relatively small role in this phase (table 4). Labor is less than 3 percent (on average) of the (value-added) cost of post-weaning beef production and the demand for labor is relatively elastic (-1.184). Grain accounts for about 60 percent of post-weaning cost, pasture is about 25 percent, and capital is a relatively small share of post-weaning value-added cost (13 percent). Pasture and grain are not perfect substitutes, although a limited degree of substitutability is possible. For example, if the price of grain is high relative to forage, the producer can keep cattle on pasture longer or feed a ration with higher forage proportions -- thereby substituting away from grain. However, capital is a complement to pasture. This may reflect the higher capital costs of land management (i.e., fence, equipment, etc.) that accrue when pasture is used compared to an intensive confinement (feedlot) setting.[16]

Phase 3: Packer. Beef and hides are supplied by the final (packer) phase of our beef supply model (figure 1). Cost and input demand functions for U.S. beef packers have been fitted and reported by Melton and Huffman (1995). In their model, the number of head and average slaughter weight per head are the units of output; and labor, capital, materials (packaging), and all other (defined residually) are the inputs in the value-added beef packing process. Estimates of the weight of retail beef and hide production can be obtained by applying a constant retail product percent and hide weight to the number slaughter and average slaughter weight used as outputs of their model. Packer cost and input demand functions also include non-wage effects of unionization, trend, and scale in terms of the number of commercial-size packing plants comprising the packing phase of the U.S. beef industry. Wage rates of packing labor are endogenous and related to manufacturing wage rates and the degree of unionization in meat packing.

The empirical results show that packer labor represents a large share of (value-added) cost, is highly own-wage inelastic, and has few good substitutes. Over the period considered, the non-wage cost effects of unionization are typically greater than the wage effects. That **is, unions may have been** successful in increasing member's wages above those of non-members in the past, but not during the **study period.** Unions do affect work rules, which affect costs over the study period. Management thus has an incentive to reduce labor costs by substituting capital or other inputs for labor, adopting labor saving technologies, and relocating to areas of lower wage rates and/or lesser union power.

Inter-phase Flows. Linkages between the three phases of our beef supply model are established by the flows of animals. These flows are defined by a number of accounting identities. Specifically, we use the average weaning rate (calves weaned per cow) to estimate the total number of beef calves produced in a year from a given herd size. The total number of calves sold at weaning is equal to the total beef calves produced less death losses and calves retained for replacement in the breeding herd plus dairy calves sold. The latter quantity is an exogenous variable in our model. The total number of head slaughtered is then equal to the total number of calves sold less post-weaning death losses plus beef and dairy cows culled, where the number of dairy cows culled is also exogenous.

Mexican Beef Industry Supply and Input Demand Functions

The aggregate Mexican production data that do exist are inadequate to estimate a beef industry model for Mexico comparable to that estimated for the U.S. To proceed, we subjectively adjust the U.S. estimates to a Mexican standard using the few published data on Mexico and estimates of U.S. technology. A brief summary of these adjustments follows.

Leather. We believe that it is reasonable to assume that hide processing technology in Mexico is similar to the U.S., or Mexico could not have absorbed a large share of the U.S. leather industry over the past 30 years. Hence, the U.S. leather input demand functions and elasticities are adopted to summarize the Mexican leather industry.

Packing. Beef packing in Mexico currently differs from U.S. operations in both technology and size. Estimates are that these differences account for about 12 percent less output per head slaughtered (on a constant weight basis) and about 25 percent higher aggregate input use (Crom; Drewer and Nilson). U.S. cost and input demand functions are thus subjectively adjusted to a Mexican standard using the limited data available on current Mexican beef packing. With technology transfers, Mexico could develop a packing phase comparable to the U.S. Hence, U.S. packing cost and input demands functions, adjusted for scale and Mexican prices, are used to describe Mexican beef packing after technology transfer.

Post-weaning. Little U.S. style post-weaning beef production currently exist in Mexico because of grain shortages and high grain prices. Current Mexican post-weaning production is best represented as a forage-based operation with substantially lower slaughter weights. This difference results in lower Mexican average cost per head and higher pasture use than in the U.S. These adjustments are made to obtain an initial estimate of post-weaning costs and input demands in Mexico using current Mexican technology. With post-weaning technology transfers, Mexico could develop a U.S. style system. U.S. cost and input demand functions, adjusted for scale and Mexican prices, are thus used to describe post-weaning production in Mexico after a technology transfer.

