MEXICAN MEAT DEMAND ANALYSIS:

A POST-NAFTA DEMAND

SYSTEMS APPROACH

by

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CHAPTER I

INTRODUCTION

As the result of a more global and technologically advanced world, transporting massive amounts of goods over large distances in a short amount of time is now expected on a daily basis. Accordingly, it has become more efficient for countries to increase international trade, especially in the agricultural sector where most goods are perishable. There are many examples of this, such as the General Agreement on Tariffs and Trade (GATT); the GATT was signed in 1947 to promote free trade between members by reducing tariffs and other barriers to international trade, and eliminating discriminatory treatment in international commerce. Eventually, it was replaced by the WTO in 1994. Countries in close proximity to each other are forming free trade areas to encourage growth and increase each other's market size by favoring exclusive exchanges. The European Economic Community, now known as the European Union, started in 1957 and is the world's leader in enacting trade barrier reductions and economic integration. The U.S. and Canada began to follow suit by forming the Canada-U.S. Trade Agreement (CUSTA) which grew to become the North American Free Trade Agreement (NAFTA) by incorporating Mexico in 1994.

It was unclear if all markets would be affected in the same way by NAFTA, if at all. After arduous discussions and vigorous debates between the participating governments, it was decided that the tariff changes would be immediate for some goods and gradually implemented for others. Fall-back options, if necessary, would exist so neither economy would suffer from the stress of an immediate market shock.

To aid the smooth implementation of NAFTA's policy, it was decided that the existing tariffs for each country would slowly be decreased by predetermined percentages every year. As a result, tariff rate quotas were enacted with the intent of gradually decreasing them to finally attain completely free trade in North America by 2008. Many types of meat are already freely traded between Mexico and the U.S., but there are some types, such as chicken legs, that are still restricted.

Though trade between Mexico and the U.S. hasn't become completely free yet, remarkable growth in certain market sectors has resulted. One of the most affected agricultural sectors is the meat industry. Overall, Mexico has gone from a small-key player in the pre-1994 U.S. export market to the 2nd largest importer of U.S. agricultural products in 2004 (USDA), and NAFTA may be credited as a major catalyst for this change. The allowance of free trade removed the hurdles that impeded business between the two countries. As a result, Mexico has provided a growing meat market for the U.S., leading to an increase in sales and profits for the U.S. meat industry. This coincides with a noticeable increase in Mexican per capita GDP that has created large changes in meat consumption patterns, implying that Mexicans can now afford to buy more meat and thus per capita meat consumption has grown.

Since the induction of NAFTA, which now governs poultry trade between the U.S. and Mexico, U.S. poultry exports to Mexico have increased significantly. Mexico is now the third largest importer of U.S. poultry, and is forecasted to be ranked second within the next few years (Hahn et. al. 2005). The free trade agreement has enabled the U.S. to expand its poultry industry through lower tariffs, and thus increased Mexican trade and demand for poultry in Mexico. Mexico began lowering tariffs in 1994 and has since slowly implemented the new policy leading to free trade. Free trade is agreed to be accomplished by 2008.

Beef is the largest meat import for Mexico, and in 2003, Mexico imported $604 million worth of beef from the U.S. Overall, Mexico has been the second largest export market for U.S. beef, consuming about five percent of all U.S. exports of beef in 2003. But, with the discovery of Bovine Spongiform Encephalopathy (BSE) in the U.S. in 2003, U.S. beef exports were banned. Mexico was the first country to re-open its border, and has now established itself as the largest importer of U.S. beef. Since the induction of NAFTA though, the demand for beef has been unstable. Irregularities, such as the peso devaluation in 1995, have hit the market hard. Despite this, the outlook on Mexican beef demand is favorable, as it is expected to continue to grow in conjunction with the Mexican economy (Hahn, et al.).

The Mexican pork market has also grown steadily in recent years. Mexico is now the second largest importer of U.S. pork (USDA), with pork exported to Mexico in 2005 valued at $363.492 million (FAS). The demand for pork is expected to continue rising in the future as the Mexican economy grows. These are all signs that the effects of NAFTA have been beneficial to the U.S. meat export market, but the full effects of NAFTA on the bilateral meat trade are yet to be seen (Hahn, et al.).

Mexican consumption has risen for all three types of meat since 1970. As can be seen in Table 1.1 and Figure 1.1, beef represented the largest portion of meat consumed in Mexico in 1970 but pork became the most consumed meat from 1975-1985. On the other hand, chicken has experienced the strongest and most consistent growth, maintaining the largest share of meat since 1995. Chicken is considered a cheap alternative to beef and pork, and has accordingly experienced a jump in consumption after the economic crises of 1982 and 1995. There hasn't been an economic crisis in Mexico since 1995, which has helped meat consumption to become more balanced over time.

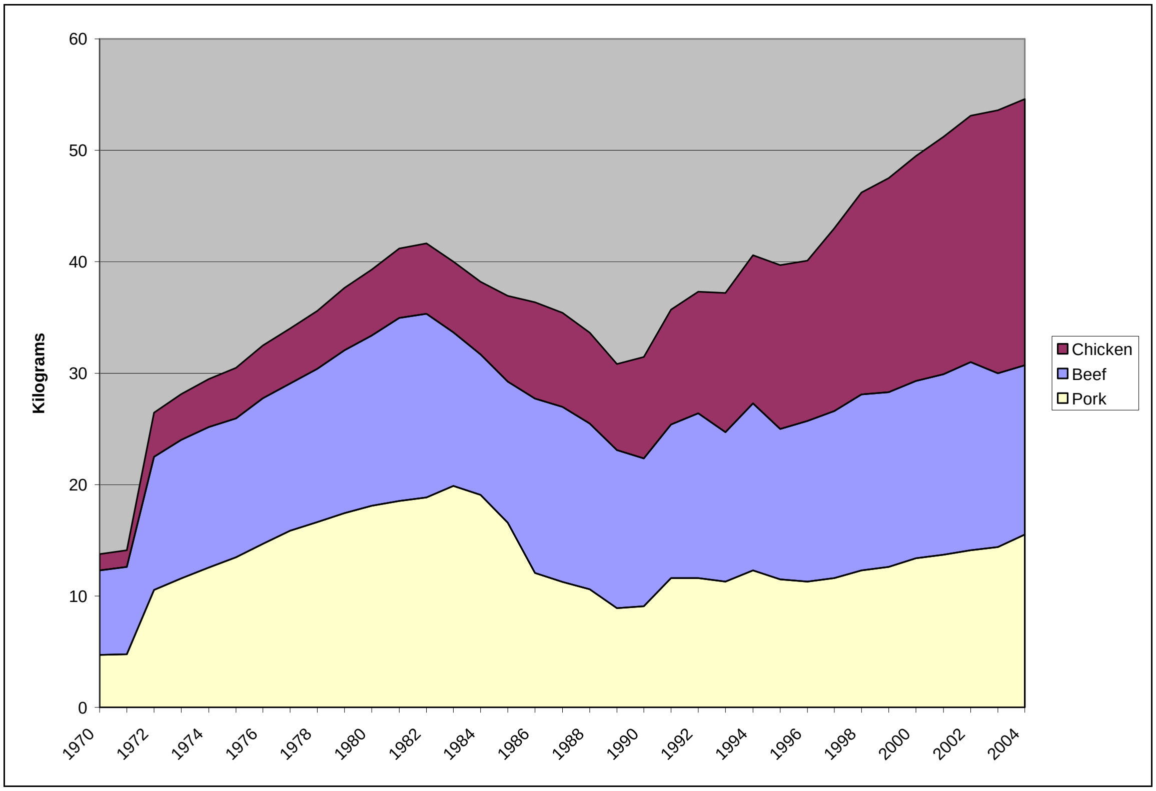

Figure 1.1 Mexican Per Capita Meat Consumption: 1970-2004
Sources: Carlos Salinas de Gortari & SAGARPA

Table 1.1 Mexico: Shares of Meat Consumption

Year	Chicken	Beef	Pork
	%	%	%
1970	10.60	55.19	34.20
1971	10.55	55.52	33.92
1972	14.97	45.20	39.83
1973	14.61	44.19	41.20
1974	14.59	42.72	42.69
1975	14.89	40.90	44.21
1976	14.56	40.27	45.17
1977	14.53	38.84	46.63
1978	14.58	38.69	46.73
1979	14.80	38.92	46.28
1980	15.02	38.92	46.07
1981	15.17	39.84	44.99
1982	15.15	39.62	45.23
1983	15.83	34.45	49.73
1984	17.09	33.00	49.91
1985	20.84	34.24	44.91
1986	23.71	43.11	33.18
1987	23.86	44.35	31.79
1988	24.29	44.22	31.49
1989	25.11	45.99	28.90
1990	28.93	42.19	28.87
1991	28.85	38.66	32.49
1992	29.22	39.68	31.10
1993	33.60	36.02	30.38
1994	32.76	36.95	30.30
1995	37.03	34.01	28.97
1996	35.91	35.91	28.18
1997	38.14	34.88	26.98
1998	39.18	34.20	26.62
1999	40.42	33.05	26.53
2000	40.81	32.12	27.07
2001	41.60	31.64	26.76
2002	41.62	31.83	26.55
2003	44.03	29.10	26.87
2004	43.77	27.84	28.39

Sources: 1970-1990: Carlos Salinas de Gortari. *Quinto Informe de Gobierno*. November 1993.
1991-2004: SAGARPA

Real prices for all three types of meat have decreased in Mexico since 1970, but beef has experienced the least price decline relative to the two other types of meat. Accordingly, consumption shares of beef have decreased the most in the past 35 years. Chicken, on the other hand, has experienced the largest relative price decline and has experienced the most growth in consumption shares. However, due to falling prices over the years, total meat expenditures have decreased despite rising consumption. This is shown in Figure 1.2. and Figure 1.3.

