MODELING THE EVOLVING MEXICAN CATTLE AND BEEF INDUSTRY AND THE ECONOMIC IMPACTS OF ADDITIONAL BEEF FABRICATION

By

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AND BEEF INDUSTRYAND THE ECONOMIC

IMPACTS OF ADDITIONAL BEEF FABRICATION

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I may not have gone where I intended to go, but I think I have ended up where I needed to be.

-Douglas Adams, Dirk Gentley's Holistic Detective Agency

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Title of Study: MODELING THE EVOLVING MEXICAN CATTLE AND BEEF INDUSTRY AND THE ECONOMIC IMPACTS OF ADDITIONAL BEEF FABRICATION

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Abstract: Beef packing infrastructure in Mexico has changed dramatically in recent years with a significant proportion of domestic beef production now fabricated into boxed beef in place of the carcass based system that dominated historically. Conversion to a boxed beef system increases beef value potential as boxed primals can now be targeted to appropriate markets to increase overall carcass value. An important component of this increased value is the ability to export specific products to higher value foreign markets.

This research adapts and expands the GANAMEX model, a regional linear programming of the Mexican cattle industry to compare a scenario without boxed beef production to a benchmark where boxed beef production occurs. The addition of fabrication technologies begins to move Mexico from a cow-calf industry built on live cattle exports and U.S. meat imports to an industry that produces higher quality cows and is more feedlot oriented. As the gap between comparative advantages in beef production and beef prices narrows, the trade relationship between the U.S. and Mexico will become more sensitive to arbitrage opportunities in the world beef market and geographical product flows.

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CHAPTER I

INTRODUCTION

Since Spanish Conquistadors came to Mexico looking for precious metals bringing with them Spanish cattle, the beef industry has been important to Mexico (Peel 2002). Since the last half of the 19th century cattle production in northern Mexico has had strong ties to the United States (Peel 2005). Mexico and the United States vary a great deal but when it comes to cattle it is imperative to think about these countries as a single market driven by regional markets, and specific beef markets composed of trade across borders. The United States and Mexico have differences in their cattle industries but each share similarities and thrive because of the symbiotic relationships.

The Mexican cattle industry can be broken into three regions: the arid and semi-arid regions of the north, the tropical south, and the temperate central region (José García-Vega and Gary W. Williams 1996). Historically, cattle production in the north has been focused on the export of calves to the United States. Temperate inland and tropical coastal areas have produced grass fed beef to sell in local markets. Cattle production in these regions consists of dual purpose production of dairy-zebu cross cattle that are used for milk as well as meat production (Peel 2005; José García-Vega and Gary W. Williams 1996). Historically, the U.S. and Mexico have had different comparative advantages in: raising different types of cattle, feedlots, slaughter houses, packaging, and marketing. Furthermore, historically each country has had different demands for

different products that come off a beef carcass. Economists agree that the Mexican and U.S. cattle and beef industries provide great opportunity and will continue to evolve and adjust to future challenges (Christie Guinn and Rhonda Skaggs 2002; Peel 2001a, Peel 2002).

This thesis consists of two essays. The first deals with conversion of the GANAMEX model to a welfare maximization model; expansion of model structure and updating the model to represent a current baseline. The second essay is an application of the updated GANAMEX to estimate the impacts of the recent change of the Mexican beef sector from a carcass-based market to boxed beef fabrication and marketing. The remaining sections of this chapter discuss the linear programming methodology used in the GANAMEX model.

Modeling the Mexican Beef Cattle Industry (outline)

GANAMEX was developed as a linear programming model because of the proper attributes a linear program possesses when researching markets like the Mexican cattle and beef industries. An econometric model would not suffice because of data difficulties and changing underlying economic conditions (Hazel and Norton). Linear programming can be done with limited historical data and Mexican data availability and accuracy is a challenge. According to , José García-Vega and Gary W. Williams (1996) this data is not "…readily available nor reliable" (pg.6). Peel (An Assessment of Mexican Livestock Industry Data), provides a comprehensive report of Mexican data and also points out weaknesses that must be considered. Hazel and Norton (1986) detail the basic components of linear programming models that are also found in Cunningham (2006):

1. Optimization. An appropriate objective function is either maximized or minimized.
2. Fixedness. At least one constraint has a nonzero right hand side coefficient.
3. Finiteness. There are only a finite number of activities and constraints to be considered in order that a solution may be sought.
4. Determinism. All coefficients in the model are assumed to be known constants.

5. Continuity. Resources can be used and activities can be produced in fractional units.
6. Homogeneity. All units of the same resource or activity are identical.
7. Additively. When two or more activities are used, their total product is the sum of their individual products; no interaction effects between activities are permitted.
8. Proportionality. Regardless of the level of activity used, the gross margin and resource requirements per unit of activity are constant. A constant gross margin per unit of activity assumes a perfectly elastic demand for the product, and perfectly elastic supplies of any variable inputs that may be used.

Next, linear programming models have the ability to include detail such as regional, production, and marketing systems and are more desirable for rapidly changing industry structure (Hazel and Norton 1986; Johansson, Peters, and House 2007).

Some of the limitations of a linear programming model are that the model is not objectively estimated and results are not easily validated.

ESSAY I

GANAMEX 2010: A CONVERSION AND EXPANSION OF THE GANADERÍA MEXICANA MODEL

GANAMEX, a linear programming model, was developed by Peel in 2001 to model the Mexican cattle and beef industry. Since its development in 2001 the model is constantly evolving and relevant applications continue to emerge. In 2003 GANAMEX was updated to a new baseline and used to summarize the impacts of Country of Origin Labeling. A situation where no cattle imports from Mexico to the U.S. could occur was analyzed (Peel 2003b). Also, research was done to estimate scenarios of Mexican beef demand where increases in beef consumption and also the proportion of each type of beef were examined (Peel 2003a). Later, the model was expanded to allow for more specific regional impacts. Research was done in 2006 to explore the impacts of Tuberculosis (TB) health campaigns in Mexico. TB restrictions were applied and the results, expectations of production decisions, were analyzed to show impacts of the restrictions (Cunningham 2006).

GANAMEX contains nine production regions, ten feedlot centers, four slaughter regions, and seven consumption regions. Tables 1-1, 1-2, and 1-3 describe the regions.

Table 1-1. Cattle Production Regions

Region	Region Name	States Included	Representative City
P1	North	Baja California, Baja California Sur, Sonora, Chihuahua, Coahuila	Chihuahua, Chih.
P2	Northeast	Nuevo Leon, Tamaulipas	Monterrey, N.L.
P3	Central Mesa	Durango, Zacatecas, San Luis Potosi, Aguascalientes	Zacatecas, Zac.
P4	Cordillera	Queretero, Hidalgo, Puebla, Tlaxcala, Mexico, Morelos, Guanajuato, Jalisco, Michoacán, Distrito Federal (DF)	Guadalajara, Jal.
P5	Pacific Coast	Sinaloa, Nayarit	Culiacan, Sin.
P6	Southern Sierra Madre	Colima, Guerrero, Oaxaca	Oaxaca, Oax.
P7	Veracruz	Veracruz	Veracruz, Ver.
P8	South	Tabasco, Chiapas	Villahermosa, Tab.
P9	Yucatan	Yucatan, Campeche, Quintana Roo	Merida, Yuc.

Table 1-2. Feedlot Regions

Region	Region Name	Representative City
F01	Northwest	Mexicali, B.C.
F02	La Laguna	Torreon, Coah.
F03	Northeast	Monterrey, N.L.
F04	Pacific Coast	Culiacan, Sin.
F05	Cordillera	Guadalajara, Jal.
F06	Huasteca	Tampico, Tamp.
F07	Central Mesa	San Luis Potosi, S.L.P.
F08	Veracruz	Veracruz, Ver.
F09	Tabasco	Villahermosa, Tab.
F10	Yucatan	Merida,Yuc.

Table 1-3. Consumption Regions

Region	Region Name	States Included	Representative City
C1	Northwest	Baja California, Baja California Sur, Sonora, Sinaloa	Hermosillo, Son.
C2	North Central	Chihuahua, Durango, Comarca Lagunera	Chihuahua, Chih.
C3	Northeast	Coahuila, Nuevo Leon, Tamaulipas	Monterrey, N.L.
C4	Tapatio	Nayarit, Jalisco, Aguascalientes, Colima, Guanajuato, Zacatecas	Guadalajara, Jal.
C5	Central	San Luis Potosi, Queretero, Hidalgo, Puebla, Mexico, Michoacan, Tlaxcala, Guerrero, Oaxaca, DF	Mexico City, DF.
C6	Gulf	Veracruz, Tabasco, Chiapas	Veracruz, Ver.
C7	Yucatan	Campeche, Yucatan, Quintana Roo	Merida, Yuc.

Note: Comarca Lagunera includes the following Municipios; five of which are in Coahuila: Torreón, Matamoros, San Pedro, Francisco I. Madero, and Viesca. Ten are in Durango: Gómez Palacio, Ciudad Lerdo, Tlahualilo, Mapimí, Rodeo, Nazas, San Juan de Guadalupe, San Luis del Cordero, Simón Bolívar, and San Pedro del Gallo.

Within the production regions four types of cow-calf production systems result in four types of cattle: northern-style (V1), semi-intensive (V2), traditional (V3), and criollo (V4), three types of forages are used: non-irrigated pasture, irrigated pasture, and esquilmos, and two types of stocker systems are utilized, intensive and extensive. Within the finishing sector there are four types of finishing systems: fed for northern-style (M1) meat, fed for Mexican fed (M2) meat, supplemented grass finished for traditional (M3) meat, and grass finished for traditional (M3) meat. The finishing system used determines the one of four meat types that results from the respective system. Production costs are allocated to each possible outcome before slaughter in each in each production region and feedlot center. After finishing, the cattle are either slaughtered locally or at a federally inspected (TIF) plant. The resulting meat is then available for shipment to any of the seven consumption regions in the transportation portion of the model. The trade component of the model relates to the export of calves, feeder cattle, middle meats consisting of loin and rib primals from Mexican-fed cattle, and cull meat and the import of middle meat and slaughter cows (Cunningham 2006).