Pre-weaning. Pre-weaning production in Mexico is comparable to the U.S. because both are forage based. However, more extensive production practices in Mexico result in lower average weaning rates and lower animal weights at a given age than in the U.S. Current Mexican pre-weaning production costs (per unit land area of pasture and range) are obtained by adjusting U.S. relationships to reflect these differences.

Trade Model Solutions

Most prior analyses of the NAFTA have been short-run in nature. They have assumed that current production practices and technical comparative advantages will prevail post-NAFTA and concentrated on short-run price and income changes. As a result, these analyses have reported that NAFTA will tend to increase the magnitude of current beef trade flows -- Mexico will export more feeder calves to the U.S. and import more beef from the U.S. (Brown, 1992; CAST, 1993; Rosson et al, 1993; USDA-OE, 1993).

Over the long-term NAFTA will do more than remove barriers affecting the balance of beef trade. It provides incentives for foreign investment that may enhance technology transfers and for changing the allocation of land, labor, and other available resources. In the long-run, technology transfers have the potential to alter the comparative advantage of member countries, given natural resource endowments, in ways that could change greatly the structure of North American beef production. These changes could effect the direction and magnitude of U.S. -Mexican beef industry trade flows.

Alternative Trade Scenarios

To examine these issues, we define three scenarios yielding estimates of long-term post-NAFTA effects on U.S.-Mexican beef trade relative to a 1987-90 pre-NAFTA base:

1. *Full Technology Transfer*: U.S. beef production, processing, and marketing technologies are transferred to Mexico along with the capital investment necessary to establish an integrated pseudo-U.S. style beef industry in Mexico and the infrastructure required to support it, including a stable monetary system and fiscal policy.
2. *Full Technology Transfer plus Increased Mexican Income:* a real 10% increase in Mexican per capita income (relative to the U.S.) through a 20% increase in real wage rates.
3. *Full Technology Transfer and a Change in Exchange Rate:* a 20% real devaluation of the peso (relative to the U.S. dollar).

These three scenarios are longer-run in the sense that in each case technology changes and full adjustments occur. Outcomes are measured relative to a pre-NAFTA base (1987-90). We think of these as extreme (potential) outcomes because each assumes a full and spontaneous technology transfer, i.e., we assume that the entire Mexican beef industry adopts all new technology to meet post-NAFTA market conditions. Technology transfer is aided by geographical proximity of source and receiving countries, by incentives for and protection of foreign capital investment, and availability of supporting information and inputs. New technologies, however, may not be fully transferred to Mexico or adopted and transfers may not be spontaneous. Hence, the realized long-run effects of NAFTA may fall short of our projections. However, we lack insights and data needed to propose "better" scenarios.

In the second scenario, we recognize that NAFTA will affect all segments of the Mexican economy. But-fisher, Robinson, and Thierfelder, among others, have suggested that NAFTA will cause Mexican per capita real income to increase (relative to the U.S.). We accommodate this possibility by modeling a 10 percent increase in real per capita income in Mexico (relative to the U.S.), which is significant relative to past performance (see table 1). We further assume that earnings represent one-half of GNP and that all of the income increase is in the form of higher wage rates. Thus, we have assumed that the prevailing Mexican wage rate will increase over the long run by 20 percent (relative to the U.S.) following NAFTA.

In the third scenario, a one-time devaluation of the Mexican peso occurs to restore long-run equilibrium between the dollar and peso in the foreign exchange markets. Mexico has a historic pattern of episodes of exchange rate support by the central bank followed by major devaluations. Recall that Mexico held the value of the peso during the base period (1987-90) in the face of more rapid inflation than in the U.S. A devaluation of the peso relative to the dollar increases the cost of U.S. goods imported to Mexico and reduces the price of Mexican goods exported to the U.S. It also reduces the relative cost (in U.S. dollars) of inputs in Mexico, such as labor. Clearly, such a devaluation may affect trade flows, but it is debatable whether NAFTA will change the frequency or size of future peso devaluations. We, however, have chosen to analyze a long-run one time, 20 percent devaluation in the Mexican peso (relative to the U.S. dollar) from pre-NAFTA levels. That change is viewed as bringing the two currencies into long-run equilibrium where currency growth in each country is thereafter equal to the growth in domestic real income and the flexible currency exchange rate shows no particular long-term trend, although hort-run fluctuations could occur (Dombusch, 1976).