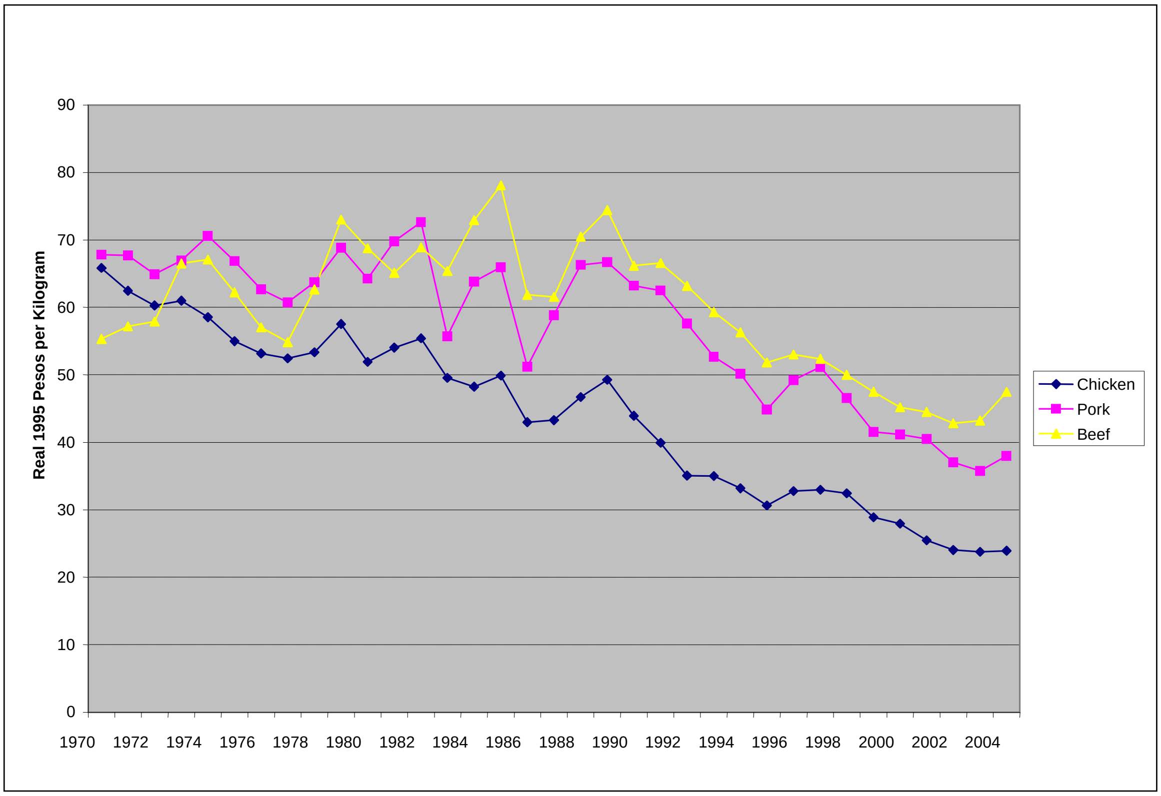

Figure 1.2 Trends in Real Mexican Consumer Meat Prices
Source: Bank of Mexico

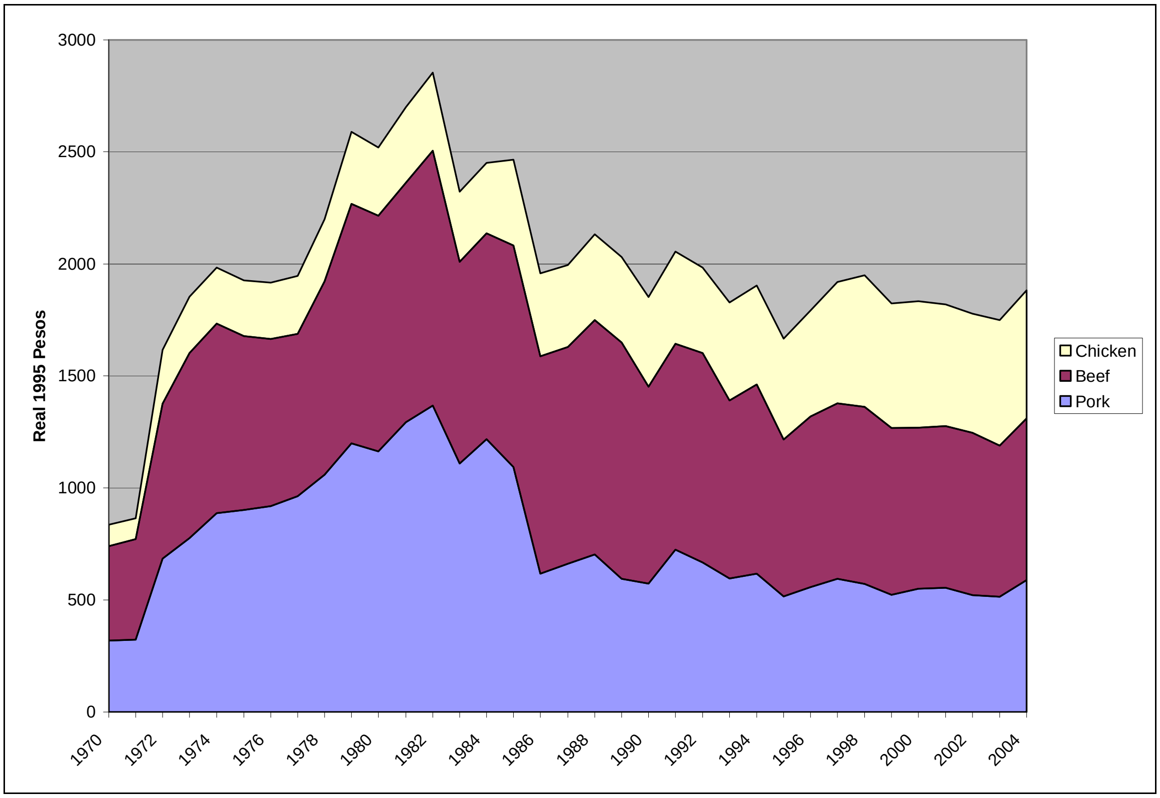

Figure 1.3 Mexico: Real Per Capita Meat Expenditures

Source: Bank of Mexico, SAGARPA

Expenditure shares are more closely reflecting price changes of each type of meat since NAFTA in 1994, as can be seen in Figure 1.3 and Table 1.2. That is, as the price of a meat has fallen in relation to the other two main types of meat, the consumption share for that meat has generally risen.

Table 1.2 Mexico: Real Per Capita Meat Expenditures

Year	Chicken	Beef	Pork	Total
	Real 1995 Pesos			
1970	96.13	420.49	319.33	835.96
1971	93.07	448.22	324.15	865.44
1972	238.74	692.38	684.18	1615.30
1973	250.74	826.51	775.88	1853.13
1974	251.75	844.54	887.94	1984.23
1975	249.62	775.82	901.14	1926.58
1976	251.52	746.23	919.21	1916.96
1977	259.17	724.36	963.15	1946.68
1978	276.90	862.80	1059.59	2199.29
1979	320.40	1069.40	1198.94	2588.74
1980	306.32	1051.30	1162.99	2520.61
1981	337.73	1068.49	1293.20	2699.42
1982	349.70	1136.72	1367.98	2854.40
1983	313.59	901.03	1108.32	2322.94
1984	314.95	919.40	1216.82	2451.17
1985	384.06	987.88	1094.29	2466.23
1986	370.43	969.28	617.29	1956.99
1987	365.79	966.83	662.17	1994.80
1988	381.65	1048.01	701.88	2131.54
1989	381.21	1055.24	594.35	2030.80
1990	399.86	877.92	573.83	1851.61
1991	411.20	918.48	725.03	2054.71
1992	382.20	934.92	667.99	1985.10
1993	437.54	794.38	595.51	1827.43
1994	441.19	844.69	617.05	1902.93
1995	450.57	699.83	515.95	1666.36
1996	472.06	763.67	555.95	1791.68
1997	540.89	785.26	593.57	1919.72
1998	586.97	790.01	572.24	1949.22
1999	554.61	745.48	522.99	1823.08
2000	564.21	718.58	551.40	1834.18
2001	542.43	721.04	554.86	1818.33
2002	531.70	723.84	522.31	1777.85
2003	561.37	674.23	514.84	1750.44
2004	571.61	721.46	588.90	1881.97

Source: Bank of Mexico, SAGARPA

Since the Mexican demands for beef, pork, and poultry have increased, the Mexican demand for U.S. meat imports has risen accordingly to satiate the market. On the other hand, Mexican production of these meats has also increased with the growth in meat consumption. Whether or not the demand for meat will continue to increase in the future will, in effect, determine how much meat Mexico will produce to meet its consumption demand. The end results may help to forecast the import demand Mexico will have for U.S. grains to feed their livestock.

Forecasting future trends of the Mexican domestic and import markets for specific meats, livestock, and feed grains requires an accurate understanding of the nature and magnitude of the parameters of Mexican meat demand, including the strong interrelationship between the differing types of meat. The purpose of this paper is to expand the knowledge of demand for meat in Mexico by estimating the current demand parameters. Econometric techniques are also employed to determine whether or not NAFTA has significantly altered preferences for meat in Mexico since 1995.

Problem Statement

The meat and poultry industries form the largest segment of the U.S. agricultural economy. As one of the largest importers of these meats after NAFTA, Mexico may have a significant impact on the future of the U.S. meat industry. A clear understanding of the Mexican demand parameters of meat is critical to forecast U.S. export trends and, in conjunction with livestock and grain models, may aid in the simulation of alternative scenarios in integrated North American meat systems.

Objectives

The main objective of this study is to estimate the parameters of Mexican demand for beef, pork, and chicken using the most recent data available and the most appropriate demand system methodology. Updated cross-price and expenditure elasticities are estimated to support a more accurate analysis of the effects of prices and income on Mexican demand for meat. A test for structural change is included to examine if a change in preferences exists for meat in Mexico after the NAFTA implementation.

Specifically, the purpose of this paper is to:

- Test for the most appropriate demand system for meat demand in Mexico using a statistically acceptable method;
- Estimate the parameters of demand in Mexico for beef, pork, and chicken;
- Calculate the respective Marshallian and Hicksian price and expenditure elasticities;
- Test for a structural change in meat demand since NAFTA.

CHAPTER II

LITERATURE REVIEW

The purpose of this chapter is to explain how this study is related to previous literature and how it will add to the general body of knowledge. Previous literature reviewed in this chapter is separated into three groups: (1) studies focusing on the Mexican economy; (2) studies performed on the validity of demand system models; and (3) related publications using demand system analyses to estimate food demand parameters in Mexico.

Structure of the Mexican Economy

Mexico's economy has experienced many changes in the past 35 years, including severe peso devaluations during the 1982 and 1994-1995 economic crises. Meat consumption has differed over the years from varying causes as well. Market factors, such as increased meat advertising, growing numbers of fast food franchises, and exposure to new cuts and meat products, are believed to have led to changing meat preferences, as well as availability of higher quality meat and growing health concerns. These changes have been supported over the years by recent rising income levels throughout the Mexican workforce.

