THE EFFECTS OF NAFTA ON U.S. AND MEXICAN RICE MARKETS AND TRADE

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Abstract: Utilizing a nonspatial price equilibrium model of the rice industries in the U.S. and Mexico, this study analyzes the past and future expected effects of NAFTA on U.S. and Mexican rough and milled rice markets and trade and the contribution of NAFTA relative to that of other key factors likely to impact U.S. and Mexican rice, including the Mexican economic crisis of the mid-1990s and growth in Mexican per capita incomes.

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EXECUTIVE SUMMARY

Since NAFTA was implemented in 1994, Mexico has become the single largest export destination for U.S. rice primarily due to declining production of Mexican rice, the geographical proximity of the U.S. ,and a ban on Asian rice imports as a result of "phytosanitary concerns". Prior to NAFTA, to encourage the utilization of domestic milling capacity as rice production declined, the Mexican government set a tariff on milled rice at 20% *ad valorem*, double the 10% tariff on rough rice imports, providing an incentive for imports of rice in rough rather than milled form. Under NAFTA, tariffs on both rough and milled rice were to be phased out in equal increments over a ten-year period, reaching zero by 2003.

What have been the effects of NAFTA on U.S. and Mexico rice markets and trade? What are the implications of NAFTA for future rice trade between the two countries? What has been the relative contribution of NAFTA to changes in U.S.-Mexico rice trade? What are the key factors that will have a continuing impact on the growth and composition of U.S.-Mexico rice trade in the future? Utilizing a nonspatial price equilibrium model of the rice industries in the U.S. and Mexico, this study analyzses the past and future effects of NAFTA on U.S. and Mexican rough and milled rice markets and trade and measures the contribution of NAFTA to U.S.-Mexico rice trade relative to that of other key factors likely to impact that trade, including changes in the value of the Mexican peso against the U.S. dollar and growth in Mexican per capita incomes. A 27 equation, nonspatial price equilibrium conceptual model that captures the economic interrelationships in U.S. and Mexican rice markets is developed and then the parameters of the model are estimated. After validating the model through historical simulation and sensitivity analysis, the model is used to simulate the past and possible future effects of the declining Mexican tariff rates under NAFTA, the 1994-95 Mexican economic crisis, and potential growth in real per capita Mexican incomes on U.S. and Mexican rough and milled rice markets.

For the analysis, a ten-year baseline simulation forecast was first established with the model. The baseline provided estimates of the values of the endogenous variables over the next decade assuming NAFTA remained in effect and all other exogenous variable follow paths devoid of extreme events (weather, etc.) and consistent with past market behavior. Then the model was used to simulate four scenarios: (1) No NAFTA; (2) No Devaluation; (3) No NAFTA or Devaluation; and (4) Lower GDP Growth over the historical and forecast time period.

In general, the simulation results under the four scenarios suggest that the combined effects of NAFTA and the 1994-95 peso devaluation on U.S. exports of both rough and milled rice to Mexico have had and are expected to be negative. In the case of U.S. milled rice exports, however, the results suggest that NAFTA has had and will continue to have a large positive effect, offsetting to a great extent the large negative effect of the devaluation. Thus, despite the fact that U.S. milled rice exports to Mexico have actually declined since NAFTA was implemented, NAFTA has helped boost the level of those exports, contrary to the concerns

expressed by some in the U.S. rice industry. The primary reason for the decline has been the devaluation of the Mexican peso and the accompanying economic crisis in Mexico.

This study also finds that perhaps more important that either NAFTA or the Mexican economic crisis of the mid-1990s for the future of U.S. rice exports to Mexico is the annual rate of economic growth in Mexico. Just a 1% increase in the real Mexican per capita GDP would generate an annual increase of 30% in U.S. milled rice exports to Mexico as well as higher U.S. farm and milled rice prices. At the same time, Mexican domestic demand would likely increase reaching a level almost 20% above the baseline in 2009.

Other key conclusions from the simulation analysis include the following:

- The devaluation is the major reason why U.S. rice exports to Mexico have not switched from rough to milled form as many researchers had predicted and many in the U.S> rice industry expected.
- Rough rice exports were 20% lower than they would have been in 1995 if the Mexican peso devaluation had not occurred while U.S. milled rice exports to Mexico were 56% less in 1995 and 84% less in 1999 as a result of the devaluation.
- From 1994 through 1999, NAFTA accounted for 22% of the total reduction in U.S. rough rice exports to Mexico with the devaluation accounting for the remaining 78%.
- Had the devaluation not occurred, U.S. milled rice exports to Mexico would have been expected to surpass rough rice exports by 2003 (rough basis) and would have been expected to be about twice as large by 2009.
- U.S. milled rice exports to Mexico are likely to be over twice as large in 2003 as might have been the case if NAFTA not been implemented. By 2009, milled rice exports to Mexico are likely to be 30% greater than otherwise as a result of NAFTA.
- NAFTA has had a negative effect on the rough rice market of Mexico. Mexican farm prices, production, and quantity demanded for processing all decreased as a result of the agreement.
- The peso devaluation, on the other hand, has had and is expected to have an overwhelmingly positive impact on Mexican rice production at the expense of the consumption of rice in Mexico. Mexican farm prices of rice since the 1995 have been more than double what they would have been largely as a result of the devaluation.
- Mexican rough rice production is expected to increase roughly 3 million cwt above what would have been expected had the devaluation not occurred over the next decade.
- The Mexican peso devaluation has had the effect of depressing Mexican milled rice demand which has retarded the growth in Mexican milled rice imports from the U.S.

THE EFFECTS OF NAFTA ON U.S. AND MEXICAN RICE MARKETS AND TRADE

Although not among the largest rice producers in the world, the U.S. ships rice to over 100 countries making the U.S. one of the largest world rice exporters (USA Rice Federation). Since NAFTA was implemented in 1994, Mexico has become the single largest export destination for U.S. rice, averaging 421,000 tons (rough basis) between 1994/95 and 1998/99 primarily due to declining production of Mexican rice, the geographical proximity of the U.S. and a ban on Asian rice imports as a result of "phytosanitary concerns".

The vast majority of U.S.-Mexico rice trade has been in the form of rough rice.[1] From 1994 to 1998, rough rice averaged 76% of total U.S. rice exports to Mexico. One reason that rough rice dominated U.S. exports to Mexico during the 1990s is the tariff differential between rough and milled rice. Prior to NAFTA, to encourage the utilization of domestic milling capacity as rice production declined, the Mexican government set a tariff on milled rice at 20% *ad valorem*, double the 10% tariff on rough rice imports, providing an incentive for imports of rice in rough rather than milled form. Under NAFTA, tariffs on both rough and milled rice were to be phased out in equal increments over a ten-year period, reaching zero by 2003. In June of 2002, however, in response to rapidly growing imports, Mexico imposed anti-dumping duties on imports of U.S. long-grain milled and semi-milled white rice. In 2003, the U.S. filed a complaint with the WTO and the Mexican anti-dumping order is now under review by a WTO dispute settlement panel.

What have been the effects of NAFTA on U.S. and Mexico rice markets and trade? What are the implications of NAFTA for future rice trade between the two countries? Have other factors such as relative economic growth and technology adoption had effects on that trade? What has been the relative contribution of NAFTA to changes in U.S.-Mexico rice trade? What are the key factors that will have a continuing impact on the growth and composition of U.S.-Mexico rice trade in the future? Unfortunately, previous studies of U.S. and Mexican rice markets and trade and NAFTA have provide little insight on the answers to these and other related critical questions for the U.S. and Mexican rice industries.

Much of the research on U.S.-Mexico rice trade has been largely descriptive in nature (e.g., Cramer, Young, and Wailes and Salin, et al.). Only major two studies of the effects of Mexican tariffs on U.S.-Mexico rice trade have been published. Hansen et al. modified the Arkansas Global Rice Model to include a Mexican sub-model for an analysis of the removal of Mexican rice tariff barriers and the associated effects on the two countries. The model, however, lacked sufficient detail for an in-depth analysis of rough vs. milled rice trade impacts on the rice markets in the U.S. and Mexico and other key issues. At the same time, the analysis provided no measurement of the relative contribution of NAFTA to the likely changes in U.S.-Mexico rice trade. Fuller, Fellin, and Salin employed a spatial equilibrium model to analyze factors influencing future rice trade between the U.S. and Mexico. Their analysis focused only on long

[1] Rough rice still contains the husk and must be further processed, or milled, before it can be consumed.

grain rice trade and analyzed both the effects of rice tariff elimination and the re-entry of Thai rice into the Mexican rice market. Unlike the Hansen et al. study, the Fuller, Fellin, and Salin analysis considered the separate markets for rough and milled rice. However, as with any spatial equilibrium analysis, their results are essentially *ex post* with no analysis of the dynamic effects over time of the incremental tariff reduction.