Results and Discussion

The U.S. and Mexican beef industry models are joined by an inter-country trade sector that equalizes prices on traded commodities between the countries (within the range defined by transportation costs and subject to any trade restrictions) and includes over 80 equations.” For convenience, all prices are expressed in dollars at the prevailing peso:dollar exchange rate. We also assume that Mexican labor is only one-third as productive as U.S. labor for similarly skilled jobs (Martin, 1995). Hence, the effective Mexican wage rate (adjusted for productivity) is three times the observed wage rate.”

To pre-test our overall trade model, independent solutions were obtained for each country over the period 1965-90 using actual levels of exogenous variables (where available) and traded quantities. That is, quantities in each country were essentially treated as exogenous and (endogenous) beef prices were obtained from the models’ solutions. The models’ results were generally within 10 percent of the actual prices available for these years, and the models were thus judged to adequately represent the U.S. and Mexican beef industries.

Although the Mexican and U.S. beef production models are dynamic (i.e., inventories depend on price expectations and past inventories), our primary interest is in long-run equilibrium changes arising from one-time changes in NAFTA policy. Hence, we **focus on static equilibrium solutions** (where no further changes are made in response to the one-time change in policy).” We consider these solutions to be partial equilibrium in the context of the overall economy of each country, but multi-sector equilibriums in the context of the beef industry because both beef and hide prices and quantities are endogenous, as are the prices of *“single use”* inputs (e.g., packer labor).

Levels of key exogenous variables in each country are set to a base level equal to the average of 1987-90 (table 6). Although the base period is several years prior to the enactment of NAFTA, it was a period of relative economic stability in both countries. Hence, the anticipatory effects of NAFTA. and other shocks to the domestic beef markets are minimized. We hold these exogenous variables fixed so that the solutions to the model represent the post-NAFTA partial equilibrium adjustments required in the beef industry (relative to 1987-90 levels of exogenous variables), as summarized in table 7.

The most consistent and dramatic long-run post-NAFTA change is in the size of the Mexican cow herd. In each scenario, the Mexican cow herd is about twice its pre-NAFTA size (i.e., from 8.3 to about 16 million head post-NAFTA). This expansion can be attributed to earlier weaning of calves and technical changes in post-weaning production practices, including confinement feeding of high grain diets to fed-beef. As a result, forage resources, which continue to be limited in many areas of Mexico by sparse precipitation, are freed-up to support an expanded cow herd size." This change, coupled with an improved weaning rate associated with improved pre-weaning production technology, more than doubles the number of calves Mexico produces each year and expands the quantity of beef supplied at each level. Hence, lower retail beef prices are observed in each of our post-NAFTA scenarios.

Mexican consumers enjoy the greatest price benefit (about $.60 per pound decline for retail beef), but the retail beef price also declines by about 10 percent in the U.S. market. Because NAFTA will expand market access and improve production technology, Mexican producers will also realize higher live animal prices and U.S. producers will receive lower prices for live animals.

Whereas analyses of NAFTA's short-run effects (i.e., assuming constant technology in Mexico) have consistently shown increases in the volume of beef animals exported to the U.S. and in the volume of retail beef and feed grain imported from the U.S. (CAST, USDA), our results show that in the long-run important changes in both the volume and direction of trade occur. If Mexico is able to adopt U.S. style beef production technology, it will be able to expand its beef cow herd enough to export about four million additional head of feeder cattle to the U.S. each year (relative to the 198790 base). Our results, however, also show that Mexico could meet its domestic beef demand and export about 750 million pounds of beef to the U.S. Hence, Mexico has the potential to become a major source of U.S. beef feeder animals (accounting for about 20 percent of U.S. slaughter numbers). Furthermore, unlike prior short-run analyses of NAFTA, our results indicate that instead of becoming a customer for U.S. beef, Mexico could become a major supplier of beef to the U.S. market (about 3 percent of U.S. consumption). The combination of increased Mexican live animal and beef exports post-NAFTA would be enough for Mexican production to account for about one-fourth of total U.S. beef consumption.