Mexican employers are demanding higher educated and skilled workers, and are paying higher wages in return. Despite higher wages overall, Melendez (2001) finds that wage inequality has risen in Mexico since 1984, when trade liberalization in Mexico began. This disparity is attributed to the increasing demand for educated and skilled workers and the reflective decline of uneducated workers' incomes. It is found that the real hourly earnings of workers with college or high school educations grew 9.2% from 1984 to 1994, while they dropped between 9.0 and 19.1% for uneducated workers. After the 1995 economic crisis, the wages of those skilled workers increased 8.2% during 1996-1998 but did not move for unskilled labor. Another study by Airola (2001) affirms these trends as well, and attributes the change to privatization and domestic reform. Along with these wage changes in Mexico, average real per capita GDP has steadily increased almost 12% from 1994-2004 (Bank of Mexico). Both studies find that agriculture is declining in Mexico though, coinciding with increasing imports of agricultural products.

Though the effects of the 1994-1995 crisis were the most severe experienced by Mexico since the 1930s, Kose, Meredith, and Towe (2004) partly attribute Mexico's rapid recovery to policies set into place by NAFTA. Real GDP and investment levels recovered to pre-crisis levels faster than ever in its history. NAFTA is also attributed with stabilizing Mexico's economy over time. An example of this is portrayed when inflation peaked at 52% in late 1995, a rate well below inflation observed during other financial crises in Mexico. Inflation then steadily decreased through the rest of the decade. Mexico was even able to enjoy the lowest and most stable inflation rates in its history by 2003. The study also shows that a statistically significant structural break occurred in 1993 in both the level and the share of foreign direct investment in GDP in Mexico.

Demand System Modeling

Deaton and Muellbauer (1980) suggest the superiority of the Almost Ideal Demand System (AIDS) in an article that introduces the AIDS model, explains it in detail, and compares it to the Rotterdam model and translog model. The AIDS model possesses most of the properties desirable in demand analysis. It is capable of explaining most of the variance of the commodity expenditures but is inconsistent with a rational consumer decision hypothesis unless a time trend is allowed for omitted variables. Use of demand systems allows for simultaneous estimation of a set of demands that are closely related, on which the theoretical restrictions of consumer theory are able to be applied. More specifics are discussed later in the conceptual framework section.

The AIDS model is also approximated linearly, forming the linearized almost ideal demand system (LA/AIDS). The LA/AIDS is applied by Taljaard, Alemu, and van Schalkwyk (2003) in a study that estimates demand for meat in South Africa from 1970-2000. This research shows that the LA/AIDS model can be useful to compare elasticities from country to country because of coinciding time periods and techniques. The model concludes that beef and mutton are still considered luxury items in South Africa while chicken remains a normal good.

Another study by Burton and Young (1996) measures the impact of BSE on the demand for beef in Great Britain using a dynamic AIDS model of meat demand, including beef, lamb, pork, and poultry. Media coverage and advertising of BSE in Great Britain was included as an argument of the demand function, measured by the number of newspaper articles from 1989-1993 that mention BSE. Using the AIDS model, it is easy to see that there has been a significant impact of beef demand in Great Britain since the BSE scare and exactly how much demand has consequently shifted. All meats are found to be net substitutes and the demand for pork and poultry appears to slightly increase at the expense of beef and lamb over time. The model results show a significant 4.5% long-term reduction in the beef market by the end of 1993 due to the impact of BSE.

A study done by Fraser (2000) examines the demand relationships for meat in the United Kingdom. The Generalized Maximum Entropy (GME) method is used to eliminate the effects of severe collinearity among variables that are often found in demand estimations, making them unreliable. Using this approach, cross-price, own-price, and expenditure elasticity estimates are formed that are reliable and consistent. They concluded that this method may be more accurate to use to estimate an AIDS model than the traditional maximum-likelihood (ML) techniques.

The Rotterdam Model, developed by Barten and Theil (1964), is a directly specified system that doesn't assume a particular utility function and allows the classical theoretical demand restrictions to be imposed. By utilizing the Rotterdam model, Capps et al. (1994) is able to estimate meat demand parameters in the Pacific Rim region. Though elasticities for beef, pork, and chicken differ amongst the individual Pacific Rim markets, beef and pork are found to be net substitutes in all the Pacific Rim countries. Time-series data provides results for trends, and use of the Rotterdam model enables simultaneous-equation bias to be accounted for. A test for separability between fish and other meats determined that fish should not be included in the model with beef, pork, and chicken. This conclusion supports the results of other studies that agree that marine products are separable from other meats. An approach to test for endogeneity of total expenditures is also presented and explained. By augmenting the demand system with a regression of the total expenditure variable on the set of exogenous variables: beef, pork, chicken, and marine products, it is found that endogeneity exists and is accounted for in the model. This method is thus useful for both testing and correcting the problem of endogeneity of expenditures, if endogeneity is found to be present.

Eales and Unnevehr (1993) perform simultaneity and structural change tests on U.S. meat demand. Through the use of an inverse almost ideal demand system, they find that endogeneity exists for prices and quantities demanded. No significant structural change is found with the IAIDS model for the mid-1970s using an intercept binary variable with a Wald test. Though structural change exists when the AIDS model is run, it disappears when the model is corrected for endogeneity.

Davis (1997) presents a methodological review of models and the logic of hypothesis testing for structural change. Three main diagnoses are found for explaining a change in meat market demand: 1) a change in preferences, 2) measurement or technique refinement, 3) more generalized demand structures. Through Davis' framework, it is concluded that structural change can never be tested because it violates the laws of logic. The main dilemma presented implies that competing theories can always be generated by altering a subset of the assumptions that are considered problematic. Davis suggests that pursuing more general demand structures will be more informative than refining empirical techniques. Davis' findings suggest the need for more evolved modeling, as discussed in the following chapters.

Food Demand Parameter Estimates in Mexico

Malaga and Williams (1999) use the Barten approach in an application to demand systems of fresh vegetables in the U.S. and Mexico. The study finds that the Rotterdam model is most appropriate, when compared to the AIDS model, and should be used when estimating demand systems for vegetables in the U.S. and Mexico. A weak separability test suggests that onions don't belong in the demand system as a salad vegetable. Expenditure elasticities are above one for all vegetables except tomatoes, implying that most vegetables are still considered luxury goods in Mexico.

Garcia Vega (1995) performed the most comprehensive study on Mexico's meat demand using time-series data. He examines the demand for meat in an integrated dynamic analysis that includes the livestock, meat, and feed grain industries. As fish is not considered part of the Mexican consumer meat budget due to seasonal consumption habits, their meat analysis includes beef, pork, and chicken in Mexico. His study doesn't focus solely on the demand of meat, but includes the Mexican livestock and feed grain industries as well. The integration of the model components creates some data convergence problems that may have produced skewed results. The LA/AIDS, Rotterdam, and single equation models are used to examine the meat sector in Mexico. However, no test is performed to determine which model specification is the most appropriate. The SUR Rotterdam expenditure elasticities derived show that pork is a luxury good and that beef and chicken are normal goods. The Hicksian own-price elasticities for beef and pork are expected to be negative, but show up positive. Significance of Hicksian elasticities is also a large problem, without a single elasticity found to be significant at the 5% level. Marshallian and Hicksian elasticities show unexpected meat complementarities. One Marshallian chicken/beef and both Hicksian chicken/beef elasticities show to be complementary meats.

The study also discusses the impact on Mexican meat demand since the 1970s, when the demand for meat switched from mainly beef consumption to pork. The Mexican hog industry growth spurred this change in the 1970s and 1980s until 1982, when the Mexican economic crisis occurred. When this happened, chicken became the most demanded meat as a result of cheap prices. The economic crisis of 1994-1995 also caused the model results in the study to fail to provide evidence of structural changes in Mexican meat demand. It does succeed, however, to show a positive correlation between per capita consumption of beef and pork in Mexico and per capita income. Garcia Vega's study includes data only up to 1991, and has not been updated to include the effects of NAFTA's implementation. Since 1994, there has been a rise in per capita GDP and corresponding changes in Mexican meat consumption patterns. Hence, an updated study using recent data to provide an in-depth analysis of the Mexican meat demand system is needed.

Williams and Garcia Vega (1996) find that Mexican beef production decreased from 1986-1991 as a result of trade liberalization in Mexico, but the inelasticity of beef demand resulted in a much larger percentage of revenues for beef producers due to a consequent increase in beef prices. Thus, an actual increase in profits for the Mexican beef industry was seen during that time. But, contrary to what the authors found about the inelasticity of beef, the study also shows that Mexican meat (including beef, pork, and chicken) consumption as a whole was down despite rising meat imports for the time period of 1986-1991. The research is limited to data before 1991 though, and is unable to address any changes after 1991, when consumption begins to steadily rise. This observed fluctuating demand for meat in Mexico is one reason why it has become important to accurately identify the demand parameters and test for significant magnitude changes.

Garcia Vega and Gracia's (2000) results concerning demographic variables in meat consumption is interesting to note as Mexican income continues to increase. As Mexico's economy has grown steadily, consumers have been spending a smaller proportion of their income on food, as expected from Engel's Law. The model used to find these results is based on the Almost Ideal Demand System (AIDS) specification, but adapted since the AIDS model is dependent on prices. Due to the fact that the data Garcia Vega and Gracia uses lacks information about prices, they derive the AIDS model into a demographic augmented Engel Curve. This inhibits the model from deriving price elasticities. In 1984, Mexicans spent 44% of their expenditures on food. In contrast, by 1994, per capita income had risen more than 100% since 1984 and food expenditures had fallen to 34%. The study also reveals that highly educated people are consuming less meat, but meat consumption overall is growing.

A similar demand analysis of food in Mexico by Dong, Gould, and Kaiser (2004) uses 1998 cross-sectional household survey data in an Amemiya-Tobin approach implemented into an AIDS model. This approach allows for household heterogeneity while using a simulated maximum likelihood model estimation. Pork and beef are found to be strong complements, but poultry and beef are estimated to be substitute goods in Mexico. The results estimate a disaggregated food demand system in Mexico, but don't analyze trends that could be derived from time-series analysis.

A study by Golan, Perloff, and Shen (2001) focuses on Mexican meat demand and uses the Amemiya-Tobin framework with a GME approach on 1992 cross-sectional survey data with an almost ideal demand system and also finds it to be more practical and efficient than the ML method. The model incorporates five types of meat: beef, pork, chicken, processed meat, and fish, but no tests for separability are performed. All Marshallian and Hicks-compensated own-price elasticities are negative, and most of the elasticities are statistically significant at the 5% level. Beef, pork, and fish expenditure elasticities are all found to be luxury goods. Hicksian cross-price elasticities show beef, pork, and chicken to have substitute good effects on each other as well. However, the cross-price Hicksian elasticities for fish are all found not to be significant at the 5% level, supporting the conclusion that fish is separable. Golan, Perloff, and Shen attempted to compare their results with previous findings, but could find no other estimates of meat demand price elasticities for Mexico besides their own.