In contrast to previous analyses, this study utilizes a nonspatial price equilibrium model of the rice industries in the U.S. and Mexico to consider the past and future effects of NAFTA on U.S. and Mexican rough and milled rice markets and trade. In addition, the study measures the contribution of NAFTA to U.S.-Mexico rice trade relative to that of other key factors likely to impact that trade, including changes in the value of the Mexican peso against the U.S. dollar and growth in Mexican per capita incomes.

Following a brief discussion of U.S. and Mexican rice industries and trade, a conceptual model that captures the economic interrelationships in those markets and their trde interaction is then presented. The econometric analysis based on the conceptual model is presented next along with a discussion of the data used in the analysis and the results of model validation. The model is then used to simulate the past and possible future effects of the declining Mexican tariff rates under NAFTA, the 1994-95 Mexican economic crisis, and potential growth in Mexican real per capita incomes on U.S. and Mexican rough and milled rice markets and trade.

U.S and Mexican Rice Markets and Trade

While rice production in both countries was highly influenced by domestic agricultural policy in the past, domestic government policies in both countries have recently become more market-oriented while still providing income support for producers. U.S. rice production has grown steadily over time due to increases in long grain rice acreage and yield increases. In contrast, Mexican rice production has been highly variable due to production practices relying heavily on sporadic rainfall.

While increasing in both countries, rice demand in the U.S. has grown more rapidly over time than in Mexico. The relatively more rapid U.S. growth in rice consumption is the result of the dramatic rise in processed food utilization as well as the growing health-consciousness of consumers. Much of the increase in Mexican rice demand is the result of population growth although per capita demand has increased as well. Increases in consumer education and wealth in Mexico as economic growth occurs over time will likely build the demand for rice in Mexico.

The U.S. is one of the world's largest rice exporters depending on foreign markets for sales of about 50% of domestic production. Although the majority of U.S. rice exports are of the milled, long grain variety, the U.S. is the only major exporter of rough rice which have shown remarkable growth, currently accounting for more than 30% of all U.S. rice exports. Nevertheless, total U.S. rice exports have remained relatively stable in recent years as the growth in long grain rough rice exports have just offset declines in exports of milled and other classes of rice.
In the late 1980s along with the unilateral opening of its markets to trade, Mexico began importing large quantities of rice in both rough and milled form, currently importing nearly 50% of consumption. In 1990, the milled rice tariff was increased to 20% ad valorem compared to

10% on rough rice imports to protect the Mexican milling industry. The resulting tariff differential boosted Mexican rough rice imports dramatically so that by 1998 rough rice accounted for 86% of total Mexican rice imports from the U.S. Although U.S. rice exports to Mexico make up less than 15% of total U.S. rice exports, Mexico has become the largest export destination for U.S. rice. The U.S supplies virtually all of Mexican rough rice imports and nearly 80% of Mexican milled rice imports. The elimination of the Mexican rice import tariffs which was completed in January of 2003 has widely been expected not only to boost Mexican imports of rice but to shift the composition of Mexican rice imports toward milled rice. The Mexican economic crisis that began in December 1994 and the accompanying devaluation of the Mexican peso and the subsequent adjustments in the economy, however, have obfuscate the effects of NAFTA on Mexican rice imports.

Conceptual Model of U.S. and Mexican Rice Markets

This section presents a conceptual model for the analysis of the effects of NAFTA and other factors on the U.S. and Mexican rice industries. After reviewing agricultural trade methodology, a 27 equation, multiple-region, nonspatial, price equilibrium model is presented as the model of choice based on both the characteristics of the rice markets of the U.S. and Mexico and the objectives of the study. The conceptual model is then laid out drawing from neoclassical economic theory, previous work in market analysis and trade, and an understanding of the structure of U.S. and Mexican rice industries (see Welch and Williams). The model consists of three regional components (U.S. supply and demand, Mexican supply and demand, and ROW excess demand) subdivided into rough and milled rice components and linked via price and trade equations. Empirical results and model validation will be presented in the following section of this report.

Agricultural Trade Modeling Methodology

All scientific research, which includes agricultural trade research, begins with a problem needing an explanation (Tweeten). Theory is used to conceptually outline the problem and determine a method of solution. Conceptual models are then transformed into an appropriate quantitative trade model. The objectives of trade models are to explain the world, forecast future conditions, and analyze impacts of policy decisions (Tweeten). Thompson discusses two general methods for quantitatively modeling agricultural trade. The first and simplest method, two-region modeling, consists of simply adding an aggregate rest of the world (ROW) export demand or import supply equation to an existing domestic market model. The problem with this specification, however, lies in the inability of the model to capture interrelationships between the two trading regions. Only domestic policy issues in the country being modeled can be analyzed since the ROW equation contains no information as to the structure of supply and demand in individual ROW countries. Therefore, effects of exogenous shocks and/or policy changes in individual ROW countries on the ROW excess supply or demand equation cannot be easily analyzed.

The second method, multiple-region modeling, deals with the interrelation problem by specifically linking trading regions through a system of simultaneous equations. A multiple region model is more relevant for analyzing the effects of NAFTA on the two interrelated regions of the U.S. and Mexico.

There are three subclasses of multiple-region trade models: nonspatial price equilibrium models, spatial price equilibrium models, and market share models. A nonspatial price equilibrium model includes greater domestic market detail and is better validated than other multiple-region models and, thus, is the preferred model for the study (Thompson).

The next consideration in model choice deals with type of equilibrium. Both general equilibrium (GE) models and partial equilibrium (PE) models are applied to trade analysis**.** General equilibrium models attempt to incorporate all factors influencing the problem including both agricultural and non-agricultural commodity markets, and macroeconomic relationships (Tweeten). While GE models generate useful intersectoral effects, they have heavy data requirements and have tended to perform poorly in simulation. Furthermore, by treating commodities at a high level of aggregation, GE models lack sufficient specific commodity detail for a comprehensive market analysis (Liapis, Krissoff, and Neff).

Partial equilibrium commodity models often assume technology, macroeconomic relationships, and other commodities and markets are exogenous or remain constant in the analysis (Tweeten). Nevertheless, Hertel, Peterson, and Stout found GE closure is not crucial to obtaining an accurate assessment of the price and quantity effects of agricultural trade liberalization. In addition, a PE model corresponds to diagrammatic market representations and is the model of choice for commodity market analysis. The results of PE models may be effectively explained as shifts in and movements along supply and demand schedules (Hertel, Peterson, and Stout). A PE modeling framework will be utilized because the analysis to be conducted is concerned with the effects of NAFTA on a specific commodity (rice) market.

In summary, based on both the characteristics of the rice markets of the U.S. and Mexico and the objectives of the study, a multiple-region, non-spatial, partial equilibrium model will be utilized in the analysis.

Now that the general conceptual modeling framework has been determined, specific contents of the model will be addressed. Trade models are based on domestic market behavior (Tweeten). Consequently, their ability to meet trade-modeling objectives is dependent upon the quality of quantitatively estimated market behavior parameters. In order to ensure quality parameter estimates, model specification will draw upon both neoclassical economic theory and previous work in the fields of market analysis and trade.

U.S. - Mexico Rice Model Model Assumptions and Specification

Based on a review of related literature and a separately published qualitative analysis of U.S. and Mexican rice Markets (Welch and Williams), the model developed for the analysis of NAFTA and U.S. Mexico rice markets and trade includes three regional components (U.S. supply and demand, Mexican supply and demand, and ROW excess demand), a price linkage component, and a trade component.

Although the U.S. produces long, medium, and short grain rice, all Mexican rice production is considered to be long grain (Hansen et al.). Furthermore, over the period 1979-1998, 98% of U.S. rice exports (calendar year) to Mexico were long grain. Thus, the quantitative analysis considers only long grain rice. However, there are two separate markets for long grain rice: the rough rice market and the milled rice market. Previous research on the effects of freer trade has mostly ignored these separate markets. To analyze the effects of the declining tariff differential between the two types of rice under NAFTA, both rough and milled rice markets are modeled for each country.

A key consideration in the formulation of both the supply and demand specifications is the possibility of structural change. Changes in governmental policies and politics can alter the structure of markets. Structural changes in Mexico possibly include Mexico's accession to GATT in 1986, NAFTA in 1994, and farm policy reforms. Examples of possible structural change within the U.S. include NAFTA and the various farm bills. Structural change tests will be done to determine whether such events have had an impact on Mexican and U.S. rice markets because ignoring structural changes can result in biased parameter estimates (Judge et al.).