We expect Mexico to remain feed grain deficient. Hence, its ability to achieve this level of production depends on importing an additional 150-200 million bushels of feed grain per year from the U.S. at a price of about $2.80 per bushel (with an assumed perfectly elastic U.S. supply). Feeding imported grain will increase the cost of feeding cattle in Mexico relative to the U.S. by about $.06 per pound of post-weaning weight gain (about $45 per head). However, the increased feeding cost is not enough to offset the cost savings (largely through labor cost savings) of about $75 per head (about $.07 per pound) that would be realized from slaughter and post-slaughter processing in Mexico.

Although some other studies have suggested that one of the primary effects of NAFTA on agricultural trade will be through higher income levels in Mexico (Rosson et al), our results suggest relatively small long-run effects of a 10 percent increase in Mexican real income (relative to the U.S.). Beef prices in both Mexico and the U.S. rise slightly (about $.01 per pound), but the majority of the demand effects due to higher Mexican income are accommodated by increased production (i.e., nearly 500,000 beef cows are added to herds in each country). Mexico continues to export beef (about 750 million pounds per year) and calves (about 3.5 million head) to the U.S. The slightly reduced level of calf exports (about 500,000 head) and the larger cow herds in Mexico and U.S. are, however, adequate to meet the increased demand in Mexico without significant increases in the prices of either meat or live animals.

When we add the effects of a one-time devaluation of the peso (relative to the U.S. dollar), we find that additional changes in U.S.-Mexican beef production and trade patterns occur. In this scenario, the prices of Mexican inputs fall relative to the U.S. due to the devaluation, and relative trade volumes shift from raw commodities or intermediate products, such as live animals, toward higher-valued, more fully processed products, such as retail beef. In particular, when the peso is devalued by 20 percent, long-run Mexican exports of feeder cattle are reduced about two million head (from 3.54 million head per year to 1.3 million head) relative to the full technology transfer only scenario and Mexican exports of beef are increased about 1.6 billion pounds (from 750 million pounds to 2.3 billion pounds).

To understand this shift, bear in mind that purchased inputs, such as labor, account for a small share of live animal cost. In post-slaughter production and processing, however, purchased inputs account for the majority of the costs incurred. When the prices of these inputs are reduced, as with devaluation, Mexico gains an additional comparative advantage in the labor-intensive, phases of beef production and processing. Hence, there is an incentive to do more post-slaughter processing in Mexico before exporting the product. At the same time, devaluation causes Mexican wage rates and income (in U.S. dollars) to decline. This causes Mexican beef demand to decline, provides further incentives to increase beef exports from Mexico to the U.S., and reduces retail beef prices in both countries.

Summary

Mexico has a comparative advantage for low-skilled, labor-intensive industries. Beef production is not generally viewed as such an industry and thus not vulnerable to moving to Mexico. Previous analyses of NAFTA effects on U.S.-Mexican beef trade have reported an increase of Mexican exports of feeder calves to the U.S. and of beef imports from the U.S. However, these analyses have failed to see the significance of labor intensive processing and technology transfers that can be important to long-term post-NAFTA adjustments.

The slaughter animal typically represents about half of the average retail value. Much of the difference is associated with processing (e.g., slaughter, cutting, packaging, etc.), which is labor intensive. Thus far, Mexico has not had the level of technology, capital, and infrastructure needed to capitalize on its low wage rates in beef processing. However, NAFTA will have effects that extend beyond trade. NAFTA also lowers barriers to capital investments and technology transfers between the countries. In the long-run, these technology transfers could alter the comparative advantage of beef production and processing in ways that affect both the magnitude and direction of trade between the countries.

We analyzed these longer-run effects of NAFTA by assuming that U.S. beef production and processing technology, including the needed capital investment and infrastructure, were fully transferred to Mexico. We also considered two additional post-NAFTA scenarios: a 10 percent increase in real Mexican per capita disposable income (20 percent increase in real wage rates) and a 20 percent devaluation in the peso relative to the U.S. dollar were added to the full-technology transfer scenario.

In all three scenarios, our results show that Mexico would dramatically expand the size of its cow herd (nearly double). The expanded supply and lower post-slaughter processing cost in Mexico give it a comparative advantage in beef production, despite the fact that most of its feed grain requirement will be met by imports from the U.S. As a result, Mexico is able to expand its exports of feeder calves to the U.S. by about 3.54 million head when technology is transferred (relative to a 1987-90 base level) and when Mexican real income also increases by 10 percent. Mexico is also able to become a beef exporter (750 million pounds per year) and beef prices in both countries decrease.