No economic crises have arisen in Mexico since 1995, but Mexico's economy has experienced drastic changes. With the integration of North American markets, Mexico is able to benefit from increased foreign investment that boosts GDP as well as an influx of U.S. businesses that offer new products. These developments greatly influence consumers' tastes and demands. Past literature agrees that demand systems are the most effective way to estimate demand parameters of interrelated goods and that different system approaches are beneficial for different purposes.

CHAPTER III

CONCEPTUAL FRAMEWORK

This section provides a conceptual framework of 1) modern demand theory and 2) the theoretically sound models used to estimate the demand parameters including both single equation models and multiple equation demand systems.

Economic theory expresses consumer behavior in terms of preferences limited by a budget constraint. These preferences are represented by a utility function in which rational consumers are expected to maximize utility subject to their budget constraint.

A consumer's purchases are restricted to their allotted income, as exemplified by the budget constraint. A demand curve can thus be mathematically derived through the combined maximization of a Lagrangian equation. The consumer is expected to maximize a Lagrangian objective function of the form:

$$ø = U(q_i) + \lambda(y - \Sigma\, p_i q_i)$$

$$\text{for all } i = 1,\ldots,n$$

where U = consumer's utility function,

q = quantity of each good consumed,

λ = a Lagrange multiplier,

y = total income,

p = prices of each good.

The first order conditions for maximization are:

$$\partial ø / \partial q_i = U_i - \lambda p_i = 0$$

$$\text{thus } U_i = \lambda p_i$$

and

$$\partial ø / \partial \lambda = y - \Sigma p_i q_i = 0$$

$$\text{thus } \Sigma p_i q_i = y.$$

The result of the process of constrained maximization yields the Marshallian demand function. The Marshallian demand function is a function that expresses the quantities of goods demanded by an individual in terms of the price of relevant goods and the income of the individual:

$$q_i = g_i\ (p,y).$$

An increase in the price of a good will affect Marshallian demands in two ways: through the price change itself and through the effective change in the value of the individual's income. When the restriction of cost minimization is included, the Hicksian demand function is produced:

$$q_i = h_i\ (u, p).$$

The Slutsky equation is derived by differentiating the demand function (q_i) with respect to p_j:

$$s_{ij} = \partial h_i / \partial p_j = (\partial g_i / \partial x) * q_j + \partial g_i / \partial p_j$$

where $\partial g_i / \partial p_j$ is the uncompensated price derivative of q_i with respect to p_j and s_{ij} = a matrix of Slutsky terms. This equation represents the substitution effect that is comprised of the income and uncompensated price effects, and is the basis for Slutsky symmetry where $s_{ij} = s_{ji}$, which is discussed later. If the 'pure' price effect is to be considered we get the Hicksian, or compensated, demand. The Hicksian demand function is a function that expresses an individual's demand for goods by means of prices at a particular level of utility. Unlike the Marshallian demand function, a change in the price of a good will have only one effect on the Hicksian demand function; as the level of utility is held constant, this is the substitution effect.

Based on the results of constrained optimization given 'well behaved' utility curves, economic principles suggest that consumer demand is dependent on several variables. 1) The price of the product will have an inverse impact on the quantity demanded. 2) The price of substitutes will have a direct relationship on the demand of a product. In the case of meat, poultry is generally assumed to be a substitute for beef and pork, and pork is assumed to be a substitute for poultry and beef. If the price of beef increases, the quantity demanded for poultry and pork are expected to consequently increase. 3) Income will have a direct effect by allowing consumers to budget the purchase of the product or not. Utility maximization is assumed; thus, under a budget constraint, demand is dependent upon prices and income, given tastes and preferences aren't measurable or quantifiable. If tastes and preferences change, the demand parameters are expected to change as well.

In order to estimate the parameters of meat demand using microeconomic demand theory, quantity demanded is a function of the interrelated price of each meat and consumer's income such that:

$$Q = f(\text{Pricech}, \text{Pricep}, \text{Priceb}, I).$$

More precisely, the included variables are:

- Q = the per capita quantity demanded of a particular meat,
- Pricech = the price that consumers pay for chicken,
- Pricep = the price that consumers pay for pork,
- Priceb = the price that consumers pay for beef, and
- I = income.

Conventional estimations of demand parameters use this single equation method. This approach implies a ceteris paribus condition in which all prices are held constant except the one being estimated. The above formula is an example of how a single equation model would estimate, say, the quantity demanded of chicken alone. It would only incorporate the real prices of chicken and chicken substitutes (pork and beef), for instance, with real income. This method treats each commodity's demand as a unique relationship, independent of demands and prices of other goods. The coefficients derived for each variable can easily be used to equate into elasticities. In the case of strongly interrelated demands, as it is in meat demand, the prices of each commodity are dependent upon each other and continuously react to each other. Thus, a more appropriate model is needed that will accurately depict the interrelation among demands.

To account for this interrelation, more complex models have been developed to allow the estimation of 'demand systems'. They consist of sets of demand equations instead of a single demand equation. By doing so, simultaneity of demand relationships is taken into account and ceteris paribus conditions are no longer required. Complete demand specifications are also favorable because they allow for incorporation of restrictions from economic demand theory and, in doing so, decrease the amount of parameters to estimate.

There are four classical demand restrictions required to conform to economic theory: 1) adding up, 2) homogeneity, 3) Slutsky symmetry, and 4) negativity. Adding up uses the Marshallian and Hicksian demand functions by requiring the parameters representing the consumption of all goods and their substitutes purchased to equal one, meaning the estimated demand functions must add up to the total expenditures:

$$\Sigma\, p_i h_i\,(u,p) = \Sigma\, p_i q_i\,(e,p) = e$$

where p_i = price of good i,

h_i = Hicksian demand for good i,

u = utility,

q_i = Marshallian demand for good i, and

e = total expenditure.

The homogeneity restriction requires that the demand functions are homogenous of degree zero in prices and total expenditures. That is, if the consumer's budget rises or decreases at the same rate as prices, quantities demanded will remain the same. The Hicksian demands are homogenous of degree zero in prices, Marshallian demands are homogenous in total expenditures and prices together. This is also known as the "absence of money illusion" and is expressed by:

$$h_i\,(u, \Psi p) = h_i\,(h, p) = q_i\,(\Psi x, \Psi p) = q_i\,(e, p)$$

where Ψ is any positive constant representing a consistent change in prices and expenditures.

The Slutsky symmetry restriction implies that the cross-price derivatives of the Hicksian demands are symmetric. Slutsky symmetry allows this to be a testable restriction by forming a consumer's substitution matrix, which is the consumer's response to price changes. In this way symmetry is a test of the consumer's consistency of choice. Slutsky symmetry is derived as:

$$\partial h_i\,(u,p)/\partial p_j = \partial h_j\,(u,p)/\partial p_i$$

$$\text{for all } i \neq j$$

where the effect of price of commodity j on the demand for commodity i is equal to the effect of the price of commodity i on the demand for commodity j.

Negativity comes from the concavity of the cost function, but can't be imposed onto a demand system. It is a direct consequence of rational choice. Economic theory portends that own-price Hicksian elasticities are negative, so that as the price of a normal good increases the demand for that good decreases.

By incorporating all of the above restrictions except negativity into a demand system, the estimated demands are structured to agree with its theoretical properties. Additionally, this allows for a more parsimonious number of parameters to be estimated. This is especially important in using time-series data. Multicollinearity is also usually reduced by saving parameters to estimate. Over time, these restrictions have been incorporated into models that allow interaction of variables through the construction of a complete system.

Elasticities are derived from the estimation of demand systems, usually measuring the percentage response of the quantity demanded to a one percent change in price or total expenditure. Own-price elasticity measures the consumer reaction in quantity demanded to a change in that commodity's price, and cross-price elasticity measures the consumer reaction in quantity demanded of one commodity to a change in another commodity's price. Cross-price elasticities are normally derived for products that have interrelated demand, such as close substitutes or complements. If the absolute value of an own-price elasticity is greater than 1, the demand of the commodity is considered elastic. In contrast, it is considered inelastic if the elasticity is less than 1. For cross-price elasticities, if the elasticity is positive then the two goods are considered substitutes. If the cross-price elasticity is negative, the two goods are considered complements. Expenditure elasticities measure the percent change in the quantity demanded of a commodity from a one percent change in total expenditure. If the expenditure elasticity is positive, the commodity is considered normal. If the expenditure elasticity is negative, the commodity is considered inferior. In the Rotterdam and LA/AIDS models, compensated (Hicksian) and uncompensated (Marshallian) elasticities are derived from the estimated parameters. Compensated elasticities take into account the change in real expenditure when the price of a commodity changes.

To measure demand, consumers are aggregated in a way that is consistent and testable. Demand systems allow one avenue to achieve this through the use of empirical measurements. Single equation demand functions have historically been the most popular way to measure demand, but this approach does not allow for interactions between goods. Through the use of demand systems, close interaction is accounted for, and a closer representation of demand curves can be estimated. Unlike single equation demand functions, demand systems also allow symmetry, homogeneity, and adding up to be imposed onto the estimated demand. Demand systems are able to reduce collinearity and the number of parameters, resulting in more statistically reliable coefficients.

The LA/AIDS and Rotterdam models are two of the most used demand systems. The approach by each model is different though, and they both often produce slightly differing demand elasticities. To determine which model is most appropriate for the given data, nested models like the Barten model have been developed. By using a nested model approach, it is easily calculated through a likelihood ratio test which model is best. This approach is purely statistical and reliable, and has been a proven model throughout the years as well.

CHAPTER IV

METHODS AND PROCEDURES

To more accurately depict reality, demand systems allow for specifications to be implemented that will mirror the theoretical properties of demand that are specific to the demand functions being estimated. As previously discussed, demand systems are an improvement over single equation models because they allow for interrelationships to exist between commodities. In the case of meat, pork, chicken, and beef demands are considered strongly interrelated; this will be incorporated into the estimation of Mexican demand parameters for meat, as previously discussed in the conceptual framework. Meat consumption is assumed to be separable from other food consumption, and testable through the budget constraint. The two most applied systems for estimating demand with time-series data are the Rotterdam and LA/AIDS models.

Rotterdam Model

The Rotterdam model was developed by Barten and Theil in 1964. Unlike the AIDS model, it does not assume a particular utility function or correspond to the expenditure share of a product in a specified time period. Instead, an average of the budget share is used in current and previous time periods. By totally differentiating the classic budget constraint, adjusting for Slutsky symmetry in compensated cross-price elasticity, and imposing a budget share of ω_i, the absolute price version of the Rotterdam model results as:

$$\omega_i \, d\ln(q_{it}) = \theta_i \, d\ln(Q_t) + \Sigma_i \, \pi_{ij} \, d\ln(p_{jt}) + \varepsilon_{it}$$

where $\omega_i = (w_{it} + w_{it-1})/2$;

w_{it} = budget share of product i in period t;

q_{it} = per capita consumption of product i in period t;

θ_i = the marginal propensity to spend on the *i*th good, and together with π_{ij} are the constant parameters to be estimated;

$d\ln(Q_t) = \Sigma_i \, \omega_i \, d\ln(q_{it})$ is the Divisia volume index that should be regarded as an index representing the proportional change in real total expenditure;

p_{jt} = the price of product j in period t; and

ε_{it} = the disturbance term.