A diagrammatic representation of the U.S. and Mexican rice markets is displayed in figure 3.1. Rough rice production, beginning stocks, and imports determine total rough rice supply, which is processed into milled rice, exported, or carried over to the next marketing year. Similarly, processed rough rice, milled rice imports and beginning stocks determine total milled rice supply, which is either utilized in the domestic market, exported, or carried over to the next marketing year.

Trade in the model is determined through excess supply and demand equations. Excess supply and demand for the U.S. and Mexico are derived from their respective domestic market supply and demand equations. The ROW excess demand equation is estimated directly. An excess demand equation representing the ROW is necessary to close the model because the U.S. exports rice to countries other than Mexico. The price linkage component of the model includes factors affecting trade such as tariffs and exchange rates as well as price transmission equations linking rough and milled rice prices. The model allows the interaction of specified supply and demand equations to simultaneously determine equilibrium quantities and prices.

U.S. and Mexico Rough Rice Supply Model Components

Traditional economic theory dictates that the supply of a commodity depends on own-price, input prices, and other exogenous factors such as government programs, prices of substitute commodities, weather, technology, etc. U.S. and Mexican rice production has been highly influenced by government programs that impact producers' returns (Welch and Williams). In the U.S., such programs have not only affected plantings indirectly, but directly as well by requiring reductions in planted acreage. Therefore, the domestic market analysis includes government programs in the acreage response function. A revenue-cost, or Implicit Revenue Function (IRF), approach following Chen and Ito and Song and Carter, with modifications based on the analysis of Welch and Williams, is utilized in the model. The IRF approach collapses own-price, input prices, and all relevant policy variables into one explanatory variable, thereby eliminating multicollinearity and degrees of freedom problems associated with multiple explanatory variables. Furthermore, the IRF allows the multiple policy periods to be incorporated within a single theoretical framework (Chen and Ito).

Harvested acreage is specified as a function of planted acreage and other exogenous factors such as weather (temperature, precipitation, etc.). Since the analysis considers production at a national level, it would be difficult to form a single weather variable from state-level weather data. Therefore, a dummy variable will be incorporated for years with extreme weather conditions.

Yields, influenced by weather and technology, are assumed to be exogenous as well, a common practice in agricultural trade models (Malaga). Like weather, estimates of technological change are difficult to quantify and are considered exogenous to the model.

U.S. Rough Rice Supply

For the purpose of the IRF in the U.S., the five U.S. farm bills (1977, 1982, 1985, 1990 and 1996) will be combined into three policy periods based on similar program characteristics: (1) 1979-1981, (2) 1982-1995, and (3) 1996-1998.

In the U.S., rice producer participation in the various government programs is voluntary. Participation rates are known and assumed exogenous. Since not all producers participate in farm programs, the IRF is calculated annually for both participants and non-participants Annual participation rates are used to formulate a single value for the IRF (USIR).

(3.1) $$USIR = USIRP*(PP) + USIRNP*(1-PP)$$

where USIR = U.S. per acre implicit revenue; USIRP = per acre implicit revenue for program participants; USIRNP = per acre implicit revenue for program non-participants; and PP = program participation rates.

Implicit revenue for program participants, which represents operating returns over variable costs on a per acre basis, is calculated annually as follows for each policy period (table 3.1):

(3.2) $$USIRP_j = \Sigma_i (p_i \cdot y_i \cdot q_i)$$

where j denotes policy period; p, y, and q are $i \times 1$ vectors; p includes per cwt prices, payments, and per acre variable costs; y includes per acre actual and program yields, and others; and q includes the fraction of planted acreage eligible for payments.

The IR calculation for the first period is relatively straightforward. All producers were basically participants in the program (i.e. PP = 1). Producers could plant any acreage, but received program benefits (non-recourse loans, deficiency payments, and disaster payments) only on acreage planted within their allotments. Since the IRF calculates returns per acre, the proportion of allotment to acres planted is restricted to be less than one. Accordingly, producers received cash receipts of the farm price multiplied by yield per acre on all acres planted. Loan receipts per cwt are calculated as the difference between the loan rate and the farm price and are restricted to be greater than or equal zero. Deficiency payments per cwt are calculated as the difference between the target price and the maximum of the loan rate and the average price of the first five months of the marketing year, restricted to be greater than zero. Unlike loan receipts, deficiency payments are based on government program yield. Disaster payments, if applicable, are paid at 1/3 the target price on the difference between 75% of program yield and actual yield on eligible acres.

Implicit revenue calculation for the second period is the most complex of the three due to the expansion of program provisions. The major complicating factor lies in the permitted planting vector (Q). Supply control mechanisms introduced during this period worked by restricting acreage planted. To be eligible for program benefits, producers had to idle a minimum percentage of their base acreage, which is termed the acreage reduction program (ARP). Statistics of the U.S. Department of Agriculture (USDA) statistics indicate that approximately 100% of program participants' base acreage was further reduced under the paid land diversion (PLD), payment-in-kind (PIK), and flexibility provisions (FLEX); however, only 10%-35% were annually enrolled in the 50/92 program (USDAg). The 50/92 program allowed program participants to idle an additional 50%-92% of their remaining base acreage, but receive deficiency payments on 92% of the remainder. Total permitted plantings for participants is simply reductions taken on all base acreage less 50/92 reductions:

(3.3) $Q_i = (1\text{-ARP-PLD-PIK-FLEX})*(1\text{-S50}\cdot\text{P50})$

where i = elements of the Q vector representing cash and loan receipts, disaster payments, marketing loan gains, and variable costs; S50 = reduction required for the 50/92 program; and P50 = percent participation in the 50/92 program. The remaining elements of the Q vector for period two are calculated similarly taking into account various program provisions.

Cash and loan receipts are calculated the same as in period one. The deficiency payment calculation was changed for the 1994 and 1995 crop years. Instead of being the difference between the target price and the maximum of the loan rate and the five-month average price, deficiency payments were calculated as the difference between the target price and the minimum of the calendar year average price and the five-month average price. The marketing loan program, initiated in 1986, allowed producers to repay CCC loans at the lesser of the loan rate or the world price. The marketing loan gain is only received if the farm price is above the repayment rate. If the farm price were below this level, the producer would lose money by cashing out the loan and selling on the open market.

Implicit revenue for period three is straightforward. The major difference between the first two periods and period three is the absence of deficiency payments. Deficiency payments were eliminated in order to sever the linkage between income support payments and market prices. Production Flexibility Contract (PFC) payments were introduced as replacement, and were paid on 85% of the program yield.

In order to link the different program periods in the model, a switching procedure utilizing dummy variables is incorporated as follows:

(3.4) $USIRP = USIRP_1*D1 + USIRP_2*D2 + USIRP_3*D3$

where D1 = 1 for 1979-1981, 0 otherwise; D2 = 1 for 1982-1995, 0 otherwise; and D3 = 1 for 1996-1998, 0 otherwise.

Implicit revenue for non-participants is simply the difference between revenue and variable cost and is calculated the same for all three policy periods.

(3.5) $USIRNP = USFP*USY - USVC$

where USFP = farm price per cwt; USY = yield per acre; and USVC = variable cost per acre.

While the IRF deals with returns per acre, government programs also directly restrict acreage planted. This direct effect on planted acreage will be represented as the acreage limit ratio (ALR) following Song and Carter. Only producers participating in government programs are required to restrict planted acreage. Thus, calculation of the ALR is analogous to that of the USIR (equation 3.1) and is based on participation rates and reduction percentages as follows:

(3.6) $$ALR = (1\text{-}ARP\text{-}PLD\text{-}PIK\text{-}FLX)*(1\text{-}S50\cdot P50)*PP + (1\text{-}PP)$$

Both medium grain rice and soybeans are hypothesized to substitutes in rice production. However, previous studies have found soybeans to be an insignificant determinant of supply (Grant, Beach, and Lin, Song and Carter). In addition, farm prices for long and medium grain rice are highly correlated, which can lead to poor estimation results.

Harvested acreage is specified to be a function of planted acreage. U.S. rough rice production is calculated as acres harvested multiplied by yield per harvested acre.

Thus, the U.S. rough rice supply model is specified as follows:

(3.7) $$USAP = f(USIR, ALR, Other)$$
(3.8) $$USAH = f(USAP)$$
(3.9) $$USQPR = USAH*USY$$

where USAP = U.S. planted acreage; USIR = U.S. implicit revenue; ALR = acreage limit ratio; Other = medium grain rice and/or soybeans (farm price or IR); USAH = U.S. harvested acreage; USQPR = U.S. rough rice production; and USY = U.S. rough rice yield.