When technology is transferred and the peso is devalued 20 percent, Mexico exports only about 1.3 million additional head of feeder calves (relative to pre-NAFTA), but increases beef exports to about 2.3 billion pounds per year. Devaluation of the peso has the effect of reducing input prices (in U.S. dollars), including wage rates, in Mexico. Labor-intensive, post-farm processing operations become relatively inexpensive to perform in Mexico. Hence, Mexico increases its processing and reduces its exports of raw commodities relative to our other solutions. We have analyzed only the consequences of a re-alignment in relative currency values associated with bringing the peso into a new long-term equilibrium with the dollar. However, our results suggest that the long-term effects of NAFTA on the North American beef industry depend on the level of technology in each country and currency exchange rate policies. Short-run analyses fail to capture these important effects of trade liberalization.

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Endnotes

[1] Opportunities and responsibilities associated with foreign capital investments are also to be strengthened by the NAFTA. Most restrictive requirements are to be eliminated and a general prohibition on expropriating post-NAFTA investments should make foreign capital investments in Mexico much safer. In addition, within six years of enacting the NAFTA, transportation services in North America are to become international so that goods can freely hauled between the countries.

[2] The population of Canada was about one-ninth that of the U.S. in 1990.

[3] The U.S. also has federal marketing order systems in effect for fresh fruits and vegetables and grade A fluid milk. The marketing order applies to the quantity and quality of a product that may go through commercial markets and these may affect marketings regionally.

[4] One commercial firm with interests in both the U.S. and Mexico has indicated that the retail beef cut-out percentage in Mexico (retail weight as a percent of slaughter weight) is only about 34 percent compared to 47 percent in the U.S. About 12 percent of the lost production (22 pounds per head) can be largely attributed to waste.

[5] The exception is hotel, restaurant, and institutional sales, especially those catering to tourist trade.

[6] Mathematical representations of key equations in the model are summarized in Melton and Huffman (1994) for the interested reader.

[7] The assumption of a perfectly inelastic pasture supply is justified by its close linkage to land area. The inelasticity of grain supply is more subjective. However, grain trade is a subsidiary consideration in this study, and data do not readily exist to estimate aggregate grain cost functions for the multiple grains (species) used in beef production.

[8] Econometric estimates of the AID equations and other functions used in this model are available from the authors on request.

[9] Although the negative income elasticity for beef is unusual, negative income (expenditure) elasticities have been reported for other nutritious foods such as apples (-.35) (Huang, 1985).

[10] We have also checked our implied price and income elasticities for Mexico against those of other, somewhat comparable countries, e.g., Spain (Chung, 1994), and found them to be fairly consistent.

[11] As a practical matter, the herd equation is estimated in components. One equation is estimated for number of cows culled and another is estimated for number of replacements retained.

[12] USDA typically reports herd inventories as of January 1. Thus, the herd inventory on January 1 in the current year depends on the inventory on January 1 last year plus net changes that occurred over the prior year due to culling, replacement, and death loss.

[13] Trapp (1987) analyzed optimal culling strategies and herd size changes in response to cyclical beef price changes and trends, but still assumed that the trends and cycles would repeat with certainty.

[14] Although recent data may reflect current structures, the cow and calf price series were also examined for the period 193590. Although the R^2 dropped to about .80, there was no major change in the coefficients or structure of the model, which suggests major structural similarities over the longer term.

[15] The reader should note that these estimates are made on price series that have been back-differenced. This is a common Box-Jenkins practice to remove seasonal price effects and obtain a stationary series. In our estimates, the series are cyclically differenced once to obtain a stationary series and reflect inter-year (cyclical) rather than intra-year (seasonal) real price changes. For example, the calf and cull cow price differencing of 10 and 12 years, respectively, seems to reflect the cyclical nature of beef production biology.

[16] The investment in a new large-scale commercial feedlot (including a feedmill) is no more than about $300 per animal capacity.

[17] Some of the equations are accounting identities and others are estimated. To conserve space only those estimated equations that we judge to be most important have been discussed in the paper.

[18] If Mexican labor were assumed to be equally productive to U.S. labor, the effective wage rate in Mexico would be equal to the observed wage, which is one-third of the value used in our model. Hence, there would be even greater pressure to shift labor intensive aspects of beef production from the U.S. to Mexico, i.e., Mexican beef production approaches the level of U.S. production.