The classical properties of demand theory can be imposed on the system by the following restrictions:

Adding up:

$$\Sigma_j \, \theta_j = 1$$

Homogeneity:

$$\Sigma_j \, \pi_{ij} = 0$$

Slutsky Symmetry:

$$\pi_{ij} = \pi_{ji}$$

Marshallian (uncompensated) and Hicksian (compensated) elasticities are calculated from the estimated coefficients as follows:

1) Marshallian Price Elasticity: $(1/\omega_i)*(\pi_{ij} - \omega_j\theta_j)$

2) Hicksian Price Elasticity: π_{ij}/ ω_j

3) Expenditure Elasticity: θ_j/ ω_j

The estimation of the Rotterdam model requires that one meat demand equation be omitted from each system. This avoids the singularity of the variance-covariance matrix of disturbances. The parameters associated with the omitted demand equation are recovered through the application of the neoclassical restrictions. The Rotterdam model also 1) satisfies the axioms of choice exactly, 2) aggregates perfectly over consumers without invoking parallel Engel curves, 3) has a functional form which is consistent with known household-budget data, and 4) is simple to estimate.

LA/AIDS Model

The AIDS model was introduced in 1980 by Deaton and Muellbauer. It possesses a functional form consistent with household budget data and is usually used in the linear form (LA/AIDS) as suggested by Stone:

$$\omega_{it} = \alpha_i + \Sigma \gamma_{ij} \ln p_{jt} + \beta_i \ln (Y_t/P_t^*) + \varepsilon_{it}$$

where ω_{it} = expenditure share of product i;

α, β, and γ are parameters;

p_{jt} = the nominal price of product j;

Y_t = expenditure on the set of products;

P_t^* = a price index defined by Stone's linear approximation; and

ε_{it} = the disturbance term.

The LA/AIDS model preserves the generality of the Rotterdam model and can be thought of as an arbitrary first-order approximation to any demand system. The theoretical restrictions apply to the parameters as in the Rotterdam model.

Adding up:

$$\Sigma_i \alpha_i = 1$$

$$\Sigma_i \beta_i = 0$$

$$\Sigma_j \gamma_{ij} = 0$$

Homogeneity:

$$\Sigma_i \gamma_{ji} = 0$$

Slutsky Symmetry:

$$\gamma_{ij} = \gamma_{ji}$$

Slutsky symmetry assumes that the log of the Mexican demand for meat is calculated as the summation of the budget shares of beef, pork, and chicken multiplied by the log of their respective retail prices. Like the Rotterdam model, one meat demand equation should be omitted.

Following Alston and Green (1990), the Marshallian (uncompensated) and Hicksian (compensated) elasticities are calculated from the estimated coefficients as follows:

1) Marshallian Price Elasticity: $-\delta_{ij} + \gamma_{ij}/w_i - \beta_i w_j/w_i$

2) Hicksian Price Elasticity: $-\delta_{ij} + w_j + \gamma_{ij}/w_i$

3) Expenditure Elasticity: $1+ \beta_i/w_i$

δ is equal to one if i=j and zero if otherwise. Shazam econometrics software is used for all programming.

Barten's Method

Empirical studies have shown that the estimated coefficients and elasticities may differ when using the LA/AIDS or Rotterdam models. Difficulties arise when comparing demand systems because of problems like the R^2 statistic being relatively meaningless for comparison. It is also difficult because the dependent variables are not the same for the two systems, and a comparison between systems as a whole and not equation by equation is required. An alternative approach, Barten's method, allows for more appropriate hypothesis testing.

To distinguish which model is most accurate given the set of data, Barten's method will be used to compare the coefficients of the models available. By applying Barten's test, a clear indication is given as to which model of Mexican demand for meat should be used. Barten model specification is depicted as:

$$\omega_i \text{ dln } (q_i) = d_i \text{ dln } (Q) + \Sigma_j e_{ij} \text{ dln } (p_j) + \delta_1 [\omega_i \text{ dln } (Q)] - \delta_2 [\text{dln}(p_i) - \text{dln } (P)]$$

where $\omega_i = (w_{it} + w_{it-1})/2$;

w_{it} = budget share of product i in period t;

qi = consumption of each meat;

$\text{dln } (q_i) = \ln (q_{it} + q_{it-1})$;

Q = average expenditure of each meat consumed;

$d\ln(Q) = \Sigma_i \omega_i \, d\ln(q_i)$;

p_j = price of each meat;

$d\ln(p_j) = \ln(p_{jt} + p_{jt-1})$;

P = average price share of each meat;

$d\ln(P) = \Sigma_i \omega_i \, d\ln(p_i)$;

δ_1 = the coefficient associated with the difference between the Rotterdam and the CBS system, or the Rotterdam and AIDS expenditure coefficients; and

δ_2 = the coefficient associated with the difference between the Rotterdam and the NBR systems, or the Rotterdam and AIDS price coefficients.

The Barten model empirically tests δ_1 and δ_2 to estimate whether the AIDS or Rotterdam model is most appropriate. If δ_1 and δ_2 are equal to zero, the Rotterdam model is appropriate; if δ_1 and δ_2 are equal to one, the AIDS model is the best fit for the data. The likelihood ratio test is used to measure Barten's method results.

Test for Structural Change

Mexico's changing economy and shifting meat consumption provides a basis to support the hypothesis that a structural change has taken place in the meat sector during the past decade. The largest catalyst in Mexico's economic changes may be credited to NAFTA. NAFTA was the first comprehensive free trade agreement between advanced countries and a developing economy, and attributed to the stability of the Mexican economy (Kose, et al. 2004). The amount of industry, from maquiladoras to fast food, that has moved into Mexico from the U.S. has introduced new products at lower prices and has boosted the Mexican per capita GDP. To account for this, a test is desired to examine if changes in tastes and preferences might have shifted the parameters of Mexican meat demand after NAFTA.

Structural change has often been suggested through the evidence of parameter instability. However, Chavas (1983) suggests that changes in parameters over the years may not be enough to affirm structural change. Structural change is defined by Chavas as a change in the basic hypotheses used in the analysis of economic behavior; model specification and period selection might influence the results obtained. To avoid these problems, two period selections are used to test for structural change in Mexican meat consumption behavior. Tests for structural change have been performed for meat demand in several different ways, but the most common approach for a demand system is a simple intercept dummy (or binary) test. Eales and Unnevehr (1993) use this approach in combination with a Wald test, but admit that their findings are only indicative, not decisive. Even though their findings suggest there has been no structural change in U.S. meat since the mid-1970s, there is still a strong possibility that an intercept dummy is not a valid test for structural change and there actually has been a shift in demand.

With this in mind, an intercept binary variable can be included into the demand system that is equal to zero from 1970-1994 and equal to one for 1995-2004[1]. This accounts for two extra coefficients in the system, one for each of the intercept shifter

[1] Interaction terms are often helpful in determining shifts in demand, but are difficult to utilize in demand systems due to the imposed restrictions on the whole system.

dummy variables in each of the meat demand equations. Though there are three meats being tested, the one dropped equation from the meat demand model results in the need for only two binary variables. The inclusion of the intercept binary variables allows a shift in the demand intercept due to effects from NAFTA. As a result, the new estimated parameters are expected to be closer representations of current meat demand in Mexico than without the binary variables.

This approach should more accurately reflect meat demand in Mexico by expanding the degrees of freedom through means of applying data before 1995 and combining it with current information after 1995. The elasticities are then compared to Garcia Vega's 1970-1991 results to determine if elasticities have changed in the past decade. Though performing this structural change test may decrease the significance of the individual coefficients, this is the best alternative we are able to find to estimate the parameters with time-series data given the lack of information due to the short time elapse since 1995.

Data

Mexican data for the consumption of beef, pork, and chicken is available from 1970-2004, adding up to 35 years of data. By combining this information with real prices of each meat and the real total expenditures of each meat from the same period, meat demand will be derived to apply towards the models.

Consistency, accuracy, and availability are all problems while researching Mexican data, though. To circumvent this problem, only sources that are comparable or consistent are used. Prices of each meat are obtained from a single Mexican source: the Bank of Mexico. Consumption, though, is from two sources: SAGARPA, the Mexican department of agriculture and the 1993 Mexican Presidential Report to the Congress. This seems the most appropriate, as the data reflects the apparent consumption estimated by both official Mexican sources. U.S. Department of Agriculture (USDA) data is considered for the same time period, but the variability of the information doesn't reflect the results of other sources and the methods for measurement of the meat are assumed to be different than Mexican sources.

Prices of Chicken, Beef, and Pork

All prices included in the models are in real 1992 pesos per kilo of meat. The data used represent what the average consumer actually paid in each year, thus equating to nominal consumer prices (Table 4.1). To convert to real prices to account for inflation, all observations have been deflated using the 1992 Consumer Price Index (CPI) for the Mexican economy. Current consumer prices and CPI for 1970-2004 were both found by accessing the Bank of Mexico, an official Mexican source. All data sets are on an annual basis, providing 35 observations for the model.

Prices of meat in Mexico haven't always been determined by market forces. Beef has historically been subject to the strictest government controls because it serves as a price indicator for other meats (Garcia Vega). Beef prices have fluctuated throughout the years, increasing variably in the 1970's and 1980's but steadying in the early 1990's after Mexico's free trade agreements came into effect. Beef has now declined to the lowest real price that it has been at in the past 35 years. Pork prices have reflected beef prices, with similar fluctuations throughout time. Pork was more expensive per kilogram in 1970, but permanently fell below beef prices in 1983. The price of pork stabilized, like beef, in the early 1990's and only increased slightly as a result of the 1995-1996 peso devaluation. Chicken has experienced some of the fluctuations that beef and pork underwent, but has gone through the least variation in the past 30 years; chicken has been very consistent in its price decline and consumption increase. Technology has strongly affected the price of chicken by increasing production efficiency and lowering the final cost to consumers. U.S. chicken prices have aided the drop in price to Mexican consumers as Mexican imports of U.S. chicken have increased. Over the past 30 years, the real consumer price of chicken in Mexico has decreased over 63%.