Mexican Rough Rice Supply

Unlike the complicated construction of the IRF for the U.S., the Mexican IRF is relatively straightforward and can be calculated as a single period even though policies have changed over time (table 3.2). The mathematical representation of the Mexican IRF is similar to that of the U.S. and is represented by equation 3.10.

(3.10) $$MXIR = \Sigma_i (p_i \cdot y_i \cdot q_i)$$

where p, y, and q are $i \times 1$ vectors; p includes per cwt prices and payments, and per acre variable costs; y includes actual per acre yields, and others; and q includes the fraction of planted acreage eligible for payments.

Three main policy tools have been employed to support Mexican rice producers: (1) guaranteed prices, (2) ASERCA payments, and (3) PROCAMPO payments. There are no acreage reduction requirements in order to be a participant in these programs.

Guaranteed prices served the same function as the loan rate in the U.S. by creating a price floor. Producers received the maximum of the farm price or the guaranteed price times yield per acre. ASERCA payments were paid on actual yield, but were not paid on total production. As a result, the per acre value of these payments must be discounted by the percentage of total production ASERCA payments represent. Likewise, PROCAMPO payments (a per acre subsidy similar to the PFC contracts in the U.S.) are not paid on total planted acreage, and must be discounted by the percentage of total acreage PROCAMPO payments represent.

Major competing crops are corn, dry beans, and fresh vegetables, whose production has been encouraged by the Mexican government for a number of reasons. Corn and dry beans are considered staple crops in Mexico. Their production has been encouraged to promote food self-sufficiency. Fresh vegetables are a valuable export crop, and have been encouraged to generate foreign exchange.

Drawing on the above discussion, the Mexican rough rice supply is as follows:

(3.11) $MXAP = f(MXIR, Other)$
(3.12) $MXAH = f(MXAP)$
(3.13) $MXQPR = MXAH*MXY$

where MXAP = Mexican planted acreage; MXIR = Mexican implicit revenue; Other = corn, dry beans, vegetables (farm price or IR); MXAH = Mexican harvested acreage; MXQPR = Mexican rough rice production; and MXY = Mexican rough rice yield.

U.S. and Mexican Rough Rice Demand

The annual supply of rough rice is either processed or carried over to the following marketing year. Rice processors convert rough rice into edible, milled rice thereby linking production at the farm level to consumption at the retail level. Rice processors choose the quantity to mill based on profitability as measured by the milling margin which is calculated as the difference between the milled rice price adjusted by the milling coefficient, and the farm price of rough rice:

(3.14) $M2 = (MP*MC) - FP$

where M2 = milling margin; MP = per cwt milled rice price; MC = milling coefficient, the fraction of milled rice obtained from a given quantity of rough rice; and FP = per cwt rough rice price.

In terms of producer theory, the milling margin is the first derivative the producer's unconstrained profit function with respect to the input, rough rice and represents the return to rice milling. This specification does not account for rice milling byproduct (bran, etc.) revenues or other variable costs such as wages. Nevertheless, byproduct revenues and other variable costs are small relative to milled rice revenues and rough rice input expenses, and are left out of the specification. However, processors are limited by both rough rice supply and milling capacity. Thus, processing demand is specified as a function of the milling margin, the supply of rough rice, and the milling capacity.

Rice is a storable crop that can be carried over to the following marketing year. When rough rice prices are low, producers may opt to store their harvest anticipating higher prices the following period. Large supplies of rough rice tend to depress rough rice prices and increase ending stocks. In addition, government programs that set a price floor below market price can increase ending stocks.

U.S. Rough Rice Demand

U.S. rice processors mill both long and medium grain rice. Processors determine the quantity of long grain rice to process by examining relative profitability, which is represented by the ratio of long to medium grain milling margins. As discussed above, they are constrained by the supply of rough rice (the sum of rough rice production and beginning stocks), and milling capacity.

U.S. rough rice ending stock demand is a function of the farm price of rough rice, the loan repayment rate, and rough rice supply. The loan repayment rate is determined by both the loan rate and the marketing loan program and represents the effective floor price. The loan rate acts as a price floor for producers by allowing them to forfeit their rice to the CCC. The marketing loan program has had a significant impact on stocks by allowing producers to repay loans at the lesser of the loan rate or the world price, which allows the possibility of setting the effective floor price below the loan rate.

U.S. rough rice demand is specified as follows:

(3.15) $USDP = f(USM2L/USM2M, USQPR+USESR_{t-1}, USMCAP)$

(3.16) $USESR = f(USFP, LRR, USQPR+USESR_{t-1})$

where all variables are assumed to be subscripted by t unless otherwise specified; USDP = U.S. rough rice processing demand; USM2L= U.S. long grain rice milling margin; USM2M = U.S. medium grain rice milling margin; USQPR= U.S. rough rice production; USESR = U.S. rough rice ending stocks; USMCAP = U.S. milling capacity; USFP = U.S. per cwt farm price; and LRR = U.S. per cwt loan repayment rate.

Mexican Rough Rice Demand

In Mexico, since all rice production is considered long grain, no variable representing a substitute commodity is in the estimated processing demand equation. Furthermore, since Mexico utilizes less than 30% of its milling capacity, milling capacity is not considered a constraint to processing demand.
Ending stocks are specified to be a function of the farm price, the guaranteed rice price, and rough rice supply. When in effect, the guaranteed price acted as a price floor with the government acting as the buyer of last resort.

Mexican rough rice demand is specified as follows:

(3.17) $MXDP = f(MXM2, MXQPR+MXESR_{t-1})$

(3.18) $MXESR = f(MXFP, MXGP, MXQPR+MXESR_{t-1})$

where all variables are assumed to be subscripted by t unless otherwise specified; MXDP = Mexican rough rice processing demand; MXM2= Mexican rice milling margin; MXQPR =

Mexican rough rice production; MXESR = Mexican rough rice ending stocks; MXFP = per cwt Mexican farm price; and MXGP= per cwt Mexican guaranteed price.

U.S. and Mexico Milled Rice Supply

Milled rice production is calculated by adjusting processing demand by the milling coefficient.

U.S. Milled Rice Supply

(3.19) USQPM = USDP*USMC

where USQPM = U.S. milled rice production; USDP = U.S. demand for processing; and USMC = U.S. milling coefficient.

Mexican Milled Rice Supply

(3.20) MXQPM = MXDP*MXMC

where MXQPM = Mexican milled rice production; MXDP = Mexican demand for processing; and MXMC = Mexican milling coefficient.

U.S. and Mexico Milled Rice Demand

Milled rice is either consumed or carried over to the next marketing year. Neoclassical demand theory suggests that the demand of a commodity be determined by its own-price, prices of substitute or complimentary commodities, income, and population. Like rough rice, milled rice is a storable crop and can be carried over to the next marketing year. Milled rice stocks in both countries are specified to be a function of their respective milled rice prices and supplies.

U.S. Milled Rice Demand

U.S. rice is consumed domestically in three primary outlets: (1) direct food use, (2) processed food use, and (3) beer (Welch and Williams). Unfortunately, the surveys that are used to compile the information on rice usage have not been done on an annual basis. As such, annual quantities of rice by use are impossible to ascertain. Therefore, domestic rice demand will be modeled as an aggregate commodity. The wholesale milled rice price will be utilized in lieu of the retail rice price. Medium grain milled rice competes with long grain rice for U.S. demand share and is used as a substitute commodity.

Based on the above considerations, U.S. milled rice demand is as follows:

(3.21) $USDD = f(USMP, USMPM, USPCY)*USPOP$

(3.22) $USESM = f(USMP, USQPM+USESM_{t-1})$

where USDD = U.S. domestic milled rice demand; USMP = per cwt U.S. price of long grain milled rice; USMPM = per cwt U.S. price of medium grain milled rice; USPCY = U.S. per capita income; USPOP = U.S. population; USPQM = U.S. milled rice production; and USESM = U.S. milled rice ending stocks;

Mexican Milled Rice Demand

Mexican milled rice demand is specified similarly to that for the U.S. with one exception. Unlike the U.S., Mexican rice is considered a homogeneous product. As such, prices of other milled cereal products are specified to represent a substitute commodity for rice demand.