[19] In these solutions, 22 to 30 years are required to re-attain a stable equilibrium after the one-time economic shock.

[20] Because of the lower average productivity of its forage (land) resources, Mexico still has a lower average long-run stocking rate than the U.S. (i.e., 23 acres per cow in Mexico versus about 18 acres per cow in the U.S.).

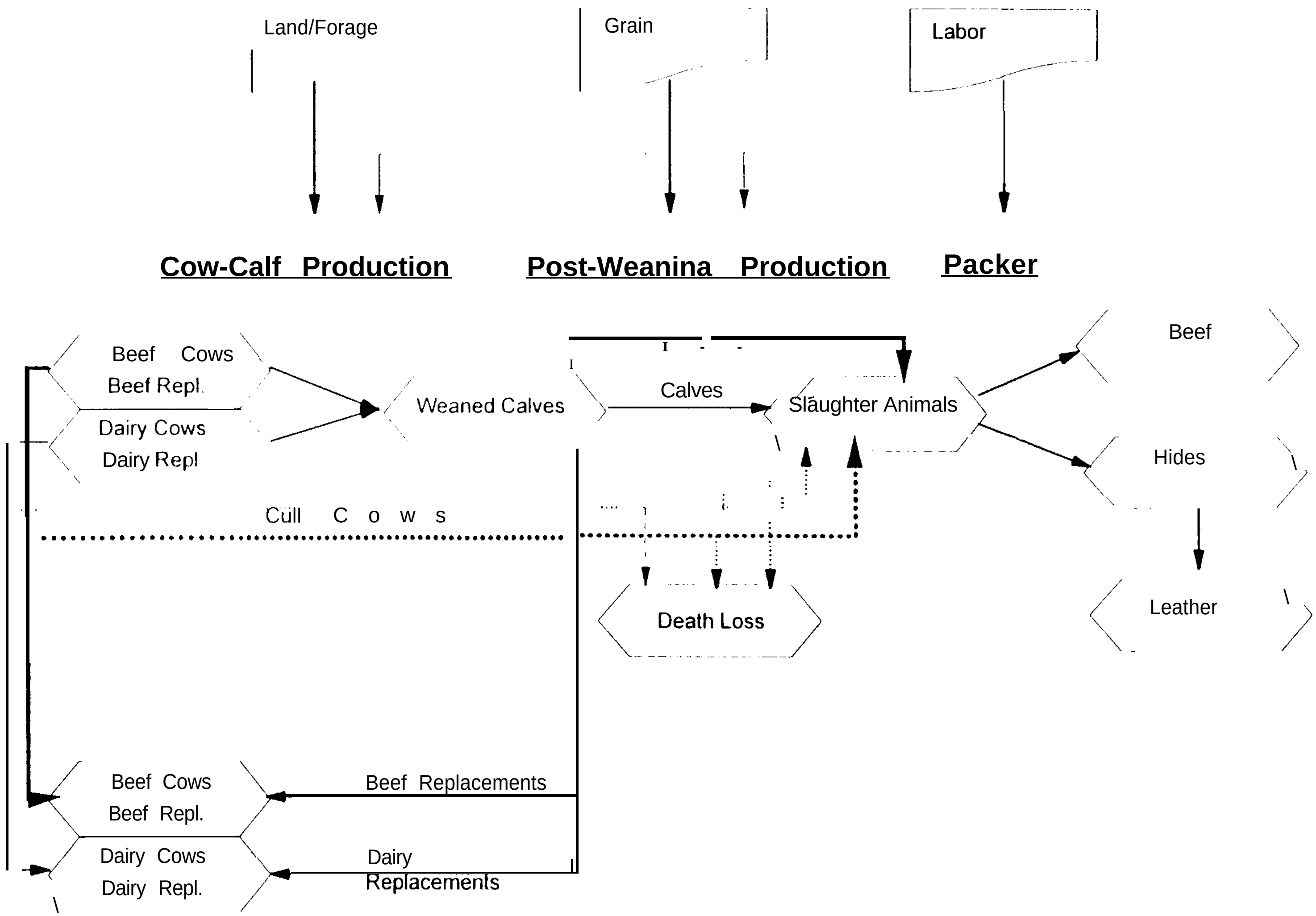

Figure 1. Beef supply system model.