Table 4.1 Mexico: Consumer Meat Prices (Real 1992 Pesos per Kilogram)

Year	Chicken	Pork	Beef
1970	65.85	67.80	55.33
1971	62.46	67.67	57.17
1972	60.29	64.91	57.89
1973	61.01	66.94	66.49
1974	58.55	70.58	67.08
1975	54.98	66.85	62.22
1976	53.18	62.66	57.05
1977	52.46	60.73	54.83
1978	53.35	63.72	62.66
1979	57.52	68.83	73.00
1980	51.92	64.25	68.76
1981	54.04	69.79	65.11
1982	55.42	72.61	68.89
1983	49.54	55.72	65.39
1984	48.23	63.81	72.91
1985	49.88	65.96	78.09
1986	42.97	51.18	61.86
1987	43.29	58.81	61.54
1988	46.71	66.28	70.48
1989	49.25	66.71	74.42
1990	43.94	63.20	66.16
1991	39.92	62.50	66.56
1992	35.06	57.59	63.17
1993	35.00	52.70	59.28
1994	33.17	50.17	56.31
1995	30.65	44.87	51.84
1996	32.78	49.20	53.03
1997	32.98	51.17	52.35
1998	32.43	46.52	50.00
1999	28.89	41.51	47.48
2000	27.93	41.15	45.19
2001	25.47	40.50	44.51
2002	24.06	37.04	42.83
2003	23.79	35.75	43.22
2004	23.92	37.99	47.46

Source: Bank of Mexico

Quantity Demanded

For 1970-1991, per capita meat consumption is collected from the annual Mexican Presidential Report to the Congress as published in Garcia Vega's dissertation (1995). The Presidential Report compiles data from all of the official Federal agencies in Mexico. For 1992-2004 the (SAGARPA), also a Mexican source that reports similar and consistent units of demand to the Presidential Report, is used. The data given is domestic consumption of meat in thousand metric tons, which is then converted to kilograms for consistency of data (Table 4.2). Yearly quantities demanded of meat have varied through the years, such as a large jump in the demand of meat in 1986. The main demand changes are believed to have occurred because of the effects of Mexican reform as the country signed the GATT and NAFTA agreements. A large decline observed in 1982 reflects a financial crisis that lasted until the late 1980's, when the economy began to stabilize.

Table 4.2 Mexico: Per Capita Meat Consumption (Kilograms)

Year	Chicken	Beef	Pork
1970	1.4	7.6	4.7
1971	1.4	7.8	4.7
1972	3.9	11.9	10.5
1973	4.1	12.4	11.5
1974	4.3	12.5	12.5
1975	4.5	12.4	13.4
1976	4.7	13.0	14.6
1977	4.9	13.2	15.8
1978	5.1	13.7	16.6
1979	5.5	14.6	17.4
1980	5.9	15.2	18.1
1981	6.2	16.4	18.5
1982	6.3	16.5	18.8
1983	6.3	13.7	19.8
1984	6.5	12.6	19.0
1985	7.7	12.6	16.5
1986	8.6	15.6	12.0
1987	8.4	15.7	11.2
1988	8.1	14.8	10.5
1989	7.7	14.1	8.9
1990	9.1	13.2	9.0
1991	10.3	13.8	11.6
1992	10.9	14.8	11.6
1993	12.5	13.4	11.3
1994	13.3	15.0	12.3
1995	14.7	13.5	11.5
1996	14.4	14.4	11.3
1997	16.4	15.0	11.6
1998	18.1	15.8	12.3
1999	19.2	15.7	12.6
2000	20.2	15.9	13.4
2001	21.3	16.2	13.7
2002	22.1	16.9	14.1
2003	23.6	15.6	14.4
2004	23.9	15.2	15.5

Sources: 1970-1990: Carlos Salinas de Gortari. *Quinto Informe de Gobierno*. November 1993.
1991-2004: SAGARPA.

CHAPTER V

RESULTS AND DISCUSSION

The coefficients and elasticities of the demand model used to analyze the Mexican meat demand system are presented and discussed in this chapter. Binary variables are then incorporated into the demand system to account for changes since NAFTA. By dropping one equation from the model, the singularity of the variance-covariance matrix of disturbances is avoided. The neoclassical demand restrictions are imposed and the parameters associated with the omitted demand equation are recovered. Significance of each variable is represented by t-values, instead of standard errors, for convenience. Parameter estimates and significance of the coefficients and elasticities are then compared to the work of the most related research by Garcia Vega.

Barten's method fails to statistically reject either the Rotterdam or LA/AIDS model, as calculated from the log-likelihood test. With two degrees of freedom, a likelihood ratio value larger than 5.99 would result in the rejection of the null hypothesis that the given demand system is an appropriate fit for the data. The Rotterdam is equated to have a likelihood ratio of 4.5 and the LA/AIDS has a likelihood ratio of 0.3596. Because the Rotterdam model is used most often with time-series regressions and has previously been determined to be appropriate for Mexican data (Malaga 1997), the Rotterdam is assumed to be more appropriate than the LA/AIDS and is used for further analysis.

The Rotterdam model is estimated through nonlinear maximum likelihood method using the Shazam econometric software. Autocorrelation is corrected for through the use of the Cochrane-Orcutt method[2].

Non-estimated parameters for the Rotterdam model were recovered using the classical restrictions of homogeneity, symmetry, and adding up (Table 5.1). The coefficients are then used to derive the corresponding elasticities (Table 5.2). The own-price coefficients for chicken and pork are found not to be significant at a 5% significance level, but beef may be considered marginally acceptable. Each beta coefficient used to derive the expenditure elasticities is found to be highly significant at a 5% level. The derived cross-price coefficients of beef and pork are the only two that are found to be significant at a 5% level, with a t-value of 2.12. All other derived cross-price coefficients are not statistically significant. Even though the model results in low parameter significance, Garcia Vega's results show similar significance problems with the Rotterdam system, as not a single meat demand coefficient derived by Garcia Vega's study resulted in a significant t-value at a 5% significance level.

[2] Prais-Winston estimation is not used due to the limitations of demand systems.

Table 5.1 Meat Demand in Mexico: Rotterdam Model Parameter Estimates

	Chicken	Beef	Pork
Price of Chicken	-0.0293 (-0.6422)	-0.0551 (-1.2137)	0.0844 (1.3112)
Price of Beef	-0.0551 (-1.2137)	-0.1437* (-1.7526)	0.1987** (2.1211)
Price of Pork	0.0844 (1.3112)	0.1987** (2.1211)	-0.2831 (-0.2819)
Expenditures	0.1598** (8.6282)	0.2834** (7.8934)	0.5568** (13.7783)
R-Square	0.5039	0.4537	----
D-W Statistic	2.9689	2.9334	----

---- Pork equation was omitted. Parameters were recovered using classical restrictions of demand theory.

→t-values are in parentheses

* significant at the 10% level
** significant at the 5% level

The Rotterdam model results in negative own-price Marshallian and Hicksian elasticities for all three types of meat, whereas Garcia Vega found beef and pork to have positive own-price Hicksian elasticities. Garcia Vega also resulted in unexpected complementarities that seem to have corrected with additional data. Pork is found to be slightly complementary through both Hicksian and Marshallian cross-price elasticities, which is in agreement with Garcia Vega's findings. Pork is also still found to be the most own-price elastic good in both Marshallian and Hicksian terms, followed by beef. Chicken, though, is still found to be quite inelastic to prices. Therefore, the demand for chicken may be suspected to be dependent upon expenditures more than price. Pork expenditure elasticity is above 1, at 1.45, indicating that it is still considered a luxury good in Mexico, while chicken and beef are both shown to still be normal goods.

The expenditure elasticities are all highly significant at a 5% level, and the overall significance of the Marshallian elasticities has increased since Garcia Vega's findings. The Marshallian chicken-pork elasticity is now significant at a 5% level, as well as the chicken-beef Marshallian elasticity and the own-price beef and pork Marshallian elasticities. The cross-price Marshallian elasticity for beef-chicken is significant at the 10% level. The Hicksian elasticities show own-price pork to be significant, and cross-price pork-beef and beef-pork to all be significant at the 5% level. The Hicksian own-price elasticity of beef is significant at the 10% level.

Table 5.2 Meat Demand in Mexico: Rotterdam Model Elasticities

Expenditure Elasticities			
	Chicken	Beef	Pork
	0.8328** (8.6282)	0.6691** (7.8934)	1.4481** (13.7783)

Marshallian (Uncompensated) Elasticities			
	Chicken	Beef	Pork
Chicken	-0.3125 (-1.3188)	-0.9125** (-4.0975)	-0.6756** (-2.0770)
Beef	-0.2024* (-1.8957)	-0.6226** (-3.2741)	-0.0361 (-0.1654)
Pork	0.1396 (0.8357)	0.2046 (0.8509)	-1.2931** (-4.4154)

Hicksian (Compensated) Elasticities			
	Chicken	Beef	Pork
Chicken	-0.1526 (-0.6423)	-0.2869 (-1.2137)	0.4395 (1.3113)
Beef	-0.1299 (-1.2137)	-0.3391* (-1.7526)	0.4691** (2.1211)
Pork	0.2194 (1.3113)	0.5169** (2.1211)	-0.7364** (-2.4908)

→t-values are in parentheses

* significant at the 10% level
** significant at the 5% level

Binary (Dummy) Results

As explained previously in the methods and procedures chapter, intercept binary variables are introduced that equal zero from 1970-1994 and equal one from 1995-2004 to represent changes in tastes and preferences that may have occurred due to the induction of NAFTA (Table 5.3). The binary variables adjust the intercept, enabling a quantification of any changes in tastes and preferences. Thus, if the t-values for the binary terms are significant, there is support that a structural change exists and the demand elasticities should be adjusted for the structural change.

Table 5.3 Meat Demand in Mexico: Rotterdam Model Parameter Estimates with Binary Variables

	Chicken	Beef	Pork
Price of Chicken	-0.0224	-0.0681	0.0906
	(-0.3668)	(-1.3356)	(1.4525)
Price of Beef	-0.0682	-0.1106	0.1788**
	(-1.5675)	(-1.4386)	(2.0237)
Price of Pork	0.0906	0.1788**	-0.2694**
	(1.4524)	(2.0237)	(-2.4910)
Expenditures	0.1578**	0.2895**	0.5527**
	(8.6912)	(8.7406)	(14.6356)
Intercept Binary (D)	-0.0252	0.0734**	----
	(-1.3659)	(2.0346)	
R-Square	0.5295	0.5106	----
D-W Statistic	2.7126	2.7027	----

---- Pork equation was omitted. Parameters were recovered using classical restrictions of demand theory.