Mexican milled rice demand is specified as follows:

(3.23) $MXDD = f(MXMP, CEREAL, MXPCY)*MXPOP$

(3.24) $MXESM = f(MXMP, MXQPM+MXESM_{t-1})$

where all variables are assumed to be subscripted by t unless otherwise specified; MXDD = Mexican domestic milled rice demand; MXMP = per cwt Mexican price of milled rice; CEREAL = per cwt prices of other cereal products; MXPCY = Mexican per capita income; MXPOP = Mexican population; MXQPM = Mexican milled rice production; and MXESM = Mexican milled rice ending stocks.

ROW Excess Demand

Since the U.S. exports rice to countries other than Mexico, and Mexico imports rice from countries other than the U.S., excess demand equations for the ROW must be specified to close the model. The U.S. imports and Mexico exports small quantities of rice. However, these quantities are assumed to be exogenous to the model. In addition, U.S. exports to Mexico have averaged 11% of total U.S. exports (Welch and Williams). However, Mexican imports from the U.S. have averaged almost 90% of total Mexican imports over the last decade. As a result, Mexican import demand from the ROW is considered to be exogenous to the system.

Equations (3.25) and (3.26) describe the specification of ROW excess demand equations for U.S. rough and milled rice:

(3.25) $USXRROW = f(ROWM2, USQPR+USESR_{t-1}, RXRR)$

(3.26) $USXMROW = f(USMP, WMP, USQPM+USESM_{t-1}, ROWPCGDP, RXRM)$

where all variables are assumed to be subscripted by t unless otherwise specified; USXRROW = ROW excess demand for U.S. rough rice; ROWM2 = ROW rice milling margin (WMP*ROWMC-USFP); USQPR = U.S. rough rice production, USESR = U.S. rough rice ending stocks; RXRR = Real trade weighted exchange rate for rough rice; USXMROW = ROW excess demand for U.S. milled rice; USMP = U.S. milled rice price; WMP= World Milled Price; USQPM = U.S. milled rice production; USESM = U.S. milled rice ending stocks; ROWPCGDP = ROW per capita GDP; and RXRM = Real trade weighted exchange rate for rice.

The ROW excess demand equations represent ROW demand for U.S. rice. As such, these equations are specified similarly to U.S. processing and domestic demand equations with the addition of an exchange rate variable. Since the ROW is made up of numerous countries, trade-weighted exchange rates will be used in lieu of bilateral exchange rates. U.S. rough and milled rice supplies are proxies for the amount of rough and milled rice, respectively, available for export. ROW rough rice excess demand supplied by the U.S. is specified to be a function of the ROW milling margin, U.S. rough rice supply, and the real trade weighted exchange rate for rough rice. ROW milled rice excess demand is specified to be a function of U.S. milled price, World milled price, U.S. milled rice supply, ROW per capita GDP, and the real trade weighted exchange rate for rice.

Rice Price and Trade Linkages

The domestic supply and demand and ROW excess demand components outlined above will be linked through price transmission and market clearing equations. Price transmission equations include equations linking the rough and milled markets of the U.S. to their Mexican counterparts. Mexican rice prices are not only affected by U.S. prices, but by the exchange rate and tariff rates as well. Mexican farm and milled rice price transmission equations are presented in equations (3.27) and (3.28):

(3.27) $MXFP = f(USFP, ER, RT)$
(3.28) $MXMP = f(USMP, ER, MT)$

where MXFP = Mexican farm price; USFP = U.S. farm price; ER = exchange rate; RT = rough rice tariff; MXMP = Mexican milled price; USMP = U.S. milled price; and MT = milled rice tariff.

Trade between the U.S. and Mexico will be determined through excess supply and demand equations. Excess supply and demand for the U.S. and Mexico are derived from their respective domestic market supply and demand equations. The ROW excess demand equations will be estimated directly as described above.

<u>Rough Rice Market</u>

(3.29) $USXRMX = USQPR + USMR + USESR_{t-1} - USDP - USXRROW - USESR$
(3.30) $MXMRUS = MXDP + MXXR + MXESR - MXQPR - MXMRROW - MXESR_{t-1}$
(3.31) $USXRMX = MXMRUS$

where all variables are assumed to be subscripted by t unless otherwise specified; USXRMX = U.S. rough rice exports to Mexico; USQPR = U.S. rough rice production; USMR = Total U.S. rough rice imports; USESR = U.S. rough rice ending stocks; USDP = U.S. processing demand; USXRROW = U.S. rough rice exports to the ROW; MXMRUS = Mexican rough rice imports from the U.S.; MXDP = Mexican processing demand; MXXR = Mexican rough rice exports; MXESR = Mexican rough rice ending stocks; MXQPR = Mexican rough rice production; and MXMRROW = Mexican rough rice imports from the ROW.

<u>Milled Rice Market</u>

(3.32) $USXMMX = USQPM + USMM + USESM_{t-1} - USDD - USXMROW - USESM$

(3.33) $MXMMUS = MXDD + MXXM + MXESM - MXQPM - MXMMROW - MXESM_{t-1}$

(3.34) $USXMMX = MXMMUS$

where all variables are assumed to be subscripted by t unless otherwise specified; USXMMX = U.S. milled rice exports to Mexico; USQPM = U.S. milled rice production; USMM = Total U.S. milled rice imports; USESM = U.S. milled rice ending stocks; USDD = U.S. domestic demand; USXMROW = U.S. milled rice exports to the ROW; MXMMUS = Mexican milled rice imports from the U.S.; MXDD = Mexican domestic demand; MXXM = Total Mexican milled rice exports; MXESM = Mexican milled rice ending stocks; MXQPM = Mexican milled rice production; and MXMMROW = Mexican milled rice imports from the ROW.

The complete conceptual model of the U.S. and Mexican rice industries is laid out in table 3.3. A description of the variables introduced in the conceptual model is presented in table 3.4. A graphical representation of the U.S.-Mexican conceptual model is presented in figure 3.2. The price-quantity graphs represent the U.S. and Mexican rice markets at a point in time, holding all other factors affecting these markets constant. Total U.S. rough rice supply and demand is represented in the U.S. rough rice market section. Total U.S. rough rice supply is the horizontal sum of rough production, rough beginning stocks and total rough imports while total U.S. rough rice demand is the horizontal sum of demand for processing, rough ending stocks, and rough exports to the ROW. Similarly, total Mexican rough rice supply and demand is represented in the Mexican rough rice market section. Total Mexican rough rice supply is the horizontal sum of rough production, rough beginning stocks, and rough imports from the rest of the world while total Mexican rough rice demand is the horizontal sum of demand for processing, rough ending stocks, and total rough rice exports. Rough rice trade and equilibrium price is determined by the intersection of the U.S. excess supply curve and the Mexican excess demand curve. The equilibrium price feeds back through the system to determine equilibrium quantities in each segment of the market. The rough and milled rice markets of each country are connected through the demand for processing. The quantity of rough rice demanded for processing in the rough rice markets becomes milled rice production in the milled rice markets.

Total U.S. milled rice supply and demand is represented in the U.S. milled rice market section. Total U.S. milled rice supply is the horizontal sum of milled production, milled beginning stocks and total milled imports while total U.S. milled rice demand is the horizontal sum of domestic demand, milled ending stocks, and milled exports to the ROW. Similarly, total Mexican milled rice supply and demand is represented in the Mexican milled rice market section. Total Mexican milled rice supply is the horizontal sum of milled production, milled beginning stocks, and milled imports from the rest of the world while total Mexican milled rice demand is the horizontal sum of domestic demand, milled ending stocks, and total milled rice exports. As with rough rice trade, milled rice trade and equilibrium price is determined by the intersection of the U.S. excess supply curve and the Mexican excess demand curve. The equilibrium price feeds back through the system to determine equilibrium quantities in each segment of the market.

Empirical Results and Model Validation

This section presents the results of the empirical analysis based on the conceptual model presented in the previous section. Data sources and considerations are discussed first followed by a description of the method of estimation. Next, estimation results are examined and finally, results of model validation are presented. The estimated model will be used for forecasting and simulation in the section of the report.

Data Sources and Considerations

Due to the unavailability of Mexican data prior to 1979 and after 1999, the time frame of the analysis is 1979-1999. Also, because a complete series of data was not available for all variables over the entire estimation period, some adjustments in the structure and specification of the model were necessary prior to estimation.

Numerous sources were used to obtain the data necessary for the analysis. For the model of U.S. rice markets, rice production, stocks, milling coefficients, prices, and government program data were obtained from the USDA (USDAc, USDAg, USDAh). U.S. rice trade data was gathered from the U.S. Department of Commerce and the U.S. International Trade Commission (USDOCc, USITC). U.S. macroeconomic indicators and population statistics were collected from the U.S. Department of Commerce (USDOCa, USDOCb). General U.S. price indices obtained from the U.S. Department of Labor.