Table 1. Summary of macro-economic indicators for Mexico and the U.S., 1960-90.

	United States				Mexico			
	1960	1970	1980	1990	1960	1970	1980	1990
GDP								
Real (bil 1987 $ or 1975 pesos)	1,970.8	2,873.9	3,776.3	4,897.3	381.1	751	1,207.6	1,431.3
Decade growth rate (%)		37.7	27.3	26		67.8	47.5	17
Sector distribution (%)								
Agriculture	4.1	2.9	2.5	2	16	11	8	9
Industry	44	40.7	40	33.5				32.2
Services	51.9	56.4	57.5	64.5				58.8
Population								
Total (mil)	180.7	205.1	227.7	249.9	38.5	52.8	70.1	86.9
Decade growth rate (%)		12.7	10.5	9.3		3 6	28.3	21.5
Agriculture population (%)	7.5	4.8	3.3	2.2	53.1	43.9	35.7	29.2
Labor force (> age 16)								
Total (mil)	69.6	82.8	106.9	124.8	11.3	14.7	20	35.3
Decade growth rate (%)		17.3	25.6	15.4		26.3	30.8	23.5
Participation rate (%)[1]	56.1	57.4	59.2	62.7	31.4	25.6	28.3	34.4
Employees in agriculture (%)	7.8	4.2	3.1	1.7	54.2	45.2	36.1	31
Trade								
Exports to Mexico/U.S. (mil $)	820	1,704	15,145	28,375	455	839	9,688	21,922
share to total exports (%)	4	3.9	4.8	7.2	59.6	59.8	63.2	81.1
Imports from Mexico/U.S. (mil $)	453	1,299	12,774	30,797	856	1,568	12,814	15,553
share of total imports (%)	3	3.1	5	6	72.2	63.6	65.6	53.4

[1] Employment divided by total civilian noninstitutional population.

Source: Huffman (1986), U.S. President (1995), International Monetary Fund (1993), and Hall and Livas-Hernandez (1990)

Table 2. Hicksian Price and Income Elasticities of Per Capita Demand (from AIDS fitted to 1963-87).

	Prices								
	Beef[1]	Pork	Chicken	Other Animal	Plant Products	Nonfood	Real Income	Trend	Exp. Share
Beef	-0.310	0.163	0.019	0.170	-0.280	0.233	-0.100	0.00004	0.015
	(3.25)	(4.98)	(1.09)	(1.13)	(2.21)	(1.07)	(.35)	(.51)	
Pork	0.294	-0.760	0.010	0.508	-0.080	0.894	0.288	0.00001	0.008
	(4.98)	(19.16)	(.15)	(3.78)	(.68)	(.07)	(1.14)	(.02)	
Chicken	**0.100**	0.008	-0.210	-0.070	-0.150	0.305	0.801	0.00005	0.003
	(1.09)	(.15)	(3.49)	(.42)	(1.09)	(1.00)	(2.67)	(2.69)	
Other Animal Products	0.098	0.163	-0.010	-0.400	-0.560	0.706	1.349	0.00000	0.026
	(1.13)	(1.09)	(.42)	(1.26)	(2.29)	(1.73)	(2.37)	(2.78)	
Plant Products	-0.070	-0.010	-0.010	-0.240	-0.640	0.967	-0.190	0.00090	0.061
	(2.21)	(.68)	(1.09)	(2.29)	(4.33)	(5.22)	(.57)	(2.71)	
Nonfood	0.004	0.000	0.001	0.021	0.066	-0.090	1.097	0.00000	0.887
	(1.07)	(.07)	(1.00)	(1.73)	(5.22)	(4.81)	(1.34)	(1.56)	

[1] Approximate t-values are reported in parentheses below each elasticity.

Table 3. Elasticities of Input Demand in the U.S. Leather Sector (translog function fitted to 1963-85 data).

	Input Prices					
	Labor[1]	Capital	Energy	Hides	Trend	Share
Labor	-0.610	-0.010	0.003	0.618	0.000	0.345
	(27.07)	(1.08)	(2.32)	(25.27)	(3.74)	
Capital	-0.060	-0.310	0.000	0.371	0.0020	0.062
	(1.08)	(8.97)	(.34)	(5.89)	(7.20)	
Energy	0.110	-0.010	-0.610	0.508	0.0004	0.010
	(2.32)	(.34)	(13.07)	(6.99)	(7.84)	
Hides	0.370	0.039	0.008	-0.410	0.000	0.584
	(25.27)	(5.89)	(6.99)	(25.93)	(.15)	

[1] Approximate t-values are reported in parentheses below each elasticity.