→ t-values are in parentheses

* significant at the 10% level
** significant at the 5% level

The test for structural change using binary variables provides some support, atleast for beef, to the assumption that tastes and preferences have changed in Mexico since 1995. But, the parameters more closely reflect elasticities that current survey data studies have found. As seen in Tables 5.1 and 5.3, the t-value for cross-price chicken-beef parameters is -1.21 without binary terms and -1.57 when binary terms are included. Both of these t-values are not significant at the 5% level, but it is encouraging that a t-value would increase through the use of the binary terms. All three expenditure parameters' t-values increase with the addition of binary terms, as well. When the binary terms are included, the Hicksian price elasticities generally decrease, with the exception of chicken (Table 5.4). All Hicksian own price elasticities decrease with the addition of the binary terms, but chicken cross-price elasticities appear to be more price elastic than without.

The Marshallian elasticities show all the same significance with the binary variables as without, with the exception of the chicken-beef cross-price elasticity. The Marshallian chicken-beef elasticity is now calculated to be significant at a 10% level. The Hicksian elasticities also show the same significance with the binary variables as without, except for the beef own-price elasticity. The Hicksian own-price elasticity also drops from significant at a 5% level to significant at a 10% level.

Table 5.4 Meat Demand in Mexico: Derived Rotterdam Model Elasticities with Intercept Binary Variables

Expenditure Elasticities			
	Chicken	Beef	Pork
	0.8220** (8.6912)	0.6833** (8.7406)	1.4378** (14.6356)

Marshallian (Uncompensated) Elasticities			
	Chicken	Beef	Pork
Chicken	-0.2747 (-1.1822)	-0.9942** (-4.6346)	-0.6350** (-2.0085)
Beef	-0.2324** (-2.2709)	-0.5507** (-3.0849)	-0.0795 (-0.3865)
Pork	0.1569 (0.9687)	0.1462 (0.6441)	-1.2536** (-4.4964)

Hicksian (Compensated) Elasticities			
	Chicken	Beef	Pork
Chicken	-0.1169 (-0.5018)	-0.3552 (-1.5675)	0.4722 (1.4525)
Beef	-0.1609 (-1.5675)	-0.2612 (-1.4386)	0.4221** (2.0239)
Pork	0.2357 (1.4525)	0.4651** (2.0239)	-0.7009** (-2.4910)

→t-values are in parentheses

* significant at the 10% level
** significant at the 5% level

The intercept binary variable for beef is significant at a 5% significance level, which implies that there has been a demand shift for beef since NAFTA. The chicken intercept binary variable is not significant at the 5% level, but since the demand for beef and chicken is interrelated, a change in beef demand may also affect chicken demand. To test this, a joint significance test is performed on the chicken and beef binary terms within the demand system, which shows them to be significant at the 5% significance level. This may imply that there has been an overall shift in demand for meat in Mexico.

CHAPTER VI

CONCLUSIONS AND IMPLICATIONS

Since the inception of NAFTA in 1994, Mexico has become one of the leading importers of U.S. agricultural exports. This is especially true in the meat sector, where Mexico is now the second largest export market for U.S. beef and pork, and the third largest export market for U.S. chicken. Thus, U.S. meat production is becoming dependent on Mexican consumers. At the same time, increasing meat consumption is also stimulating the Mexican livestock industry, generating a growing and critical market for U.S. feed grains.

With this in mind, it is important to analyze the structure and dynamics of Mexican meat consumption. This knowledge can provide invaluable information for U.S. exporters of meat and feed grains interested in forecasting the strengths and potential growth of the Mexican market. Previous studies have modeled Mexican meat consumption in order to obtain demand parameters related to own-price, cross-price, and income effects. However, these studies only included data prior to the implementation of NAFTA or have used only one year of cross-sectional survey data. Since NAFTA has dramatically altered Mexico's per capita income, GDP, wage rate, ability to import commodities, and meat marketing strategies, it is likely that parameters that were estimated in the past are no longer applicable.

Mexican meat demand parameters have been estimated in the past in several different studies. Dong, Gould, and Kaiser (2004) used 1998 cross-sectional household survey data, and Golan, Perloff, and Shen (2001) used 1992 cross-sectional survey data to determine the demand parameters for several food items, including meat. Both of their results offer demand parameters for only a particular year, and don't incorporate any changes that may have occurred over time. But, survey data offers many more observations and increased degrees of freedom. Garcia Vega (1995) used time-series data in a Rotterdam and LA/AIDS model to estimate the Mexican demand, but failed to determine which model's results are more appropriate for the data. Their findings were also limited to data from 1970-1991. This restricted their results due to the Mexican economic crisis and peso devaluation in 1982, and didn't account for the possible effects of NAFTA. By incorporating 13 additional years, 10 of which are after NAFTA's implementation in 1994, Garcia Vega's study is expanded in order to test whether the Rotterdam or LA/AIDS model is most appropriate for Mexico and to analyze whether the demand parameters have significantly changed since NAFTA.

Meat consumption in Mexico has grown steadily since the inception of NAFTA. The consumption shares of each type of meat have changed as well. Beef represented the most highly consumed meat in Mexico in 1970, but chicken consumption has surpassed that of beef since the mid-1990s. Mexican consumers now appear to prefer chicken over beef and pork. It is possible that meat consumption behavior of Mexicans has changed, and not only in magnitudes of consumption.

Prices of meat in Mexico have also become more stable since NAFTA. Price fluctuations for meat have decreased, and imposed government tariffs are decreasing as well. Meat imports from the U.S. are continuing to rise, coinciding with decreasing meat prices since the late 1980s, when the Mexican government began to open its borders with free trade agreements.

NAFTA has also allowed less inhibited interaction between food distribution and marketing channels in the U.S. and Mexico. Companies in both countries are working closer together to target consumers and lower costs. Many new and differentiated products have been introduced into the Mexican market, as well as larger amounts of higher quality cuts of meat.

Integrated changes in relative meat prices and consumption trends have been observed in Mexico after NAFTA, suggesting that potential structural changes may have occurred on meat demand parameters. These changes have led to the necessity of updated estimations of elasticities to account for these occurrences. The elasticities derived in this study reflect these changes, and provides some evidence of structural change since NAFTA.

Using Barten's methodology and time-series data for 1970-2003, the Rotterdam model is found to be more appropriate empirical specification than the LA/AIDS model for the analysis of meat demand in Mexico when pork, beef, and chicken are analyzed. Hicksian and Marshallian own-price elasticities for all meats are negative and the expenditure elasticity for pork is found to be above one, suggesting pork is a luxury meat in Mexico.

Compared to previous studies, there is a difference in parameter estimation and resulting elasticities since NAFTA. When contrasted against Garcia Vega's findings, higher t-values are found, which can be partly attributed to the inclusion of additional data. This increases the degrees of freedom in the model, potentially providing more robust estimates. Expenditure elasticities have remained relatively constant, but individual and own-price Marshallian and Hicksian elasticities differ. Pork is confirmed by its calculated expenditure elasticity to still be a luxury good compared to beef and chicken. Beef, chicken, and pork are found to be more price elastic than they were before NAFTA. Hicksian elasticities now reflect the expected negative own-price elasticity signs, whereas beef and pork show positive own-price elasticities in studies before NAFTA. The cross-price elasticities are difficult to compare due to low significance levels, but our results confirm that cross-price relationships are weak with the exception of pork and beef. Results indicate that beef and chicken are now substitutes, but chicken and pork appear to be complements in Hicksian terms.

In comparison to cross-sectional household survey data, there are many resulting differences. Golan, et al. found that both beef and pork were luxury goods and chicken was a normal good in their study on the 1992 survey, and that all three expenditure elasticities are highly significant. The Hicksian own-price elasticities they found supported the well-behaved negativity expectations found in our time-series regressions. However, they found that all three meats are substitutes, contradicting our findings of substitutability. Their findings agree that beef-pork cross-price elasticities are statistically significant at the 5% level, but also found that beef-chicken cross-price elasticities are significant at the 5% level. Marshallian elasticities were not calculated for their estimations, and thus can’t be compared. Dong, et al. found even more contradictory results, with all three meats calculated as luxury goods instead of just poultry. Their 1998 expenditure survey data also agrees with the findings of negative own-price Marshallian elasticities, but differs in cross-price elasticities. They found that beef and pork are complements, but poultry and beef are substitutes. Poultry was found to be the most elastic, followed by beef and then pork. This is in opposition to what we found: pork is the most elastic followed by beef and then poultry. No significance values were reported by Dong, et al. though, and so can't be compared.

Structural change is commonly discussed in studies about demand for meat in Mexico, because it is often believed that Mexican consumers' tastes and preferences have changed with the country's continuously developing economy. Health concerns have altered the demand for meat, and the result of recent BSE findings in the U.S. are believed to have shifted the demand for beef even lower. Grocery stores, such as Wal-Mart, have changed the purchasing outlets for Mexican consumers, and may have resulted in changing tastes and preferences as well. Along with this is the growth of commercialized fast food restaurants that have increased the convenience of consuming meat. Mexican consumers are experiencing many changes in their economy, and it is uncertain if their tastes and preferences will remain the same over the years or not.

To statistically test whether structural change exists before versus after NAFTA, binary (dummy) variables are included into the Rotterdam model. This approach has been used in previous demand studies in other countries. The intercept dummy method shows that structural change may exist before 1995 versus after; meaning preferences in meat demand in Mexico may have shifted after NAFTA. Though the intercept binary variable results show support for the hypothesis that there has been a structural change, it doesn't necessarily prove that there has been a structural change. There is no general consensus in the literature yet as to the best approach for testing structural change in demand systems. For example, Davis (1997) concludes that testing for structural change in meat demand is illogical, as numerical shifts in parameter values may not reflect changes in consumer preferences. Unquantifiable changes in tastes and preferences may exist, but limitations in testing procedures aren't able to quantify the changes. Some changes exist in the derived demand parameters when compared to the findings of Garcia Vega, but what causes these parameter shifts is unknown.

With increasing demand and shifting preferences, Mexican imports of U.S. meat are expected to rise to meet consumers' wants and needs. The Mexican market has shown to be even more critical to U.S. meat producers in recent years than previously. With incidences such as BSE findings and resulting bans of U.S. meat by foreign countries around the world, Mexico was the first to re-open its borders and allow U.S. meat trade to resume. The strong integration between the Mexican and U.S. markets, as induced by NAFTA, is expected to continue to foster growth in U.S. meat exports in the coming years as well as Mexican consumers import more meat.

The updated parameter estimations are critical to understanding forecasted consumption and trade in meat. The estimated parameters may be connected with bilateral livestock and feed grain trade models also, and are necessary to simulate impacts of policies on market changes on the overall North American grain/ livestock/ meat markets.