The majority of relevant U.S. rice supply and demand data are published on a marketing year basis (August - July). For consistency, monthly trade and wholesale price data were accumulated and converted to a marketing year basis as well. Income and population data were only available on an annual basis.

For the model of Mexican rice markets, rice production, milling coefficients, farm price and government program data were gathered from the Secretaría de Agricultura, Ganadería, Desarollo Rural, Pesca Y Alimemtación (SAGARPAa, SAGARPAb). Mexican trade data were obtained from the Instituto Nacional de Estadística, Geografía E Informática (INEGI). Mexican population data were collected from the Food and Agriculture Organization (FAOa). Mexican macroeconomic indicators and an general price indices were obtained from the Banco de México. The Mexican wholesale price of rice was calculated by transforming an observation on the Mexican wholesale price of rice for 1998 as published by the Mexican Secretaría de Economía into a series of nominal prices utilizing the wholesale milled rice price index published by the Banco de México.

Unfortunately, Mexican rice inventory data does not exist. As a result, the equations representing Mexican stock demand were dropped from the econometric model. In addition, Mexican trade data were only available on a calendar year basis. Consequently, the market-clearing conditions that equate U.S. rice exports and Mexican rice imports were adjusted to account for the annual differences in U.S.-Mexico rice trade.

Finally, world population and income data were obtained from the World Bank while world rice prices and exchange rate data were obtained from the USDA (USDAa, USDAg).

Estimation Procedures and Results

The parameters of all model equations were estimated as a system using the 2SLS estimator in SAS to correct for simultaneous equation bias. Due to the large number of exogenous variables, the principal component procedure in SAS was utilized to form the instrumental variables necessary for 2SLS estimation. The principal component procedure condenses the instrument set while retaining its variance thereby allowing consistent parameter estimation (Bowden and Turkington, Kloek and Mennes). Each equation was then analyzed for statistical problems including autocorrelation, heteroskedasticity, outliers, structural change, etc. Modifications were made to some structural equations to correct for any problems found.

The results of econometric estimation of the model parameters are presented in table 4.1. Model variable definitions are presented in table 4.2. U.S. rough and milled rice market equations are discussed first followed by those of Mexico. Next, U.S. export demand equations are addressed. Finally, price and trade linkage equations are presented.

U.S. Rough Rice Supply and Demand

Prior to estimation, certain variables and equations were revised due to lack of relevant data. U.S. government yields, acreage allotments, and variable costs, components of the IRF are not published separately by grain length. As such, long grain government yields and acreage allotments were derived assuming that long grain government yields are the same proportion of published government yields as actual long grain yields are to actual total yields. Also, long grain acreage allotments were assumed to be the same proportion of total acreage allotments as actual long grain planted acreage is to total planted acreage. Long grain variable costs were assumed to be equal to national average variable costs.

Annual milling capacity statistics were not reported until 1994, when Food Research Associates began compiling *U.S. Rice Distribution Patterns* (McGilton). As a result, milling capacity was dropped from the U.S. processing demand equation.
U.S. rough rice supply and demand estimation results are presented in equations (4.1) through (4.5) of table 4.1. The equations provide a good fit of the data as evidenced by the coefficients of determination, or R-squares. Durbin-Watson and Durbin-h statistics indicate autocorrelation is not a major problem.

The U.S. acreage response functions in Equation (4.1) is specified to follow a partial adjustment mechanism similar to that proposed by Nerlove, a common practice in agricultural model estimation. Prior to planting, producers do not know the current value of their implicit revenue function since they do not know what prices (farm, world, etc.) will be at harvest. Consequently, an expected implicit revenue function (E(USIR)) is assumed to capture rice producer behavior in response to expected price changes and government policy changes as discussed in the previous section except that naive expectations are assumed so that the lagged price of rice rather than the current price of rice is used in IRF along with the current values of policy variables known prior to planting.

The estimating equation for the U.S. planted rice area (USAP), then, includes expected implicit revenue (E(USIR)), lagged acreage, and the acreage limit ratio (ALR). Additional variables included intercept dummy variables for the second farm program period and the years 1994 and 1996. The second farm program period (1982-1995) was the most complex and restrictive of the three periods, while the years 1994 and 1996 were outliers. Planted acreage is positively related to both E(USIR) and lagged acreage. The ALR is positively related as well and has the largest effect on planted acreage. The short-run E(USIR) elasticity of planted acreage is 0.19 while the long-run elasticity is 0.26, both of which are somewhat lower than the short- and long-run elasticities (0.28 and 0.71, respectively) calculated by Song and Carter for the Southern rice industry between 1975 and 1991.

The original specification for the USAP equation (4.1) included an expected IRF variable for both medium grain rice and soybeans. However, neither variable was a statistically significant determinant of U.S. rice planted acreage and, as a result, both were dropped from the final specification. This conforms to previous work done by Grant, Beach, and Lin.

Equation (4.2) indicates that changes in U.S. rice harvested acreage (USAH) is almost perfectly correlated with planted acreage and has average about 25,620 acres less each year than planted acreage over the period of estimation. Equation (4.3) is an identity specifying that U.S. rough rice production is the product of acreage harvested and yield in each year.

Estimated U.S. rough rice demand results are presented in equations (4.4) and (4.5) in Table 4.1. According to equation (4.4), the U.S. rice processing demand (USDP) is positively related to the U.S. long grain to medium grain milling margin ratio (USMMR) and the availability of rice for processing in each year represented by the sum of rice production and beginning stocks in each year ($USQPR+USESR_{t-1}$). The elasticity of processing demand with respect to the USMMR is 0.28 indicating processing demand is somewhat unresponsive to changes in the USMMR. The intercept dummy variable, DUSDP, represents the two years prior to the initiation of the marketing loan provision (1984 and 1985) that were characterized by significant stock build-up. Conforming to a priori expectations, the years of stock buildup had a negative impact on processing demand.

Equation (4.5) denotes that rough rice ending stocks are negatively related to the real farm price. Rough rice ending stocks are positively related to both the real loan repayment rate, the sum of U.S. production and beginning stocks, and DUSESR, a dummy variable representing years of abnormal stock buildup (1984 and 1985) and 1987, an outlier. As the loan repayment rate increases, producers choose not to redeem their loans leading to an increase in rough rice ending inventories. The dummy variable has the opposite sign in the ending stock demand equation than in the processing demand equation as expected. The elasticity of rough rice ending stock demand with respect to the real farm price is -1.76 indicating stock demand is highly responsive to farm price fluctuations.

U.S. Milled Rice Supply and Demand

Equations (4.6) through (4.8) in table 4.1 represent U.S. milled rice supply and demand. Given the unavailability of annual domestic rice demand data at the retail level as discussed in the preceding section, domestic demand is represented by total milled rice disappearance. In the final model, domestic per capita demand was estimated using a long to medium grain price ratio.

Equation (4.6) is an identity representing milled rice production, which is processing demand adjusted by the milling coefficient. Per capita milled rice demand is represented by equation (4.7). Per capita demand is negatively related to the long to medium grain price ratio and positively related to real per capita GDP. A one-unit decrease in the price ratio leads to an increase in per capita demand (measured in tenths of a pound) of 22.45 pounds, which implies an elasticity estimate of -1.57. A $1000 increase in real per capita GDP increases per capita demand by .741 pounds reflecting an income elasticity of demand of 1.38. Both estimates are above those calculated by previous researchers (Grant, Beach, and Lin, Song and Carter); however they amount to approximately two additional servings per capita per year above current consumption levels. Furthermore, Song and Carter stated higher price and income elasticities are to be expected when dealing with a heterogeneous product such as long-grain rice and using another rice type as a substitute commodity.

Estimated U.S. milled rice ending stock demand results are presented in equation (4.8). Milled ending stocks were specified to be a function of the real milled rice price, the sum of milled rice production and beginning stocks ($USQPM+USESM_{t-1}$), and DUSESM, a dummy variable representing the first two years of the marketing loan program (1986 and 1987). Milled rice ending stocks are negatively related to the real milled price. The sum of production and beginning stocks parameter is insignificant, but negative contrary to a priori expectations. However, milled rice inventories are characterized by extremely low annual variation, which presumably contributes to both the insignificance of the parameter and the relatively poor fit of the equation as a whole. Milled rice ending stocks are positively related to DUSESM. The elasticity of milled ending stock demand with respect to the real milled price is -0.48 which is much lower than the calculated price elasticity of rough ending stock demand.

Mexican Rough Rice Supply and Demand

Results of estimated Mexican rough rice supply and demand are presented in equations (4.9) through (4.14). Coefficients of determination and Durbin statistics indicate that the equations fit the data well and that autocorrelation is not a problem.