The activities in GANAMEX are specified as alternatives and include production, processing, transportation, and trade. The constraints represent the availability of resources. In

GANAMEX, there are two types of constraints, inequality and equality. Equality constraints enforce linkages related to production and processing activities and track product flows. Inequality constraints represent resource capacity and availability (Cunningham and Peel 2006). Lastly, the parameters in the model represent the productivity and input requirements (Peel 2001a). An abbreviated description of the endogenous variables, exogenous variables, and parameters are listed below (Cunningham 2006).Figure 1 shows the beef production system.

The endogenous variables in GANAMEX include each of the following activities:

-Forage use by region (by type)

-Domestic shipments of cattle by type

  -Calves between production regions

  -Stockers between production regions

  -Feeders from production regions to feedlots

-Production of meat by type and location

-Quantity, type and location of slaughter

-Quantity, type, and location of fabrication

-Domestic shipments of meat by type

  -From production regions to consumption regions

  -From feedlot regions to consumption regions

-Imports of slaughter cows by production region

-Imports of Central American calves and feeders

-Quantity, type and location of

  -Cow-calf production

  -Stocker production

  -Slaughter animal production

    -Finishing in feedlots

    -Finishing in pasture

-Exports of calves by production region

  -Male and Female

-Exports of rodeo calves

-Exports of feeders by production region

  -Male and Female

-Imports of meat by consumption region

-Exports of meat by production region

-Exports of meat by feedlot region

The exogenous variables in GANAMEX include each of the following:

-Quantity of beef consumption by type, location

-Dairy sector contributions to cattle supplies

-Trade sector Values

-Slaughter costs by type of slaughter

-Forage availability, productivity, costs

  -Feedlot capacity by region

  -Animal production and feed costs

-Transportation costs for live animals and meat

The parameters in GANAMEX include:

-Forage productivity by type and location

-Animal finishing system by type and location

-Cow-Calf Production by animal type and location

Figure 1-1. Beef Production Systems in GANAMEX

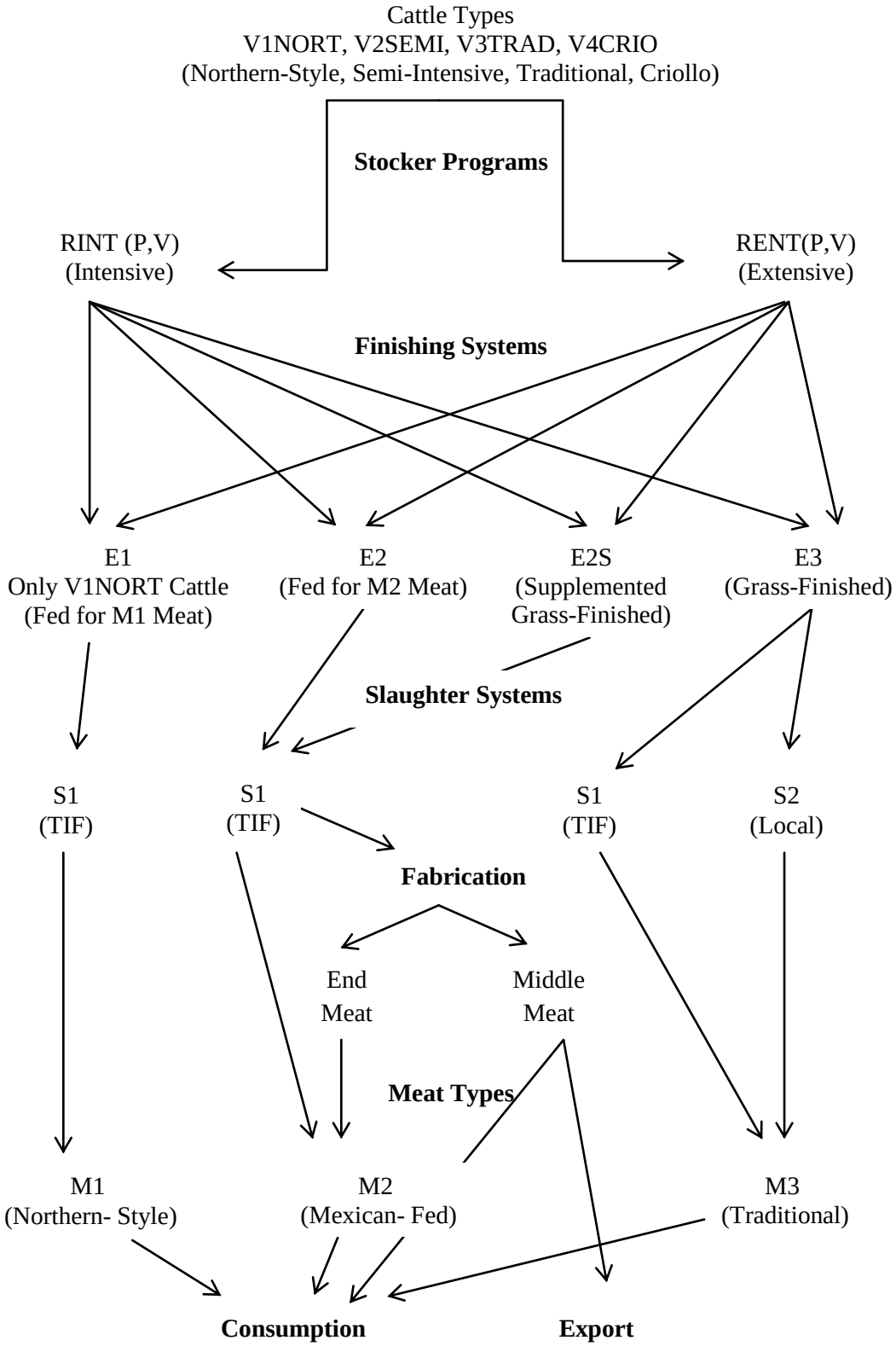
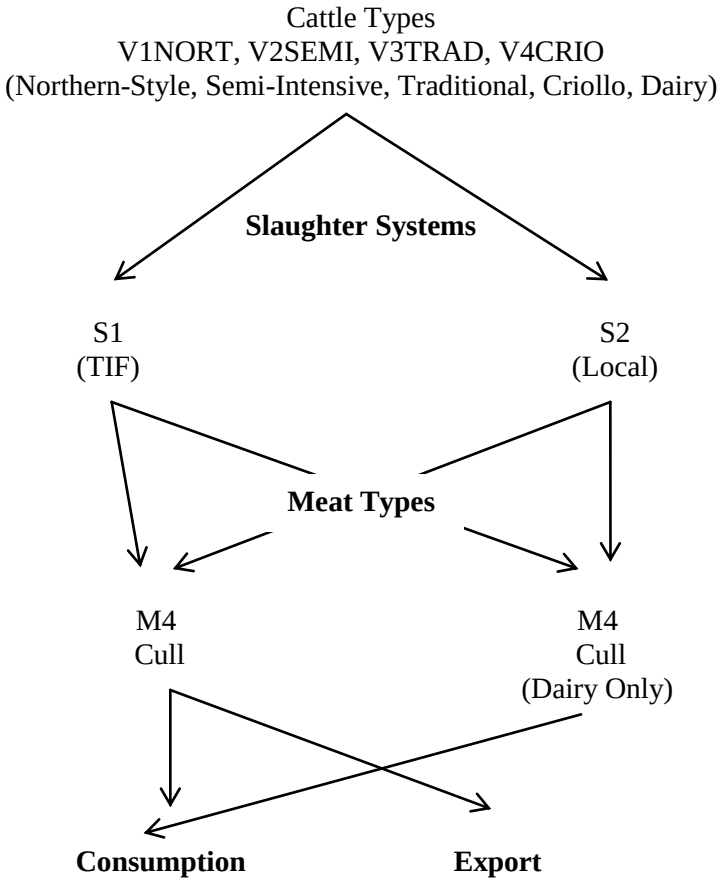


Figure 1-2. Cull Beef Production Systems in GANAMEX



Objectives

The overall objective is to update and expand the structure of GANAMEX to reflect the current situation in the Mexican cattle and beef industry and to enhance the usefulness of the model for scenario analysis.

The specific objectives are:

a. Convert the model from a cost minimization to a welfare maximization model
b. Expand model structure to include:
    i. Meat fabrication and boxed beef sales and beef exports
    ii. Add regional slaughter capacity constraints
    iii. Expand the model treatment of feed resources from crop residues (esquilmos)
    iv. Expand border crossing alternatives and associated transportation activities
c. Create a 2010 baseline for the model which includes:
    i. Updated regional population totals
    ii. Updated beef consumption profile
    iii. Updated production, transportation, slaughter and other costs
    iv. Updated trade values
    v. Updated dairy sector contributions

Methodology

In this research, GANAMEX is converted from a model that minimizes cost, to one that maximizes consumer surplus minus production cost. Recent work by Mejia (2012) used CROPMEX, a linear programming model that maximizes welfare, to determine the most economically viable allocation of resources for the production of the most important crops in Mexico. The Regional Environmental Agriculture Programming Model (REAP) is a continuation of the U.S. Mathematical Programming Regional Agriculture Sector Model (USMP) that began in 1985.Like CROPMEX, REAP uses price-quantity-elasticity combinations to generate supply and

demand curves which are used to solve for an equilibrium price-quantity relationship (Johansson, Peters, and House 2007). According to Johansson, Peters, and House (2007), in the REAP model it is relatively easy to introduce new production activities, for example, boxed beef in the case of GANAMEX. Furthermore, this type of modeling can be done with limited historical data.

Welfare Maximization

To estimate the demand curve for all beef in the national market a base price, quantity, and elasticity are exogenously specified. Data on retail beef price and per capita consumption is limited and often not consistent. Some estimates for consumption include offal consumption while others include only muscle meat. In the 2010 benchmark a base price of 55 pesos per kilogram and a base quantity of 17 kilograms per capita .The own-price elasticity for beef of 1.516 is taken from estimates by Mejia (2012). These values are consistent with industry data (Early 2013) and the household expenditure survey that was used by Mejia (2012).

A range is then specified around the base price , and quantity , where within which equilibrium is found. The minimum ( ) and maximum ( ) quantity of beef consumed are scalars that determine the quantity range.

The maximum quantity consumed is calculated by

(1.1)

The minimum quantity consumed is calculated by

(1.2)

The maximum price is calculated by

(1.3)

Where is the demand curve intercept and is the slope of the demand curve

The minimum price is calculated by

(1.4)

The demand curve is then dissected by a specified grid and at every point along the specified portion of the demand curve quantity and welfare are calculated.