Table 4. Elasticities of Input Demand for the U.S. Beef Post-weaning Sector (translog function fitted to 1963-87 data).

	Prices					
	Feed'	Capital	Labor	Pasture	Trend	Share
Feed	-0.363	0.1392	0.022	0.202	.0047	0.596
	(33.37)	(69.77)	(22.16)	(17.95)	(.736)	
Capital	0.639	-0.589	0.017	-0.067	.0028	0.129
	(69.48)	(5.89)	(1.13)	(.66)	(2.34)	
Labor	0.463	0.079	-1.184	0.643	.0014	0.028
	(22.09)	(1.13)	(4.09)	(2.13)	(2.33)	
Pasture	0.481	-0.035	0.072	-0.518	-0.010	0.247
	(17.95)	(.66)	(2.13)	(7.58)	(1.36)	

[1] Approximate t-values are reported in parentheses below each elasticity.

Table 5. Box-Jenkins parameter estimates for QRE prices.

Price	Difference	Constant[1]	Ψ_1	Γ_1	Γ_2	Θ_1	R^2	D-W	F-test
Cull Cow	12	-3.757		-1.000			0.984	1.86	1,133.91
		(18.80)		(153.05)					
Weaned Calf	10	-3.464		-0.999		-0.940	0.955	1.97	178.31
		(2.98)		(69.98)		(12.55)			
Corn Grain	6	-0.416	-0.337	-0.703	-0.999		0.943	1.86	110.16
		(6.63)	(1.94)	(13.52)	(105.70)				
Hay	6			-0.874	-0.998	-0.930	0.941	1.94	170.77
				(8.39)	(45.87)	(11.18)			
Capital	7	2.124		-1.118	1.000		0.965	1.66	291.15
		(9.12)		(21.78)	(91.07)				

[1] Approximate t-values are reported in parentheses below each elasticity.

Table 6. Levels of key exogenous variables (1987-90 average).

Variable	Unit	United States	Mexico
Wage rate	$/hr	10.83	2.01
Gross domestic product	$1000	22.29	1.73
Pork price	$/pound	1.84	1.11
Chicken price	$/pound	0.78	0.71
Other animal price	$/pound	1.17	1.32
Corn grain (feed)	$/bushel	2.25	7.65
Labor unionization	Index (1980=1.00)	0.49	0.11
Dairy cows	1000 hd	10,159	4,502
Dairy replacements	1000 hd	4,194	1,834

Table 7. Alternative long-run changes in post-NAFTA U.S.-Mexican beef trade.

Endogenous Variable	Units	Pre-NAFTA: Base solution		Post-NAFTA Alternatives: Full technology transfer		plus 10% rise in real Mexican income		plus 20% devaluation of the peso	
		U.S.	Mexico	U.S.	Mexico	U.S.	Mexico	U.S.	Mexico
Cow herd	mil head	36.18	8.31	36.54	16.33	37.03	16.59	37.7	15.99
Beef price	$/lb	2.43	2.80	2.21	2.17	2.22	2.17	2.09	2.04
Carcass price	$/cwt	107.78	88.39	94.28	92.03	94.36	92.10	88.49	86.30
Steer price	$/cwt	72.52	53.43	59.79	60.00	59.87	60.24	57.51	57.43
Feeder price	$/cwt	90.80	35.15	67.36	62.36	67.91	62.91	69.28	64.28
Feeding cost	$/lb wt gain			0.447	0.505	0.443	0.503	0.394	0.438
Packing cost	$/lb live wt			0.130	0.059	0.130	0.055	0.134	0.040
Trade Changes:[1]									
ΔBeef	bil lbs			0.75	-0.75	0.76	-0.76	2.33	-2.33
ΔAnimals (feeders)	mil hd			3.92	-3.92	3.59	-3.59	1.34	-1.34
ΔCorn	mil bu			-191.14	191.14	-189.77	189.77	-159.22	159.22

[1] We adopt the convention of representing imports as positive (+) and exports as negative (-) changes in trade flows.