Since the Mexican government does publish production cost data, real expected Mexican IR (E(MXIR)) is simply total revenue per acre from rice production and government programs. An attempt was made to account for production cost through the addition of a Mexican labor cost index to the acreage response function. However, the labor cost index was an insignificant determinant of planted acreage and was dropped from the final specification. As such, planted acreage was estimated as a function of E(MXIR), lagged planted acreage and dummy variables for 1985 and 1989, years of abnormally high plantings. All coefficients have expected signs and are statistically significant at the 5% level. The short-run elasticity of planted acreage with respect to E(MXIR) is 0.76 while the long-term elasticity is 1.24, both of which are more responsive to E(MXIR) changes than their U.S. counterparts, which was expected since Mexican government programs have had no direct acreage restrictions as did those in the U.S.

Equation (4.10) indicates that changes harvested acres can be explained by changes in planted acreage and dummy variables for 1981 and 1986. A large portion of Mexican rice production is rainfed (Welch and Williams). In 1981, precipitation in the rainfed rice producing states was well above average leading to an increase in harvested acreage, while the opposite was true in 1986. All coefficients have the expected signs and are significantly different from zero. As expected, planted acreage has the largest effect on harvested acreage.

Mexican rough rice production is calculated in equation (4.11). Mexican rough rice processing demand is represented by equation (4.12) and is determined by the real Mexican milling margin (MXMM), rough production, and two dummy variables. The first dummy variable (DMXDP) represents the years following the end of the guaranteed price system (1990 and 1991). The second (DMXDP1) represents structural changes attributed to NAFTA (1996 through 1999). The response to NAFTA appears to be lagged owing to the Mexican economic crisis that began in late 1994. Since all rice in Mexico is considered long grain, an index of processed foods was employed to deflate the milling margin. Demand for processing is positively related to the milling margin and rough production as expected. The calculated milling margin elasticity of processing demand is 0.04 for 1999. The mean elasticity (not reported) was negative as a result of utilizing a price index to calculate the Mexican milled rice price. The price index presumably measures changes in retail prices that were set below guaranteed farm prices in some years. Consequently, calculated milled prices were lower than reported farm prices in the early portion of the estimation period, which resulted in negative milling margins.

Mexican Milled Rice Supply and Demand

Equation (4.13) calculates Mexican milled rice production. Mexican per capita demand is represented by equation (4.14). Demand was assumed to be a function of real milled price, a real cereal price index (a substitute), real per capita income, and dummy variables for 1985 and 1991, outliers. The elasticity of demand with respect to real price is -0.16, the cross price elasticity is 0.67, and the income elasticity of demand is 2.37. The own-price elasticity is less than half of that reported by Sullivan, Wainio, and Roningen for 1984. However, the accuracy of the reported elasticity is questionable from both the standpoint of current relevance and that the authors did not document the origin of the value. The income elasticity, like that in the U.S., seems quite high. This may in part be explained by the relative growth rates of Mexican rice consumption and real per capita GDP. Over the study period, Mexican per capita consumption has grown at an average annual rate of 7.65%, while per capita GDP has grown at a more modest rate of 0.81%. Furthermore, a specification of the equation consisting of a trend variable was estimated to determine if the real per capita income variable was reflecting changes in Mexican tastes and preferences. However, the trend variable was statistically insignificant, and the income elasticity was unaffected.

ROW Demand for U.S. Exports

Historically, the majority of U.S. rice exports have gone to countries other than Mexico. As a result, U.S. export demand equations for the ROW were estimated to close the model. The U.S. rough rice export demand is presented in equation (4.15). The estimated coefficient on the real ROW milling margin (ROWMM) is positive as expected. However, the coefficient on the rough trade-weighted exchange rate exhibits a sign opposite to that expected. Countries facing production shortfalls have few options regarding the source of rough rice imports since the U.S. is the only major rough rice exporter. Such countries may choose to import U.S. rough rice even with high exchange rates, a fact that may contribute to the sign of this parameter estimate. The dummy variables representing 1994, when Brazil imported a huge amount of rough rice, and the *El Niño* weather pattern (DEN) are both positive and highly significant.

U.S. milled rice export demand was estimated as a function of U.S. milled price, World milled price, the sum of milled production and beginning stocks, ROW per capita income and the real trade-weighted exchange rate for rice. The negative sign on ROW per capita income (ROWPCGDP) is interesting although not altogether surprising. A number of researchers have concluded rice to be an inferior good in certain countries where rice is a dietary staple (Ito, Peterson, and Grant). The price elasticity of export demand is -0.53, the cross-price elasticity is 0.37, and the income elasticity is -1.77.

U.S.-Mexico Price Transmission Equations

Price transmission equations for the U.S. and Mexico are presented in equations (4.17) through (4.19). Mexican farm and milled prices are estimated as functions of their U.S. counterparts, the nominal exchange rate, and tariff rates. These equations were difficult to estimate owing to hyperinflation in Mexico over the study period. Numerous specifications were estimated with varying degrees of success. These included the use of real versus nominal values of prices and exchange rates as well as linear and log-linear specifications. In the end, equation specification was determined by the best combination of statistical fit and simulation behavior.

The rough rice price transmission equation was estimated in double-log form (4.17) and converted to levels in equation (4.18). The estimated coefficients on U.S. farm price, the U.S.-Mexico exchange rate, and the rough tariff rate are positive as expected. In the rough rice market, the exchange rate has a larger impact than either the U.S. farm price or the tariff rate in the determination of Mexican farm price.

Equation (4.19) represents milled rice price transmission. Real Mexican milled price was assumed to be a linear function on the U.S. milled rice price, the nominal exchange rate, and the milled rice tariff rate. The estimated coefficient on U.S. milled price was constrained to be positive to ensure plausible results in estimation and simulation. The exchange and tariff rates positively impact Mexican milled rice price as expected.

Market Clearing Conditions

Equations (4.20) through (4.25) are identities representing the market clearing conditions for the domestic rough and milled rice markets of the U.S. and Mexico, respectively, as well as identities equating rough and milled rice trade between the two countries. Equations (4.24) and (4.25) were modified to take into account the fact that U.S. export data is on a marketing year basis, while Mexican import data is reported on a calendar year basis. The difference between U.S. exports to Mexico and Mexican imports from the U.S. was calculated annually and added to the market clearing equations for both rough (DROUGH) and milled (DMILLED) rice trade to account for the differences in data collection periods. Without the addition of these variables, even a perfect statistical model would not return the true values of U.S. exports to Mexico and Mexican imports from the U.S.

Model Validation

According to Kost, "The purpose of model validation is to increase one's confidence in the ability of the model to provide useful information" (p.1). Model validation focuses on how well the model fits individual equations, and how well it performs in simulation. Simulation performance is based on how well the model predicts the values of the endogenous variables within the sample period, how well the model responds to shocks, and model performance outside the sample period.

While a number of goodness of fit criteria have been proposed over the years, no single criterion exists for validating a multiple equation system. A model may fit individual equations quite well yet fail to track the data in simulation, and vice versa. As such, model validation consists of balancing both the performances of individual equations within the system, and the system as a whole. Since the individual equations of the model (as discussed above) seem to fit the data well, this section focuses on goodness of fit criteria for the whole model pertaining to historical simulation and exogenous shocks.

Historical Simulation

One set of goodness of fit criteria deal with simulation error, the difference between the simulated value and the actual value of any particular endogenous variable. Nominal error criteria include mean error, mean absolute error, and root mean square error (RMSE). Relative error measures include mean percentage error, mean absolute percent error, and root mean square percentage error (RMS%E). Of these, the RMS%E was determined to be the simulation error measurement of choice. By expressing error as a percentage, variables of differing measurements and magnitudes can be compared. Furthermore, RMS%E heavily penalizes large errors. As is the case with any error measurement, the smaller the value of the RMS%E, the better the predicted value tracks the actual value.

Cohen and Cyert proposed regressing the actual value of the endogenous variable on its predicted value:

$$(4.28) \qquad Y = \beta_0 + \beta_1 \cdot \hat{Y} + \varepsilon$$

This criterion ties into first of the two mean square error (MSE) decompositions proposed by Theil. The first set of criteria divides the MSE into a mean portion (U^M), a regression portion (U^R), and a deviation portion (U^D). By construction, $U^M + U^R + U^D = 1$. U^M, the mean or bias portion, reflects the differences in the means of the predicted and actual values. Values of U^M higher than 0.1 indicate a systematic bias in the equation, which must be modified (Pindyck and Rubinfeld). U^R, the regression portion, looks at the correlation between the predicted and actual value. The higher the correlation coefficient, the closer the value of β_1 (see equation 4.28) comes to one, and the lower the value of U^R. Finally, U^D deals with unexplained deviations, or the error term. Given a perfect fit (i.e. predicted = actual), $\beta_0 = 0$, and $\beta_1 =1$, which implies $U^M = U^R = 0$, and $U^D = 1$.