The objective function maximizes net welfare while simultaneously minimizes the cost associated with producing the welfare maximizing quantity of meat. The objective function is written as

(1.5)

Where

g=1…n, grid

is a point along the demand curve; is the welfare segment associated with each ; is total population; cost is the total cost of production

The welfare segment is the area under the demand curve and above production cost and is calculated by

(1.6) –

Where

is the demand curve intercept; is the quantity of meat consumed in the domestic market; is the slope of the demand curve. The parameters for the demand curve are derived from the demand for meat in the base year, the price of meat in the base year , the quantity of meat consumed in the base year , and the price elasticity of demand ( ).

The slope parameter is derived as

(1.7) ——

The intercept is obtained from

(1.8)

The total cost of production is then subtracted from . Total cost of production is

(1.9)

Where

a=1…p	production regions	North, Northeast, Central Mesa, Cordillera, Pacific Coast, Southern Sierra Madre, Veracruz, South, Yucatan
b=1…f	forage types	Irrigated pasture, native pasture
c=1…v	cattle types	Northern-style, semi-intensive, traditional, criollo
d=1…r	stocker systems	Intensive, extensive
e=1…s	finishing systems	Fed for Northern-style, Mexican-fed, supplemented grass finished, grass finished
g=1…m	meat types	Northern-style, Mexican-fed, traditional, cull
h=1…y	consumption regions	Northwest, North Central, Northeast, Tapatio, Central, Gulf, Yucatan
i=1…e	esquilmos types	Dry land: maize, sorghum, beans, sugar cane, other Irrigated: maize, sorghum, beans, sugar cane, other

j=1…b	border ports	Calexico, Nogales, Santa Teresa, Presidio, Eagle Pass, Laredo, Hidalgo

Where PF is the forage price; F is forage used; PE is the esquilmos price; E is esquilmos used; CC is non-forage calf production cost; C is calves produced; CS is non-forage cost of stocker production; S is stockers produced; CF is finishing cost; F is cattle finished; CTC is cost of shipping calves to other regions; CT is calves shipped; CTS is cost of shipping stockers to finishing; TS is stockers shipped to finishing; VCE is value of calf exports; CE is calves exports; VFE is value of feeders exported; FE is feeder exports; VRE is value of rodeo calf exports; ER is rodeo calf exports; CD is cost of dairy cows; D is dairy cows; CDC is cost of dairy calves; DC is dairy calves; CIC is cost of importing slaughter cows; CI is slaughter cow imports; CF is fabrication cost; FA is fabrication; FAC is cost of fabricating meat from a semi-intensive production system; FSC is fabrication of meat from a semi-intensive production system; FC is cost of fabricating of meat from a semi-intensive production system; CSL is cost of slaughter; SL is slaughter; CSD is cost of dairy cow slaughter; SD is dairy cow slaughter; CSM is cost of shipping meat from finishing regions to consumption regions; SM is shipment of meat from finishing regions to consumption regions; CSMP is cost of shipping meat from production regions to consumption regions; SMP is shipment of meat from production regions to consumption regions; VME is value of meat exports; ME is meat exports; VSME is value of meat exports from a semi-intensive production system; SME is meat exports from a semi-intensive production system; CIM is cost of importing meat; MI is meat imports.

Balancing Constraint

Relative to welfare maximization a convexity constraint that ensures only one point on the demand curve can be optimal is used

(1.10)

Slaughter and Fabrication

In the early 2000s evolution in the Mexican meat marketing system was apparent. The beef market was not only made up of the historical hot-carcass system that served many local markets and neighborhood meat shops, but a system that more closely resembles the U.S. was forming. This shift has been driven by economic growth and changing lifestyles (Peel 2001b). Modern supermarkets and restaurants that offer high quality federally inspected (TIF) beef are rapidly growing. To satisfy this demand, feedlots have teamed with packing plants to slaughter cattle with higher standards of hygiene and cold storage capability that allow for transport (Peel 2001b). Processing meat at a TIF plant costs 1.5 to 2 times as much as the traditional system and when shipping is also considered this type of meat, relative to price, is comparable to U.S. imports, which can be used as supplements (Peel 2001b; Peel 2005). In both marketing systems the majority of beef is marketed as carcasses or carcass units and there has been little differentiation of primal and sub primal values (Peel 2001b; Peel 2005). Recently, several large beef processing companies in Mexico have added fabrication capabilities to market meat in Spanish style quarters and to be sold in "full sets" which are essentially carcass equivalents (Peel, Mathews, and Johnson 2011). The addition of boxed beef allows different products (primal/subprimals) to be targeted to different markets and potentially opens up considerable additional beef value potential.

One of the potential markets is exports of specific products to the U.S. and other global markets. These markets were not available under the carcass based system that predominated only a few years ago. As a result, Mexican beef exports to the U.S. and other markets have grown rapidly since 2009 (Beef and veal: Annual and cumulative year-to-date U.S. trade).

TIF plants are encouraging increases in exports of Mexican beef and in 2010 Mexico was the fifth largest exporter of beef to the U.S. (Johnson 2012). Relative to beef exports, it is quite amazing how much progress has been made in roughly the last decade, but the history of TIF

plants and Mexico's capability of accessing the world market began many years ago. The TIF program began 60 years ago with 15 TIF plants but has grown to 365 plants in 27 states with additional 100 plants to become certified in 2012 (Johnson 2012). According to Johnson (2012), this increase in TIF plants has led to an increase in boxed beef. As boxed beef replaces carcasses, there are more primal and sub-primal cuts available that match U.S. preferences such as tenderloin, loin, sirloin, ribs, and short ribs; more trim is also available (Johnson 2012). Not only is the imported trim used in U.S. ground beef production, but boxed beef reinforces, as Peel (2005) notes, is a highly complementary relationship between Mexican preferences for Select products and end meats with U.S. preferences for choice middle meats.

To incorporate the new marketing systems the model is disaggregated into 4 slaughter regions. Table 1 lists the regions as designated in the model, the region names, and the production regions and feedlot centers in each region.

Table 1-4. Slaughter Regions

Region	Region Name	Production Regions Included	Feedlot Centers Included
S1	North	P1	F01, F02
S2	Central	P2, P3, P5	F03, F04, F06, F07
S3	South	P4, P6, P7	F05, F08
S4	Yucatan	P8, P9	F9, F10

The slaughter regions are then separated by TIF and municipal plus private slaughter. Table 2 shows the slaughter capacities for each slaughter type by region (Directorio Estatal y Nacional de Centros de Sacrificio).

Table 1-5. Slaughter Capacity by Region (Hd.)

Region	Region Name	TIF Capacity	Municipal+ Private Capacity
S1	North	910,440	554,280
S2	Central	1,716,960	1,484,136
S3	South	996,480	3,588,336
S4	Yucatan	350,400	459,444

Of the four cow types only Northern-Style cattle can be fed for northern-style (M1) meat and all of these cattle are slaughtered in TIF plants. Any type of cattle can be fed for Mexican-

Fed (M2) production and all of these cattle are slaughtered in TIF plants. Any type of cattle can be used for grass finished traditional (M3) meat and these cattle can be slaughtered either in a TIF or Municipal plant. A balance equation is used to transfer grass finished cattle to slaughter activities

(1.11)

Where

is grass-finished cattle; is TIF slaughter of M3 meat; is Municipal or Private slaughter of M3 meat

The following balance equation is used to transfer cull bulls to slaughter activities

(1.12)

Where

is cows; ; is bull culling; is cow: bull ratio; is TIF slaughter of M4 bull meat; is Municipal or Private slaughter of M4 bull meat

The following balance equation is used to transfer cull cows to slaughter activities

(1.13)

Where

is cows; is cow culling; is TIF slaughter of M4 cow meat; is Municipal or Private slaughter of M4 cow meat

The following balance equation is used to transfer cull dairy cows to slaughter activities

(1.13)

Where

is cull dairy cows; is TIF slaughter of M4 dairy meat; is Municipal or Private slaughter of M4 dairy meat

Next, a series of equations constrains slaughter activities by type of slaughter and region. The TIF slaughter equation is

(1.14)

Where

k=1…q, slaughter regions

is TIF slaughter capacity

The Municipal plus private slaughter equation is

(1.15)

Where

is municipal plus private slaughter capacity

Northern style, Semi-intensive, and Traditional types of cattle that are used to produce Mexican-fed meat are available for fabrication into boxed beef. The following system of balance equations is used. The first equation allows for Northern style, Semi-intensive, and Traditional cattle to be slaughtered and their respective carcass equivalents to be shipped to consumption regions, or they can be transferred to fabrication on a per head basis. Criollo type cattle are not fabricated; therefore, they are only slaughtered and marketed using the traditional carcass system.

(1.16)

Where

is Mexican fed cattle; is the adjusted carcass weight; is shipments of M2 meat; is fabrication .

Once cattle are transferred to fabrication, 25% of the adjusted carcass weight is considered middle meat, while 75% is considered end meat. Then, kilograms of middle and end meats can then be shipped in the domestic market or exported in the following equation

(1.17)

Where

is the percent of the carcass considered middle meat; is middle meat exports; is shipments of middle meat.

(1.18)

Where

is the percent of the carcass considered end meat; is shipments of end meat.

Esquilmos

Esquilmos are the crop residues left after harvest and are used to feed to livestock (Cunningham 2006). Esquilmos are considered a source of forage in the model and can be employed in diverse ways in the livestock ration. Most of the esquilmos used are from cereal grains but other crops are also important (Munoz).Esquilmos are abundant in many parts of Mexico and can reach a maximum of 20% total energy (González Muñoz 2008).

To account for this widely used source of forage, the Sistema de Información Agroalimentaria de Consulta (SIACON) database was used to obtain the average number of harvested hectares as well as yields of each crop by state and management practice from 2006 to 2010. The crops considered are the most widely used. They include: corn, sorghum, beans, sugar cane, and others, an aggregation of less important crops (González Muñoz 2008).The methods of estimating the forage yields from the grain yield data by crop are as follows.