Limitations and Future Research

Mexican data has historically been problematic, but is improving over time with better data collection methods and technology. Consistency of data is also improving with structured government recording and the data is becoming more reliable as well. The meat industry is changing so quickly though, that it is often difficult to differentiate meat products for study. Whether the meat is frozen or refrigerated; cut, prepared, or carcass; organic, branded, or natural; every differentiated product has a varying demand associated with it. Specialization of meat products is one advantage of freer world trade, as sellers are now more able to meet consumers' wants. However, this poses a problem for researchers because the products are no longer uniform. Larger databases and demand systems will help to evaluate new demand structures over time. Survey data will also aid as a comparison point and can be combined over several years to form pooled data. This approach should be more accurate at targeting the current demand as well as checking for trends over time. Surveys are being performed at frequent intervals in Mexico with extremely large sample sizes. Thus, surveys are considered more econometrically acceptable than time-series data that is restricted to low degrees of freedom, and could prove to be a more effective approach than time-series data alone.

Structural change will continue to be a topic of interest, as developing countries are signing free trade agreements that may lead to market and demand changes. Free trade agreements have shown to vastly increase per capita GDP and lower costs of goods in a developing country that makes a trade alliance with a developed country. NAFTA was the first free trade agreement to include a developing country with developed countries, and has been followed by a series of recent free trade agreements signed by the U.S. with other countries or regions.

The study of meat demand in Mexico will continue to need to be updated as major changes pursue in the Mexican economy. In 2008, all meat and feed grains traded between the U.S. and Mexico are expected to be completely free of tariffs and non-tariff barriers under NAFTA regulations. The attainment of free trade may prove to be a critical factor in increasing Mexican meat demand and changing tastes and preferences, and may also catalyze industry growth for meat in the upcoming years.

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APPENDIX A

SHAZAM PROGRAM FOR ROTTERDAM MODEL

```
READ(MASTERLIST.DIF)
GENR Y=PCH*CHCONS+PB*BCONS+PP*PCONS
GENR WCH=CHCONS*PCH/Y
GENR WP=PCONS*PP/Y
GENR WB=BCONS*PB/Y
GENR LWCH=LAG(WCH)
GENR LWP=LAG(WP)
GENR LWB=LAG(WB)
GENR LCHCONS=LAG(CHCONS)
GENR LBCONS=LAG(BCONS)
GENR LPCONS=LAG(PCONS)

**Generating Lag Prices
GENR LPCH=LAG(PCH)
GENR LPP=LAG(PP)
GENR LPB=LAG(PB)
SAMPLE 2 35
GENR DCHCONS=LOG(CHCONS/LCHCONS)
GENR DBCONS=LOG(BCONS/LBCONS)
GENR DPCONS=LOG(PCONS/LPCONS)
SAMPLE 2 35
GENR DPCH=LOG(PCH/LPCH)
GENR DPB=LOG(PB/LPB)
GENR DPP=LOG(PP/LPP)
SAMPLE 1 35
GENR LY=LAG(Y)
SAMPLE 2 35
GENR DY=LOG(Y/LY)
GENR AWCH=.5*(WCH+LWCH)
GENR AWB=.5*(WB+LWB)
GENR AWP=.5*(WP+LWP)

**Generating Dependent Variables
GENR WDCH=AWCH*DCHCONS
GENR WDB=AWB*DBCONS
GENR WDP=AWP*DPCONS

**Generating AY
GENR AY=DY-((AWCH*DPCH)+(AWB*DPB)+(AWP+DPP))
```

```
**Running System
SYSTEM 2/ RESTRICT RSTAT NOCONSTANT
OLS WDCH AY DPCH DPB DPP
OLS WDB AY DPCH DPB DPP
RESTRICT DPB:1-DPCH:2=0
RESTRICT DPCH:1+DPB:1+DPP:1=0
RESTRICT DPCH:2+DPB:2+DPP:2=0
END
SAMPLE 2 35
SYSTEM 2/RSTAT NOCONSTANT
OLS WDCH AY DPCH DPB DPP
OLS WDB AY DPCH DPB DPP
END
SAMPLE 2 35
NL 2/NCOEF=5 PCOV CONV=.0001 ITER=300 RSTAT PITER=50
EQ WDCH=C11*DPCH+C12*DPB-(C11+C12)*DPP+B1*AY
EQ WDB=C12*DPCH+C22*DPB-(C12+C22)*DPP+B2*AY
END

**Auto correction
SAMPLE 2 35
NL 2/NCOEF=5 AUTO PCOV CONV=.0001 ITER=300 RSTAT PITER=50
EQ WDCH=C11*DPCH+C12*DPB-(C11+C12)*DPP+B1*AY
EQ WDB=C12*DPCH+C22*DPB-(C12+C22)*DPP+B2*AY
END

**Interactive Term Inclusion
GENR D=DUM(TIME(0)-26)
SAMPLE 2 35
NL 2/NCOEF=10 AUTO PCOV CONV=.0001 ITER=300 RSTAT PITER=50
EQ WDCH=C11*DPCH+C12*DPB-(C11+C12)*DPP+B1*AY+D1*D
EQ WDB=C12*DPCH+C22*DPB-(C12+C22)*DPP+B2*AY+D2*D
TEST
   TEST D1=0
   TEST D2=0
END

**No Restriction
NL 2/NCOEF=8 AUTO PCOV CONV=.0001 ITER=300 RSTAT PITER=50
EQ WDCH=C11*DPCH+C12*DPB-C13*DPP+B1*AY
EQ WDB=C21*DPCH+C22*DPB-C23*DPP+B2*AY
END
```

APPENDIX B

SHAZAM PROGRAM FOR BARTEN'S METHOD

```
READ(MASTERLIST.DIF) / DIF

*Generating Total Expenditures
GENR Y=(PCH*CHCONS+PB*BCONS+PP*PCONS)

***Generating DQIT or LOG(QI/QI-1)
GENR LCHCONS=LAG(CHCONS)
GENR RCHCONS=CHCONS/LCHCONS
GENR DCHCONS=LOG(RCHCONS)
GENR LBCONS=LAG(BCONS)
GENR RBCONS=BCONS/LBCONS
GENR DBCONS=LOG(RBCONS)
GENR LPCONS=LAG(PCONS)
GENR RPCONS=PCONS/LPCONS
GENR DPCONS=LOG(RPCONS)

***Generating W*it or the Average Budget Share
GENR WTCH=(CHCONS*PCH)/Y
GENR LWTCH=LAG(WTCH)
GENR WCH=.5*(WTCH+LWTCH)
GENR WTB=(BCONS*PB)/Y
GENR LWTB=LAG(WTB)
GENR WB=.5*(WTB+LWTB)
GENR WTP=(PCONS*PP)/Y
GENR LWTP=LAG(WTP)
GENR WP=.5*(WTP+LWTP)

***Generating Q the sum of Wit*Dqit
GENR Q=WCH*DCHCONS+WB*DBCONS+WP*DPCONS

****Generating W*Qit variables for Barten Model
GENR WQCH=WCH*Q
GENR WQB=WB*Q
GENR WQP=WP*Q

***Generating DPit=LOG(Pit/Pit-1)
GENR LPCH=LAG(PCH)
GENR RPCH=(PCH/LPCH)
GENR DPCH=LOG(RPCH)
```

```
GENR LPB=LAG(PB)
GENR RPB=(PB/LPB)
GENR DPB=LOG(RPB)
GENR LPP=LAG(PP)
GENR RPP=(PP/LPP)
GENR DPP=LOG(RPP)

***Generating Wit*Dpit
GENR WDPCH=WCH*DPCH
GENR WDPB=WB*DPB
GENR WDPP=WP*DPP

***Generating P=Sum of WDPit
GENR P=WDPCH+WDPB+WDPP

***Generating Wit*(DPit-SUM(Wit*DPit)) for Barten Approach
GENR WPCH=WCH*(DPCH-P)
GENR WPB=WB*(DPB-P)
GENR WPP=WP*(DPP-P)

***Generating Wit*DQit
GENR WDCHCONS=WCH*DCHCONS
GENR WDBCONS=WB*DBCONS
GENR WDPCONS=WP*DPCONS

****Program for the Barten Approach Model on US Demand System
*Complete Model w/o Constant
SAMPLE 2 35
NL 2/NCOEF=7 AUTO PCOV CONV=.0001 ITER=200 RSTAT
EQ WDPCONS=-
(G12+G13)*DPP+G12*DPB+G13*DPCH+Q1*Q+L11*WQP+L12*WPP
EQ WDBCONS=G12*DPP-
(G12+G23)*DPB+G23*DPCH+Q2*Q+L11*WQB+L12*WPB
END

*Complete Barten Model with Constant Term
NL 2/NCOEF=9 AUTO PCOV CONV=.0001 ITER=200 RSTAT
EQ WDPCONS=A1-
(G12+G13)*DPP+G12*DPB+G13*DPCH+Q1*Q+L11*WQP+L12*WPP
EQ WDBCONS=A2+G12*DPP-
(G12+G23)*DPB+G23*DPCH+Q2*Q+L11*WQB+L12*WPB
END

*Barten Model with &1=&2=1 (AIDS) w/o Constant
```

```
NL 2/NCOEF=5 AUTO PCOV CONV=.0001 ITER=200 RSTAT
EQ WDPCONS=-(G12+G13)*DPP+G12*DPB+G13*DPCH+Q1*Q+WQP+WPP
EQ WDBCONS=G12*DPP-(G12+G23)*DPB+G23*DPCH+Q2*Q+WQB+WPB
END
*Barten Model with &1=&2=1 (AIDS) with Constant Term
NL 2/NCOEF=7 AUTO PCOV CONV=.001 ITER=200 RSTAT
EQ WDPCONS=A1-(G12+G13)*DPP+G12*DPB+G13*DPCH+Q1*Q+WQP+WPP
EQ WDBCONS=A2+G12*DPP-(G12+G23)*DPB+G23*DPCH+Q2*Q+WQB+WPB
END

*Barten Model with &1=&2=0 (Rotterdam) w/o Constant
NL 2/NCOEF=5 AUTO PCOV CONV=.001 ITER=200 RSTAT
EQ WDPCONS=-(G12+G13)*DPP+G12*DPB+G13*DPCH+Q1*Q
EQ WDBCONS=G12*DPP-(G12+G23)*DPB+G23*DPCH+Q2*Q
END

*Barten Model with &1=&2=0 (Rotterdam) with Constant Term
NL 2/NCOEF=7 AUTO PCOV CONV=.001 ITER=200 RSTAT
EQ WDPCONS=A1-(G12+G13)*DPP+G12*DPB+G13*DPCH+Q1*Q
EQ WDBCONS=A2+G12*DPP-(G12+G23)*DPB+G23*DPCH+Q2*Q
END
```

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