Corn and Sorghum

To estimate how much corn residue is available using grain yield data a series of equations is used. Joe Lauer (2006) explains the relationship between grain yield and silage yield for corn as

(1.19)

Where

is grain yield (bu/A); is silage yield (T/A)

Solving for gives

(1.20)

Another equation is used to estimate the grain equivalent per ton contained in silage. The grain equivalent is estimated by

(1.21)

Where

is grain equivalent (bu/t)

The grain equivalent is then subtracted from the estimated silage yield to obtain the amount of corn stover and converted to an as fed basis assuming that corn stover is 80% dry matter.

Beans

To estimate the amount of bean residue that is left after harvest the calculation method was used (Hickman and Schoenberger 1989). This method assumes 45 pounds of residue per bushel harvested. This amount is then converted to an as fed basis assuming that soybean hay is 89% dry matter. The same method is used to estimate the amount of "other" residue.

Sugar cane

According to McLaren (2009), after sugar cane is processed the remaining fiber, called bagasse, may be used for animal feed. SIACON reports the yield per hectare as the weight of

cane harvested per hectare and because sugar cane is not always harvested on an annual basis, the yield may not necessarily be yield per hectare per year. Therefore, the yield is adjusted by 0.92 to arrive at the weight per area per year (McLaren 2009). To estimate the amount of bagasse, or residue, available for animal feed it is assumed that bagasse contributes to 25% of sugar cane production (Betancur and Pereira Jr. 2009).The sugar cane residue is then converted to an as fed basis assuming that sugar cane is 91.5% dry matter.

Considering a 1,000 pound cow as one animal unit (AU) and assuming that a cow requires 25 pounds of esquilmos per day, the AU of feed per hectare can be calculated. Table 3 shows the AU yields by crop, management practice, and production region.

Table 1-6. Animal Units of Esquilmos Available per Hectare

	Dry Land				Irrigated			
Region	Maiz	Beans	Cane	Other	Maiz	Beans	Cane	Other
P1NO	4.1	0.6	0	0.7	13.8	1.3	10.2	5.3
P2NE	5.8	1.0	12.5	0.7	8.8	1.4	18.7	3.4
P3ME	4.0	0.5	12.3	2.0	10.1	1.5	20.5	2.4
P4CO	6.8	0.5	15.9	2.0	12.1	1.3	24.1	5.7
P5PA	5.8	1.0	18.5	1.0	18.5	1.4	22.6	4.3
P6SS	5.3	0.6	16.6	1.3	6.7	0.7	18.4	3.3
P7VE	5.5	0.6	16.2	2.8	9.1	0.8	21.9	7.3
P8SU	5.4	0.6	16.0	2.0	7.5	0.7	22.7	3.9
P9YU	4.6	1.0	13.0	2.8	7.0	2.2	17.2	4.2

Trade

To allow for more flexibility in live cattle and meat exports, as well as slaughter cattle and meat imports, the GANAMEX model has been expanded to include seven border ports in the transportation section of GANAMEX compared to the earlier version of the model, which assumed a single border port (Animal and Animal Product Import/Export). The border ports included are listed in table 4.

Table 1-7. Border Ports

Region	Representative City
B1	Calexico, CA
B2	Nogales, AZ
B3	Santa Teresa, NM
B4	Presidio, TX
B5	Eagle Pass, TX
B6	Laredo, TX
B7	Hidalgo, TX

This added structure allows for GANAMEX users to not only track product flows to and from Mexico but allows for scenario analysis of the potential impacts of closing certain ports due to health or trade policies or changes in demand for Mexican beef products in different regions of the U.S.. In addition, this detail sets the framework for future integration with U.S. programming models.

Transportation

Scalars for the cost of hauling live animals and meat, as well as the load sizes for live animals and meat are used to calculate transportation costs. Distances between each production region, feedlot center, slaughter region, consumption region, and border port are calculated using the directions feature in Google Maps which uses data from Google and the Instituto Nacional de Estadística Y Geographía (INEGI).

Benchmark

For the benchmark model, GANAMEX is configured to represent the Mexican cattle and beef industry in 2010. Data from the 2007 Censo Agrícola, Ganadero y Forestal, the 2010 Censo de Población y Vivienda, the Servicio de Información Agroalimentaria y Pesquera (SIAP), the Foreign Agricultural Service (FAS), and the Sistema Nacional de Información e Integación de Mercados (SNIIM) are used. 2010 regional population totals as well as a beef consumption profiles are used in the consumption section of the model. Relevant production, transportation, slaughter, and other cost parameters are updated to 2010 levels. The regional dairy herd, which is

considered exogenous to the beef industry, is updated to 2010 levels, and costs are associated with using dairy cows in beef production. Trade values are also updated to 2010 levels.

Benchmark Results

The benchmark model allows for the movement of calves and feeder cattle within Mexico and also allows these cattle to be exported from any production region. Also, fabrication and boxed beef capability is utilized in the benchmark. In the Benchmark results, the abbreviation Mt. will be used for metric tons.

Objective Function

The objective function maximizes consumer surplus minus cost. In the Benchmark model this value is $46,489,436,376.19.

Equilibrium

The equilibrium price is 39.141 pesos per kilogram, wholesale equivalent, while the equilibrium quantity is 15.744 kilograms per capita.

Cow Production

In the North (P1), Northeast (P2), and Central Mesa (P3) regions Northern style cattle are produced. Semi-intensive cattle production is more widespread with cattle being produced in the Cordillera (P4), Pacific Coast (P5), Veracruz (P7), and the South (P8) regions. Traditional cattle are produced in the South Sierra Madre (P6), and Yucatan (P9) regions. Criollo cattle are produced in the North (P1) and Veracruz (P7) regions. As shown in Table 1-8, total cow production is about 5.6 million head which is consistent with the Census of Agriculture (Censo Agrícola, Ganadero y Forestal 2007).

Table 1-8. Cow Production by Region and Type (Hd.)

Region	V1NORT	V2SEMI	V3TRAD	V4CRIO	Totals
P1NO	640,870			85,714	726,585
P2NE	333,573				333,573
P3ME	483,642				483,642
P4CO		183,023			183,023
P5PA		520,988			520,988
P6SS			426,685		426,685
P7VE		451,902		331,412	783,314
P8SU		1,523,049			1,523,049
P9YU			601,500		601,500
Totals	**1,458,085**	**2,678,961**	**1,028,185**	**417,127**	**5,582,358**

Forage Use

In the Benchmark model, all of the non-irrigated pasture in each region is used while 19.6 percent of the more expensive irrigated pasture is used in the Northeast (P2) region.

Esquilmos Use

The Pacific Coast (P5) region uses all of the available dry land crop esquilmos while the Southern Sierra Madre (P6) and the South (P8) regions use 100 percent of available dry land corn esquilmos. When irrigated crops are considered, the Pacific Coast (P5) region uses 36 percent, the Southern Sierra Madre (P6) region uses 80 percent, and the South (P8) region uses 78 percent of all available esquilmos. These regions combined use of dry land corn esquilmos totals 30 percent of available corn esquilmos in Mexico.

Stocker Production

Intensive Stocker Production

195,579 head of Northern style cattle are used for intensive stocker production in the Northeast (P2) region.

Extensive Stocker Production

Northern style cows are used for extensive stocker production in the North (P1), and Central Mesa (P3) regions. Semi-intensive cattle are stocked in the Cordillera (P4), Pacific Coast (P5), Veracruz (P7), and South regions. Traditional cattle contribute 54.51 percent of total extensive stocker production and these cattle are fairly evenly dispersed throughout each

production region with the Cordillera (P4) region producing the most stockers. Criollo cattle are produced in the North (P1) and Veracruz (P7) regions and contribute only 2.35 percent, the least amount of the cow types, to total stocker production. Table 1-9 explains the extensive stocker production in the Benchmark.

Table 1-9. Extensive Stocker Production by Region and Type (Hd.)

Region	V1NORT	V2SEMI	V3TRAD	V4CRIO	Totals
P1NO	375,752		382,334	17,492	775,578
P2NE			14,496		14,496
P3ME	105,383		135,901		241,284
P4CO		87,177	607,023		694,199
P5PA		248,155	94,224		342,379
P6SS			342,134		342,134
P7VE		215,248	248,245	78,318	541,811
P8SU		725,452	159,457		884,909
P9YU			236,647		236,647
Totals	**481,135**	**1,276,031**	**2,220,460**	**95,810**	**4,073,437**

Live Shipments

Calves

Calves from each cow type may be shipped among the production regions. In the benchmark model no calf shipments occur.

Stockers

41,350 head of semi-intensive calves and 175,815 head of traditional calves are shipped from Veracruz (P7) to the South Sierra Madre (P6) region. Stocker shipments from Veracruz total 217,165 head. 459,008 head of semi-intensive and 153,078 head of traditional calves are shipped from the South (P8) region to the South Sierra Madre region. Stocker shipments from the South total 612,086 head. Shipments of semi-intensive stockers total 500,358 while shipments of traditional stockers total 328,893 and 829,251is total stocker shipments.

Feeders

86 percent of feeder cattle shipments are Traditional style cattle and they are sourced by feedlots from every production region except for the South Sierra Madre (P6) and South (P8)

regions. 36 percent of feeders are shipped to the Cordillera (F05) feedlot region. Table 1-10 details feeder cattle shipments in the Benchmark model.

Table 1-10. Feeder Shipments by Region and Type (Hd.)

Source Region	VINORT	V2SEMI	V3TRAD	V4CRIO	Destination Region	Total
P1NO			162,500 *68,064		F02 *F03	230,564
P2NE	68,772		13,916		F03	82,688
P3ME	101,168		60,580		F03	161,748
P4CO			425,000		F05	425,000
P5PA			90,455		F04	90,455
P6SS						
P7VE			62,500		F08	62,500
P8SU						
P9YU			125,000		F10	125,000
Totals	**169,940**		**1,008,015**			**1,177,955**

Note: If two or more shipments are made from a single production region * denotes the feedlot region that corresponds with that shipment

Live Exports

Of the four cow types only Northern style cattle are allowed for export. The only region to export steer calves is the Central Mesa (P3) region and no heifer calves in any region are exported. The North (P1) and Northeast (P2) regions export feeder steers. The North region also exports feeder heifers along with the maximum number of rodeo steers that is limited to 15,000 head. When compared to data from the Foreign Agricultural Service's Global Agricultural Trade System (Global Agricultural Trade System 2013), calf exports are severely understated with steer calf exports accounting for only 25 percent of 2010 levels while feeder steer exports account for 84 percent of 2010 levels. The Benchmark model finds the export of feeder heifers is slightly overstated. Overall, total live exports in 2010 were about 1.2 million head (Global Agricultural Trade System 2013). Table 1-11 shows live cattle exports as found by the Benchmark model.

Table 1-11. Live Cattle Exports by Region and Type (Hd.)

Region	Steer Calves	Heifer Calves	Feeder Steers	Feeder Heifers	Rodeo Steers	Totals
P1NO			224,305	131,171	15,000	370,475
P2NE			116,751			
P3ME	169,275					
P4CO						
P5PA						
P6SS						
P7VE						
P8SU						
P9YU						
Totals	**169,275**		**341,055**	**131,171**	**15,000**	**656,500**

Live Imports

Slaughter cows may be imported from the U.S. and are constrained to 1,000 head. All available slaughter cows are imported from Laredo Texas to the Northeast (P2) region.

Finishing

Fed for Northern style (M1) meat

No cattle are finished for Northern Style meat (M1) in the benchmark model.

Fed for Mexican Fed (M2) meat

In the Benchmark model Traditional style (V3) cattle make up the majority of cattle that are finished for Mexican fed (M2) meat in feedlot regions 1-5 and the Veracruz (F08) and Yucatan (F10) regions; while 169,940 Northern style (V1) cattle being finished in the Northeast region. In the regions where cattle are finished for Mexican fed meat, all available feedlot capacity is utilized except for the Northwest (F01) and Pacific Coast (F04) regions. As seen in Table 1-12, about 60 percent of national feedlot capacity is used in the Benchmark model.

Table 1-12. Mexican Fed (M2) Production by Region and Type (Hd.)

Region	VINORT	V2SEMI	V3TRAD	V4CRIO	Total	Percent of Feedlot Capacity
F01NW			20,000		20,000	4.57
F02LA			162,500		162,500	100.00
F03NE	169,940		142,560		312,500	100.00
F04PA			90,455		90,455	28.95
F05CO			425,000		425,000	100.00
F06HA						
F07ME						
F08VE			62,500		62,500	100.00
F09TB						
F10YU			12,500		12,500	100.00
Totals	**169,940**		**915,515**		**1,085,455**	**57.85**

Supplemented Grass-Finished Production

63,285 head of traditional (V3) cattle are used for the Semi-intensive grass finished production of Mexican Fed (M2) meat in the Yucatan (P9) region.

Grass-Finished Production

Mostly Semi-Intensive (V2) and Traditional (V3) style cattle are used for grass-finished production in the benchmark. Criollo (V4) style cattle make up less than four percent of the total. The South Sierra Madre (P6) region produces the majority of grass-finished cattle coming from a fairly equal share of Semi-intensive (V2) and Traditional (V3) style cattle. Most of these grass-finished cattle are slaughtered in local or municipal plants with the only TIF slaughter occurring in the Veracruz (P7) and Yucatan (P9) regions. Table 1-13 details the location and type of slaughter activity occurring in the Benchmark.

Table 1-13. Traditional (M3) Grass Finished Cattle Production and Slaughter by Region and Type (Hd.)

Region	VINORT	V2SEMI	V3TRAD	V4CRIO	TIF Production	Local Production	Total Production
P1NO			136,476	16,793		153,269	153,269
P2NE							
P3ME			69,885			69,885	69,885
P4CO		83,689	157,742			241,431	241,431
P5PA		238,228				238,228	238,228
P6SS		500,358	657,342			1,157,700	1,157,700
P7VE		165,288		75,185	89,821	150,652	240,474
P8SU		237,426				237,426	237,426
P9YU			151,397		32,989	118,408	151,397
Totals		**1,224,990**	**1,172,841**	**91,978**	**122,810**	**2,366,999**	**2,489,810**

Cull Cow (M4) Production

About half a million head of the cow herd is culled resulting in Cull (M4) meat. Semi-intensive (V2) cows contribute the most to cull meat production because Semi-intensive cows make up the largest share of the cow herd. Slaughter of cull cows is roughly split between slaughter in TIF and local plants as found in Table 1-14.

Table 1-14. Cull Cow Use by Region, Type, and Slaughter Type (Hd.)

Region	TIF Cull Cows				Local Cull Cows				TIF Total	Local Total	TIF + Local Total
	V1	V2	V3	V4	V1	V2	V3	V4			
P1NO	58,625			6,000	5,462				64,625	5,462	70,087
P2NE					33,357					33,357	33,357
P3ME					48,364					48,364	48,364
P4CO						18,302				18,302	18,302
P5PA						52,099				52,099	52,099
P6SS							34,135			34,135	34,135
P7VE		45,190		23,199					68,389		68,389
P8SU		152,305							152,305		152,305
P9YU			2,053				46,068		2,053	46,068	48,121
Totals	**58,625**	**197,495**	**2,053**	**29,199**	**87,183**	**70,401**	**80,203**		**287,372**	**237,787**	**525,159**

Dairy Cow Use

Cull dairy cows are used in every production region in the benchmark and all but 3.2 percent of these cows are slaughtered in local or municipal plants. Table 1-15 details the regions where cull dairy cows are utilized. Because the dairy cow herd is exogenous to GANAMEX, if cull dairy cows are not used, costs are not associated to their use and cull dairy meat is not available for consumption.

Table 1-15. Dairy Cow Use by Region, Type, and Slaughter Type (Hd.)

Region	TIF Dairy Cows	Local Dairy Cows	Totals
P1NO		125,170	125,170
P2NE		4,746	4,746
P3ME		44,492	44,492
P4CO		198,730	198,730
P5PA		30,848	30,848
P6SS		51,017	51,017
P7VE	18,995	62,276	81,271
P8SU		52,204	52,204
P9YU		5,339	5,339
Totals	**18,995**	**574,822**	**593,817**

Slaughter

TIF and municipal slaughter occurs in each slaughter region in the benchmark. The Central (S2) and South (S3) regions combine to slaughter a total of 3,624,348 head, the majority of national slaughter. TIF plants are operating at about 40 percent of yearly capacity while the municipal and private plants operate at just over half of yearly capacity. These figures tend to agree with SAGARPA data with national TIF utilization at 47 percent and national Municipal and Private capacity at 55 percent (Directorio Estatal y Nacional de Centros de Sacrificio). Table 1-16 shows slaughter in each region by type.

Table 1-16. Slaughter by Region and Type (Hd.)

Region	TIF	Municipal and Private	Total	Percent of TIF Capacity	Percent of Municipal and Private Capacity
S1	247,125	283,901	531,026	27.14%	51.22%
S2	402,955	642,443	1,045,399	23.47%	43.29%
S3	664,706	1,914,244	2,578,949	66.71%	53.35%
S4	263,131	459,444	722,575	75.09%	100.00%
Total	**1,577,917**	**3,300,032**	**4,877,949**	**39.70%**	**54.22%**

Meat Shipments

Every production region except for the Central Mesa (P3), Cordillera (P4), Pacific Coast (P5), and South Sierra Madre (P6) regions ship Traditional (M3) and Cull (V4) meat to the Northeast (C3), Tapatio (C4), and Central (C5) regions. The Central region receives 58.7 percent of total domestic shipments. Detailed meat shipments are found in Table 1-17.

Table 1-17. Meat Shipments by Region and Type (Mt.)

Source Region	M1NORT	M3TRAD	V4CULL	Destination Region	Total
P1NO			13,675 *831	C3 *C4	14,506
P2NE			229	C3	229
P3ME					
P4CO					
P5PA					
P6SS					
P7VE		17,258	*20,758	C3, *C5	38,016
P8SU			33,391	C5	33,391
P9YU		6,480	429	C5	6,909
Totals		**23,738**	**69,313**		**93,051**

Note: If two or more shipments are made from a single production region * denotes the consumption region that corresponds with that shipment

Mexican Fed (M2) Meat Shipments

Because Mexican fed (M2) meat is available for fabrication, from which the fabricated middle meat cuts may be shipped in the domestic market or exported, the result is Mexican fed end meat cuts that can be shipped throughout the domestic market. In the Benchmark, exports of Mexican fed meat occur and the end meats associated with each fabricated carcass are shipped to the Northwest (C1), Tapatio (C4), Central (C5), Gulf (C6), and Yucatan (C7) consumption regions. Table 1-18 shows domestic meat shipments.

Table 1-18. Mexican-Fed M2 Meat Shipments by Region and Type (Mt.)

Source Region	M2FED	M2SFED	M2MID	M2END	M2SMID	M2SEND	Destination Region	Total
F01NW				33,521			C1	33,521
F02LA				14,741			C4	28,611
				*13,870			*C5	
F03NE				58,344			C5	13,870
F04PA				15,927			C4	58,344
F05CO				74,830			C4	15,927
F06HA								74,830
F07ME								
F08VE				11,004			C6	
F09TB						9,170	C7	11,004
F10YU				2,201			C7	9,170
Totals				**224,438**		**9,170**		**247,478**

Note: If two or more shipments are made from a single feedlot region * denotes the consumption region that corresponds with that shipment

Meat Exports

In the Benchmark, 67,870 metric tons of Mexican fed (M2) meat is exported. The Northeast (F03) and Cordillera (F05) regions account for 65 percent of total exports. As found in Table 1-19, the Tabasco (F09) region is the only feedlot region to export Semi-Intensive Mexican fed (M2) meat that is finished on grass with supplementation. Total exports in 2010 were roughly 50 to 70 percent of the Benchmark result (Global Agricultural Trade System 2013; Beef and veal: Annual and cumulative year-to-date U.S. trade).

Table 1-19. Meat Exports by Region and Type (Mt.)

Region	Mexican Fed	Semi-Intensive Mexican Fed	Totals
F01NW	1,174		1,174
F02LA	9,537		9,537
F03NE	19,448		19,448
F04PA	5,309		5,309
F05CO	24,943		24,943
F06HA			
F07ME			
F08VE	3,668		3,668
F09TB		3,057	3,057
F10YU	734		734
Totals	**64,813**	**3,057**	**67,870**

Meat Imports

In the Benchmark meat may be imported from any border port to any consumption region. In GANAMEX, Northern style (M1) meat is equivalent to high quality U.S. fed beef and Mexican fed (M2) meat is lesser quality relative to U.S. standards, but is the preferred meat type in Mexico (Cunningham 2006). With both meat types imports are used to supplement domestic production.

Northern Style (M1) Meat Imports

Every consumption region imports Northern style (M1) meat, with the Central (C5) region importing 36 percent of total imports from Hidalgo Texas. Table 1-20 shows Northern style meat imports.

Table 1-20. Northern Style M1 Meat Imports by Region (Mt.)

Source Region	M1NORT	Destination Region	Total
BP1			
BP2	31,361	C1	31,361
BP3			
BP4	29,163	C2	29,163
BP5			
BP6	47,940	C3	67,899
	*19,959	*C4	
	79,602	C5	
BP7	*8,088	*C6	93,375
	**5,685	**C7	
Totals	**221,798**		**221,798**

Note: If two or more shipments are made from a single border port * denotes the consumption region that corresponds with that shipment

Mexican Fed (M2) Meat Imports

70.4 percent of total meat imports come from Mexican fed (M2) meat and every region except for the Tapatio (C4) and Yucatan (C7) regions import Mexican fed meat. Table 1-21 shows the amount of Mexican fed (M2) meat that is imported. Overall, combined meat imports in 2010 account for about 23-30 percent of combined meat imports in the Benchmark model.

Table 1-21. Mexican Fed M2 Meat Imports by Region (Mt.)

Source Region	M2FED	Destination Region	Total
BP1			
BP2	92,307	C1	92,307
BP3			
BP4	54,007	C2	54,007
BP5			
BP6	103,550	C3	103,550
BP7	254,152	C5	277,118
	*22,966	*C6	
Totals	**526,982**		**526,982**

Note: If two or more shipments are made from a single border port * denotes the consumption region that corresponds with that shipment

Consumption

Total domestic consumption is 1,768,600 metric tons in the Benchmark and the Central (C5) region consumes 45 percent of all beef consumed in Mexico. Table 1-22 describes total domestic meat consumption in detail.

Table 1-22. Total Meat Consumption by Region and Type (Mt.)

Region	M1NOR	M2FED	M3TRAD	M4CULL	Total
C1NW	31,362	95,828	19,166	27,877	174,233
C2NC	29,164	54,007	10,801	14,042	108,013
C3NE	47,940	103,550	17,258	23,011	191,758
C4TP	19,959	105,498	108,349	51,323	285,130
C5CE	79,602	326,366	246,765	143,283	796,015
C6GO	8,088	33,971	82,500	37,206	161,765
C7YU	5,685	11,371	23,258	11,371	51,685
Totals	**221,799**	**730,590**	**508,098**	**308,113**	**1,768,600**

Mexican fed (M2) meat is the most widely consumed of the four meat types in the Benchmark with total per capita consumption of 6.5 kilograms per year. Yearly per capita consumption is highest in the Northeast (C3) region and lowest in the Yucatan (C7) region. In the Central (C5) region, which includes Mexico City, per capita consumption is 15.5 kilograms per year. Because of the inclusion of Mexico City, which represents the diversity of Mexican consumption because of the variance in preferences and incomes, the Central region is representative of Mexican beef consumption. Table 1-23 shows yearly per capita meat consumption by region.

Table 1-23. Per Capita Meat Consumption by Region and Type (Kg.)

Region	M1NOR	M2FED	M3TRAD	M4CULL	Total
C1NW	3.40	10.39	2.08	3.02	18.89
C2NC	4.89	9.05	1.81	2.35	18.11
C3NE	4.92	10.63	1.77	2.36	19.68
C4TP	1.16	6.12	6.28	2.98	16.53
C5CE	1.55	6.35	4.80	2.79	15.49
C6GO	0.55	2.31	5.62	2.54	11.02
C7YU	1.39	2.77	5.67	2.77	12.60
Totals	**1.97**	**6.50**	**4.52**	**2.74**	**15.74**

Because only Northern style cattle are allowed for live export, all northern style cattle in the benchmark are exported. A percentage of the northern style cows that are used to produce those cattle are culled and used for cull (M4) meat in the domestic market. All Northern style (M1) meat consumed is imported while 72 percent of all Mexican fed (M2) meat is imported. Total imports account for 42 percent of total beef consumption in Mexico as seen in Table 1-24.

Table 1-24. Meat Consumption from Imports by Region and Type (Mt.)

Region	Percent of Northern style (M1)	Percent of Mexican Fed (M2)	Percent of Total Meat Consumption
C1NW	100.00%	96.33%	70.98%
C2NC	100.00%	100.00%	77.00%
C3NE	100.00%	100.00%	79.00%
C4TP	100.00%	0.00%	7.00%
C5CE	100.00%	77.87%	41.93%
C6GO	100.00%	67.61%	19.20%
C7YU	100.00%	0.00%	11.00%
Totals	**100.00%**	**72.13%**	**42.34%**

Conclusions

The Benchmark model allows for the domestic shipment and exports of live cattle and fabrication and export of Mexican fed (M2) meat. The welfare maximizing price is 39.141 pesos per kilogram, wholesale equivalent, and the equilibrium quantity is 15.744 kilograms per capita. Cattle production occurs in each production region and nationwide, each cow type is produced. The total cow herd is 5,582,358. 656,500 head of cattle are exported of which, 20 percent are heifers. 58 percent of feedlot capacity and 54 percent of slaughter capacity is used. 67,870 metric tons of Mexican fed (M2) meat is exported and imports make up 42 percent of domestic consumption.

Validation

Linear programming is a normative methodology and therefore does not permit objective validation. There are no statistical tests to determine the "fit" of a linear programming model but rather validation relies heavily on subjective considerations of the overall reasonableness of model solutions. This necessarily puts a large burden on the researcher to balance results relative to the intuition, logic and experience of the modeler and at the same time not prelude the model's ability to generate results that may be unexpected or unanticipated. The linearity of the model combined with optimization tends to make linear programming models exaggerate solutions for specific variables. The extent to which the comprehensive structure and robustness of the model limits this tendency is one measure of the validity of the model. Wherever possible the

GANAMEX model is validated against actual data for the benchmark period. However, it is seldom possible to simultaneously balance all solution variables and thus the model output must be subjectively evaluated in the context of the overall solution set and model response to sensitivity tests. Normatively specified model parameters may be adjusted judiciously as a part of the validation process to evaluate the sensitivity of the model and to improve the robustness of model solutions.

Linear programming models represent the long run tendency of markets. During validation, the model was unable to simultaneously solve for levels of meat and cattle exports observed in 2010. The Benchmark model tends to favor one activity or the other when adjusting the relevant parameters, such as heifer retention rates or U.S.-Mexico meat price relationships. These results suggest that during 2010, under GANAMAEX assumptions, the Mexican cattle and beef industry was operating at unsustainable levels, perhaps due to drought-forced herd liquidation.

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ESSAY II

ESTIMATED IMPACTS OF THE INTRODUCTION OF A BOXED BEEF SYSTEM IN MEXICO

Introduction

Until recent years Mexican beef has been marketed solely on a carcass basis but that began to change drastically with the evolution of the ability to market boxed beef (Essay 1). As a result, Mexico has emerged as a significant source of beef for the United States. According to the Economic Research Service Mexico is now the fourth largest exporter of beef and veal to the United States as well as being the second largest importer of U.S. beef (USDA 2012). With such a strong trade relationship, technological developments in Mexico have effects beyond the border and it is not yet understood how much boxed beef Mexico could potentially export to the United States.

How does the development of boxed beef in Mexico affect the value of Mexican beef relative to the United States and the beef trade between Mexico and the United States? Peel says, "There seems to be little doubt that Mexico will continue to have a large and important cattle and beef industry but there are many questions about exactly what the industry will look like in the future" (Peel 2001b). A new market is emerging; do you know where the new equilibrium will be?

Objectives

The overall objective of this research is to determine how the development of boxed beef in Mexico affects the value of Mexican beef relative to the United States and the beef trade between Mexico and the United States.

The specific objectives are:

a. Estimate the impacts of a scenario in which the boxed beef system in Mexico is limited to determine:
    i. The change in the domestic wholesale price of Mexican beef
    ii. The change in domestic consumption of Mexican beef
    iii. The change in Mexican import and export quantities of beef relative to the United States

Conceptual Framework

Consider beef that is sold in one of two ways, whole carcass, or boxed primal cuts which include: rib, chuck, round, loin, brisket, short plate, and flank. We can further classify these primal cuts into higher valued middle meats, loin and rib, and lower valued end meats, chuck and round. A retailer who is only interested in selling end meats will not be willing to pay as much for an entire carcass, even though it also includes higher valued middle meat cuts. Conversely, a retailer only interested in selling middle cuts will discount the carcass because it contains end cuts as well. The result is the total value of a carcass being worth less than what it would be if broken into differentiated products. Boxed beef maximizes the value extracted from a carcass resulting in higher prices received by producers and because specific cuts can be shipped wherever the greatest demand is, a product that matches consumer preferences. As a result of product differentiation, as boxed beef production in Mexico increases the Mexican beef industry will become more competitive and have a greater ability to react to market signals and experience

more efficient product flows. Furthermore, product differentiation, resulting from a boxed beef system, allows Mexico to capitalize the relationship shared with the U.S. (Essay 1).

Methods and Procedures

To accomplish the objectives of this research the GANAMEX model is used. Essay 2 gives a background of the GANAMEX model and details recent updates. A benchmark with a base year of 2010 and boxed beef capability is estimated. Then, a scenario where there is no boxed beef capability is estimated. The model will move along a segment of the demand curve and reach a new equilibrium that is associated with the highest net welfare. This new equilibrium price and quantity reveals how the value of Mexican beef has changed relative to the benchmark. The following section includes a complete documentation of the national and regional details and associated values for the net welfare maximizing benchmark model. The scenario in the following chapter is compared to the values from the benchmark model.

Results: Analysis of the Transition to a Boxed Beef System

Scenario One

In scenario one, the ability to fabricate Mexican fed (M2) meat into middle and end cuts is eliminated. The result is that M2 meat is marketed and shipped using the historic carcass based system. The structure of GANAMEX remains intact and the Mexican fed cattle that are slaughtered are shipped as carcasses just as local Traditional (M3) and Cull (M4) meat is. The results are given as percentage changes relative to the benchmark. As in the Benchmark these results indicate long-run equilibrium under the model specification and parameter assumptions. Results are not meant to forecast values but to show possible impacts on what and where production takes place as well as and trade flows within Mexico and across the border.

Scenario one shows the impacts of the ability to fabricate carcasses into boxed beef. The benchmark model allows for fabrication and export of meat, which was occurring in 2010.Thus, the result is what the Mexican cattle and beef market would have looked like if the ability to

fabricate carcasses into boxed beef did not exist in 2010. In other words, by eliminating fabrication capabilities one finds the impacts of the shift to a boxed beef system in Mexico.

The results are shown in a series of tables where a negative sign denotes a negative change from the benchmark. Also, where there is a positive value in scenario one relative to a zero in the benchmark the actual value in scenario one is listed.

Objective Function

The objective function maximizes consumer surplus minus cost. In scenario one this value is $46,186,159,295.60, a reduction of $303,277,081.59, or 0.65 percent from the benchmark model. This reduction is equivalent to a decrease of $2.70 per consumer.

Equilibrium

The equilibrium price is 39.73 pesos per kilogram, wholesale equivalent, an increase 0.59 pesos or 1.5 percent increase from the benchmark model. The equilibrium quantity is 15.468 kilograms, a decrease of 0.28 kilograms or 1.75 percent from the benchmark model.

Cow Production

The total number of cows produced in Scenario one is 6,232,121, an increase of 11.64 percent from the Benchmark. When no fabrication activity is allowed, production shifts away from Semi-intensive (V2) cow production and drastically toward the less expensive, less productive Criollo (V4) style cows in the Veracruz (P7) and South (P8) regions as seen in Table 2-1. Also, Northern style (V1) cow production moves out of the Northeast (P2) and Central Mesa (P3) regions and into the North (P1) region with overall Northern style (V1) cow production increasing.

Table 2-1. Cow production by Region and Type (Hd.)*

Region	V1NORT	V2SEMI	V3TRAD	V4CRIO	Totals
P1NO	29.54%			0.00%	26.06%
P2NE	-15.15%				-15.15%
P3ME	-7.95%				-7.95%
P4CO		-60.41%			-31.46%
P5PA		-7.86%			-7.86%
P6SS			67.04%		67.04%
P7VE		-100.00%		176.19%	16.85%
P8SU		-100.00%		1,760,966*	15.62%
P9YU			-1.34%		-1.34%
Totals	**10.51%**	**-79.38%**	**27.04%**	**562.15%**	**11.64%**

* Indicates the level in the scenario compared to zero in the Benchmark

Forage Use

In Scenario one all available non irrigated forage is being used. 87.4 percent of the irrigated pasture is used in the North (P1) region, an increase from zero in the Benchmark model. Irrigated forage use decreased by 3 percent in the Northeast (P2) region by 3 percent. Overall, 13.98 percent more irrigated pasture is used in Scenario one.

Esquilmos Use

Like in the Benchmark model, the Pacific Coast (P5) region utilizes all available dryland esquilmos while the South Sierra Madre (P6) and South (P8) regions use all available dryland corn esquilmos.

Intensive Stocker Production

486,765 head of Northern style (V1) cattle are used for stocker production in the North (P1) region compared to zero in the Benchmark. 165,956 Northern style (V1) cattle are used in the Northeast (P2) region, a 15.15 percent decrease from the Benchmark.

Extensive Stocker Production

All extensive stocking of Northern style (V1) cattle in the North (P1) region is substituted for intensive stocking and the Cordillera (P4) region begins extensive stocker production. The Veracruz (P7) and South (P8) regions drive the overall decrease in Semi-intensive (V2) extensive stocker production and the South (P8) region produces 416,144 head of Criollo (V4) style

extensive stockers. This result continues the tendency of shifting production to Criollo (V4) cows. Table 2-2 details the changes in extensive stocker production.

Table 2-2. Extensive Stocker Production by Region and Type (Hd.)*

Region	V1NORT	V2SEMI	V3TRAD	V4CRIO	Totals
P1NO	-100.00%		0.00%	0.00%	-48.45%
P2NE			0.00%		0.00%
P3ME	-7.95%		0.00%		-3.47%
P4CO	11,545*	-60.41%	0.00%		-5.92%
P5PA		-7.86%	0.00%		-5.69%
P6SS			30.63%		30.63%
P7VE		-100.00%	0.00%	176.19%	-14.26%
P8SU		-100.00%	0.00%	416,144*	-34.95%
P9YU			-1.25%		-1.25%
Totals	**-77.44%**	**-79.38%**	**4.59%**	**578.36%**	**-17.91%**

* Indicates the level in the scenario compared to zero in the Benchmark

Live Shipments

Calves

As in the Benchmark, no calves are shipped in Scenario one.

Stockers

In Scenario one no Semi-intensive (V2) stockers are shipped from the Veracruz (P7) region or the South (P8) region, a decrease of 100 percent. The North (P1) region ships 39,715 Traditional (V3) style stockers and 16,793 Criollo style stockers to the Northeast (P2) region, an increase of 100 percent for the North (P1) region. Like the Benchmark model, the Veracruz (P7) region ships 175,815 Traditional style stockers to the South Sierra Madre (P6) region, while the South (P8) region ships 153,078 Traditional style stockers to the South Sierra Madre (P6) region. 42,289 Criollo style stockers are shipped from the South (P8) to the South Sierra Madre (P6) region, an increase of 100 percent.

Feeders

Nationwide feeder shipments decrease in all but the Veracruz (P7) region where shipments are unchanged at 62,500 head to the Veracruz (F08) feedlot region. As found in Table 2-3, the Northeast (F03) region stops receiving feeder cattle shipments.

Table 2-3. Feeder Shipments by Region and Type (Hd.)

Source Region	VINORT	V2SEMI	V3TRAD	V4CRIO	Destination Region	Total
P1NO			0.00% *-78.05%		F02 *F03	-23.04%
P2NE	-100.00%				#F03	-100.00%
P3ME	-100.00%		-100.00%		#F03	-100.00%
P4CO			-37.87%		F05	-37.87%
P5PA			-100.00%			-100.00%
P6SS						
P7VE			0.00%		F08	0.00%
P8SU						
P9YU			-90.00%		F10	-90.00%
Totals	**-100.00%**		**-48.76%**			**-56.15%**

Note: If two or more shipments are made from a single production region * denotes the feedlot region that corresponds with that shipment
Designates regions no longer receiving shipments

Live Exports

Of the four cow types only Northern (V1) style cattle are allowed for export. Overall, live exports increase relative to the Benchmark. The Northeast (P2), Central Mesa (P3), and Cordillera (P4) regions begin exporting feeder heifers which contributes the most to the overall increase in live exports of 915,270 in scenario one. A detailed description of live cattle exports can be found in Table 2-4.

Table 2-4. Live Cattle Exports by Region and Type (Hd.)*

Region	Steer Calves	Heifer Calves	Feeder Steers	Feeder Heifers	Rodeo Steers	Totals
P1NO			29.54%	37.36%	0.00%	32.43%
P2NE			-15.15%	61,423*		37.46%
P3ME	-7.95%			98,021*		49.95%
P4CO	18,545*			11,667*		30,211*
P5PA						
P6SS						
P7VE						
P8SU						
P9YU						
Totals	**3.00%**		**14.24%**	**167.81%**	**0.00%**	**41.70%**

* Indicates the level in the scenario compared to zero in the Benchmark

Live Imports

As in the Benchmark model, 1,000 slaughter cows are imported by the Northeast (P2) region from Laredo Texas.

Finishing

Fed for Northern Style (M1) meat

Like the Benchmark model there is no Northern style M1 meat production in scenario one.

Fed for Mexican Fed (M2) Meat

The Northeast (F03), Pacific Coast (F04), and Cordillera (F05) regions substantially decrease the number Traditional (V3) cattle that are fed for Mexican fed (M2) meat. As in the Benchmark model no Semi-intensive (V2) or Criollo (V4) style cattle are finished for Mexican fed (M2) meat but the use of Northern (V1) style cattle is eliminated compared to the benchmark. The changes in the percent of feedlot capacity utilized can be found in Table 2-5.

Table 2-5. Mexican Fed (M2) Production by Region and Type (Hd.)

Region	VINORT	V2SEMI	V3TRAD	V4CRIO	Total	Change in Percent of Capacity
F01NW			0.00%		0.00%	0.00%
F02LA			0.00%		0.00%	0.00%
F03NE	-100.00%		-89.52%		-95.22%	-95.22%
F04PA			-100.00%		-100.00%	-100.00%
F05CO			-37.87%		-37.87%	-37.87%
F06HA						
F07ME						
F08VE			0.00%		0.00%	0.00%
F09TB						
F10YU			0.00%		0.00%	0.00%
Totals	**-100.00%**		**-41.40%**		**-50.57%**	**-50.57%**

Supplemented Grass-Finished Production

42,635 Traditional style cattle are finished using the Semi-intensive system in the Yucatan (P9) region, a decrease of 32.63 percent from the Benchmark model.

Grass-Finished Production

Grass finished cattle production shifts from the use of Semi-intensive (V2) cattle to Traditional (V3) and more importantly Criollo (V4) style cattle. Overall, grass finishing slightly

increases and slaughter of these cattle in TIF plants increase while total local slaughter remains essentially unchanged. A detailed description of the grass finished production of Traditional (M3) meat is found in table 2-6.

Table 2-6. Traditional (M3) Grass Finished Cattle Production and Slaughter by Region and Type (Hd.)*

Region	VINORT	V2SEMI	V3TRAD	V4CRIO	TIF Production	Local Production	Total Production
P1NO			9.83%	-100.00%		-2.21%	-2.21%
P2NE			53,631.16*	16,792.78*			70,423.95*
P3ME			86.68%			86.68%	86.68%
P4CO		-60.41%	102.02%			45.72%	45.72%
P5PA		-7.86%	90,455*			30.11%	30.11%
P6SS		-100.00%	15.30%	42,289.09		-30.88%	-30.88%
P7VE		-100.00%		176.19%	-80.70%	26.33%	-13.65%
P8SU		-100.00%		357,209.22*	116,755*	1.28%	50.45%
P9YU			11.77%		60.30%	-1.75%	11.77%
Totals		-79.38%	42.41%	578.36%	52.24%	-0.30%	2.29%

* Indicates the level in the scenario compared to zero in the Benchmark

Cull Cow (M4) Production

Because of the dramatic increase in the production of Criollo (V4) cows, the use of Criollo (V4) cull cows increases. On the other hand, with the decrease in Semi-intensive cow production, the slaughter of these cull cows ceases in TIF plants and decreases by about 30 percent in local plants. Table 2-7 shows that overall the use of cull cows remains virtually unchanged compared to the Benchmark results and the shares that TIF and local plants contribute to total slaughter are about the same as well.

Table 2-7. Cull Cow Use by Region, Type, and Slaughter Type (Hd.)*

Region	TIF Cull Cows				Local Cull Cows				TIF Total	Local Total	TIF + Local Total
	V1	V2	V3	V4	V1	V2	V3	V4			
P1NO	37.82%			0.00%	-59.30%				34.31%	-59.30%	27.01%
P2NE					-15.15%					-15.15%	-15.15%
P3ME					-7.96%					-7.96%	-7.96%
P4CO					5,299*	-60.40%				-31.45%	-31.45%
P5PA						-7.86%				-7.86%	-7.86%
P6SS							67.04%			67.04%	67.04%
P7VE		-100.00%		176.19%			45,115*		-6.31%	45,115*	59.66%
P8SU		-100.00%		123,268*					-19.07%		-19.07%
P9YU			15.00%				-100.00%		15.00%	-100.00%	-95.09%
Totals	**37.82%**	**-100.00%**	**15.00%**	**562.15%**	**-7.85%**	**-21.52%**	**27.35%**		**-3.78%**	**-0.02%**	**-2.08%**

* Indicates the level in the scenario compared to zero in the Benchmark

Dairy

The overall use of cull dairy cows remains unchanged in Scenario one. In the Veracruz (P7) region 10.57 percent more cows are slaughtered in TIF plants while 3.22 percent less are slaughtered locally. Total slaughter of cull dairy cows does not change from the Benchmark in the Veracruz (P7) region.

Slaughter

Utilization of TIF slaughter capacity decreases by 32.59 percent in Scenario one. Local slaughter is virtually unchanged and as Table 2-8 shows, total slaughter decreases by about 11 percent.

Table 2-8. Slaughter by Region and Type (Hd.)

Region	TIF	Municipal and Private	Total	Change in Percent of TIF Capacity	Change in Percent of Municipal and Private Capacity
S1	8.97%	-2.33%	2.93%	8.97%	-2.33%
S2	-96.29%	29.54%	-18.97%	-96.29%	29.54%
S3	-35.46%	-10.05%	-16.60%	-35.46%	-10.05%
S4	33.17%	0.00%	12.08%	33.17%	0.00%
Total	**-32.59%**	**-0.28%**	**-10.73%**	**-32.59%**	**-0.28%**

Meat Shipments

When fabrication capability is unavailable, 50 percent more Traditional (M3) meat is shipped domestically, while relative to the Benchmark, slightly less Cull (M4) meat is shipped. Total domestic shipments increased from the Benchmark model. Table 2-10 shows that shipments to the Central (C5) region increase the most of the consumption regions receiving domestic shipments.

Table 2-9. Meat Shipments by Region and Type (Mt.)

Source Region	M1NORT	M3TRAD	V4CULL	Destination Region	Total
P1NO			5.43% *515.76%	C3 *C4	34.67%
P2NE			0.00%	C3	0.00%
P3ME					
P4CO					
P5PA					
P6SS					
P7VE		-81.10%	*-4.89%	C3, * C5	-39.49%
P8SU		#21,969.00	-25.58%	C5	40.22%
P9YU		60.29%	15.15%	C5	57.49%
Totals		**50.05%**	**-6.44%**		**7.97%**

Note: If two or more shipments are made from a single production region * denotes the consumption region that corresponds with that shipment
# Indicates the level in the scenario compared to zero in the Benchmark

M2 Meat Shipments

When fabrication of Semi-intensive (M2) meat cannot occur, end meat cuts are considered part of the Semi-intensive (M2) carcass and are shipped on that basis. Compared to the Benchmark, 125,953 metric tons of domestic Semi-intensive (M2) meat shipments occur but when the decrease of Semi-intensive (M2) end meat shipments are considered, total domestic shipments decrease by 42.56 percent. Table 2-11 shows shipments from the feedlot region to consumption regions.

Table 2-10. Mexican-Fed M2 Meat Shipments by Region and Type (Mt.)*

Source Region	M2FED	M2SFED	M2MID	M2END	M2SMID	M2SEND	Destination Region	Total
F01NW	4,695			-100.00%			C1	-85.99%
F02LA	*38,149			-100.00%			C4	33.34%
				-100.00%			#C5	-100.00%
F03NE	3,507			-100.00%			C4, #C5	-93.99%
F04PA				-100.00%			#C4	-100.00%
F05CO	*61,994			-100.00%			C4	-17.15%
F06HA								
F07ME								
F08VE	*14,673						C6	33.34%
F09TB		*8,237					C7	-10.17%
F10YU	*2,935						C7	33.35%
Totals	*125,953	*8,237						-42.56%

* Indicates the level in the scenario compared to zero in the Benchmark

Designates regions no longer receiving shipments

Meat Exports

Because scenario one does not include fabrication activities the impact of no boxed beef capability results in no exports of meat.

Meat Imports

Northern Style M1 Meat Imports

In GANAMEX a consumption profile is specified where a percentage of total consumption comes from each of the four meat types. In Scenario one the net welfare maximizing equilibrium quantity is 1.75 percent less than the Benchmark. Therefore, when all Northern style (M1) meat is imported, imports of Northern style (M1) meat decreases by 1.75 percent in the regions that are importing.

Table 2-11. Northern Style (M1) Meat Imports by Region (Mt.)

Source Region	M1NORT	Destination Region	Total
BP1			
BP2	-1.75%	C1	-1.75%
BP3			
BP4	-1.75%	C2	-1.75%
BP5			
BP6	-1.75%	C3	-1.75%
	*-1.75%	*C4	
	-1.75%	C5	
BP7	*-1.74%	*C6	-1.75%
	**-1.74%	**C7	
Totals	**-1.75%**		**-1.75%**

Note: If two or more shipments are made from a single production region * denotes the consumption region that corresponds with that shipment

Mexican Fed M2 Meat Imports

The Central (C5) region's imports of Mexican fed (M2) meat increases by 26.16 percent, enough to offset the minor decreases in the Northwest (C1), North Central (C2), Northeast (C3), and the 18.56 percent decrease in the Gulf (C6) region. Imports by region are listed in Table 2-13.

Table 2-12. Mexican Fed (M2) Meat Imports by Region (Mt.)

Source Region	M2FED	Destination Region	Total
BP1			
BP2	-3.09%	C1	-3.09%
BP3			
BP4	-1.75%	C2	-1.75%
BP5			
BP6	-1.75%	C3	-1.75%
BP7	26.16% *-18.56%	C5 *C6	22.46%
Totals	**10.74%**		**10.74%**

Note: If two or more shipments are made from a single production region * denotes the consumption region that corresponds with that shipment

Consumption

Total and per capita consumption of each meat type decreases by 1.75 percent in each consumption region in Scenario one.

All of the Northern style (M1) meat that is consumed in the Mexican market is imported in both the Benchmark and Scenario one. Table 2-13 shows that the largest increase in Mexican fed (M2) imports occur in the Central (C5) region and imports decrease in the Northwest (C1) and Gulf (C6) regions.

Table 2-13. Meat Consumption from Imports by Region and Type (Mt.)

Region	Change in Percent of M1NOR	Change in Percent of M2FED	Change in Percent of Total from Imports
C1NW	0.00%	-1.37%	-1.02%
C2NC	0.00%	0.00%	0.00%
C3NE	0.00%	0.00%	0.00%
C4TP	0.00%		0.00%
C5CE	0.00%	28.42%	21.63%
C6GO	0.00%	-17.12%	-12.67%
C7YU	0.00%		0.00%
Totals	**0.00%**	**12.72%**	**8.94%**

Conclusions

The ability to market boxed beef not only increases net welfare but also per capita consumption and the price of beef decreases.

In Scenario one the ability to fabricate Mexican Fed (M2) meat into boxed beef that is available for export is eliminated. The cow herd is 6,232,121 head, an increase of 11.64 percent from the Benchmark. Dramatic increases in Criollo (V4) cow production exemplifies the tendency for the Mexican cattle industry to shift towards more productive cows raised in more intensive systems when access to meat export markets exist.

When meat exports are non-existent, fed cattle are less valuable resulting in live cattle exports increasing by 42 percent. Feedlot finishing of Mexican fed (M2) meat decreases by half and grass finished cattle production increases minimally.

Imports of Mexican fed (M2) meat increases 11 percent in scenario one. In the Benchmark model, when a carcass is fabricated the end meats are used to meet domestic consumption requirements. When no fabrication occurs, and fewer cattle are finished in the feedlot, imports supplement domestic Mexican fed (M2) production and the total share of consumption from imports increases by 9 percent.

Overall, the addition of fabrication technologies begins to move Mexico from a cow-calf industry built on live cattle exports and U.S. meat imports to an industry that produces higher quality cows and is more feedlot oriented. This research implies in the long run, the U.S. can expect the availability of calves from Mexico to decrease. As the gap between comparative advantages in beef production and beef prices narrows, the trade relationship between the U.S. and Mexico will become more sensitive to arbitrage opportunities in the world beef market and geographical product flows.

Limitations

One must be careful when analyzing meat export values in the Benchmark model. Exports of Mexican fed (M2) meat in GANAMEX are considered to be exported to the U.S. while in reality Japan and Russia are important trade partners as well. About 52 percent of total Mexican beef exports went to the U.S. in 2010 (Secretaria de Economia). Just as Benchmark

results show tendencies rather than forecasted values, the optimal export quantities considered to go to the U.S. should be carefully considered.

Further Work

If and when more detailed Mexican beef trade data becomes available other important trade partners for Mexico could be included in the model to increase the usefulness of GANAMEX in analyzing world beef market conditions and scenarios. Also, linkages to Mexican crop models such as Mejia's 2012 CROPMEX model would allow for the cattle industry to react to varying resource availability as crop prices alter feeding strategies and land use. Finally, marrying GANAMEX with other North American models would allow researchers to view the U.S., Mexican, and Canadian cattle and beef industries as they are, a single North American market.

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