Similar to the first, the second Theil decomposition consists of three values summing to one: U^M, the same as before, U^S, and U^C. The variance portion, U^S, is an indication of the model's ability to track the variability of the endogenous variables. Large values of U^S indicate either the predicted or the actual values exhibit wide variation over the sample period while the other does not. In either case, the model may need modification. The covariance portion U^C measures error remaining after the mean and variance portions have been taken into account. The ideal distribution for this decomposition is $U^M = U^S = 0$, and $U^C = 1$ (Pindyck and Rubinfeld).

Both MSE decompositions are based on Theil's inequality, a composite measure of individual variable goodness of fit. Theil's U is calculated as the RMSE of the simulation scaled such that it returns a value between zero and one. A perfect forecast, by definition, would have a RMSE of zero and thus Theil's U = 0. The worst possible forecast would return a Theil's U value of one.

Turning point errors are yet another criteria for model validation. A turning point in the data occurs when the change from one period to the next is in the opposite direction of the change in the preceding period. For an econometric model to be considered superior to a time trend model, it must be able to predict turning points (Kost). A turning point error can occur in two instances. Either the actual value exhibits a turning point, while the predicted value does not, or the actual value does not exhibit a turning point and the predicted value does.

Model validation statistics for the U.S - Mexico rice trade model are presented in table 4.3. Values for the RMS%E are respectable with a few notable exceptions. The extremely high values for the log of Mexican farm price (LMXFP) and Mexican milled rice imports from the U.S. (MXMMUS) were due to the fact that in the early part of the sample predicted and/or actual values switched from negative to positive. In the case of LMXFP, the log of a value less than one is negative. Actual values of Mexican farm prices were less than one prior to 1984. Predicted values of MXMMUS were negative in a few early years, while the actual values were positive. This is not a huge problem as the model simply predicted Mexico to export small quantities of milled rice to the U.S. instead of importing, which actually occurred. With regard to U.S. rough rice exports to Mexico (USXRMX), Mexican rough rice imports from the U.S. (MXMRUS), and U.S. milled rice exports to Mexico (USXMMX), the RMS%E is undefined when the actual value of the variable is zero, which was the case for each of these variables in at least one year.

Regression of the actual values on the predicted values yielded the estimates of β_1. In all but E(MXIR), USXMMX, and MXMMUS, the null hypothesis that $\beta_1 = 1$ could not be rejected at the 1% level. The high values of U^D for these variables and low values for the remaining variables reinforce this fact. The U^M statistic indicates an absence of systematic bias in the model since all values are well below 0.1. The model also appears to track the variation of the endogenous variables well as evidenced by the relatively low U^S statistic.

Theil's U indicates the model forecasts the endogenous variables well with the exception of the variables representing trade between the U.S. and Mexico, especially milled rice trade. The same can be said of the turning point errors. All of these variables are identities. As such, they seem to capture the majority of the majority of the simulation error in the model. The large number of turning point errors in the variables representing Mexican rough rice production (MXAP, MXAH, and, MXQPR) are not altogether surprising due to the high annual variation exhibited by these variables.

Exogenous Shocks

Applying exogenous shocks to econometric models can be used to validate certain model characteristics. Model stability can be ascertained by checking the length of time before the model returns to equilibrium. In addition, one can determine whether or not the model responds to shocks in a manner consistent with economic theory (Pindyck and Rubinfeld). Dynamic multipliers and elasticities are measures of a model's response to shocks. Multipliers reflect actual changes in endogenous variable due to a one-time shock to the system, while elasticities measure these changes in percentage terms. Dynamic multipliers and elasticities for selected variables (milled rice trade, prices, and domestic demand) in the U.S.-Mexico rice trade model responding to a 10% decrease in the Mexican milled rice tariff in 1990 are presented in table 4.4. Results indicate that the model is quite stable as values return quickly to their equilibrium levels. In addition, all variables responded in accordance with economic theory (figure 4.1). A reduction in the Mexican milled rice tariff increases effective Mexican purchasing power, which is denoted by the rightward shift of the Mexican excess demand curve. As a result, Mexican milled rice imports from the U.S. increase, U.S. milled rice price increases, and Mexican milled rice price decreases. The decrease in Mexican milled price leads to an increase in domestic quantity demanded. The increase in U.S. milled rice price has the effect of decreasing domestic quantity demanded.

Simulation Analysis of the Effects of NAFTA on U.S. and Mexico Rice Markets and Trade

To analyze the historical and potential future effects of NAFTA on U.S. and Mexican rice markets and trade, the model developed and estimated in the preceding sections of this report is simulated over the historical and a forecast period to measure the effects of the declining tariff rates under NAFTA. Also, the effects of the Mexican economic crisis of the mid-1990s and those of various potential rates of Mexican income growth are measured in the same way and compared to those of NAFTA to assess their relative importance for the performance of U.S. rice exports to Mexico historically and over a future forecast period.

To perform the simulation analysis, a ten-year baseline forecast is first established. The baseline forecast provides estimates of the values of the endogenous variables over the next decade assuming NAFTA will remain in effect and all other exogenous variables follow paths devoid of extreme events (weather, etc.) and consistent with past market behavior. Once the baseline forecast is established, the past and potential effects of the exogenous factors on the rice industries of the U.S. and Mexico will be measured by simulating off the baseline and comparing the results to the baseline.

Baseline Forecast

In order to create the baseline forecast on which the simulation analysis is based, the exogenous variables in the model were first forecast out over the ten-year horizon. The quality of the baseline forecast depends on the accuracy of the exogenous variable forecasts. Where applicable, exogenous variable forecast estimates were obtained from the *World Agricultural*

Outlook as published by the Food and Agricultural Policy Research Institute (FAPRI), the U.S. Department of Commerce (USDOCb), and the USDA (USDAi). Otherwise, forecasts for exogenous variables were assumed to follow long-term trends. Forecast values for selected exogenous variables are presented in table 5.1.

U.S. Exogenous Variable Forecasts

Exogenous variables pertaining to U.S. long grain rice supply and utilization include long grain yields, and imports as well as medium grain rice rough and milled prices. Unfortunately, forecasts obtained from FAPRI consider only total U.S. rice supply and utilization. As such, regression techniques were employed to obtain forecasts for the exogenous variables on a grain-type basis. Long grain rice yields were calculated by first regressing historical long grain rice yields on historical total rice yields. The estimated coefficients were then applied to the annual FAPRI projections for total rice yields to obtain long grain rice yield forecast values. Medium grain rough and milled prices, and long grain milled rice imports were calculated similarly. Long grain rough rice imports were assumed to be zero.

Gross domestic product and population projections were obtained from FAPRI and the U.S. Department of Commerce (USDOCb), respectively. U.S. IRF variables (loan rates, PFC payments, etc.) take into account the 2002 Farm Bill that is in effect through 2007, and were gathered from the USDA (USDAi). Values for 2008 and 2009 were assumed to be the same as those for 2007. Both the milling coefficient and the farm price index were based on the average growth rates of the last ten-years.

Mexican Exogenous Variable Forecasts

Exogenous Mexican rice supply and utilization variables include yield, rough and milled exports and imports from the ROW. Mexican yield was obtained from FAPRI. Mexican rough rice exports and rough rice imports from the ROW were assumed to be zero. Mexican milled rice exports and milled rice imports from the ROW were calculated using a ten-year moving average. As a result of the extreme annual variation exhibited by these variables, the use of average growth rates would yield implausible forecast values.

Gross domestic product and population projections were obtained from FAPRI and the U.S. Department of Commerce (USDOCb), respectively. Mexican IRF variables (payments and payment quantities and acres) were assumed to be same as those in 1999, the last year available. Inflation statistics (farm price, processed food, labor cost, and cereal indices) were calculated utilizing simple regressions of each index on Mexican CPI. The coefficients were then applied to the FAPRI projections for Mexican CPI. The U.S.-Mexico exchange rate projection was obtained from FAPRI.

ROW Exogenous Variable Forecasts

World total GDP and population forecasts were obtained from FAPRI and the U.S. Department of Commerce (USDOCb), respectively. World totals were converted to ROW values by subtracting out the values of the U.S. and Mexico. World milled price was taken directly from FAPRI and world CPI forecasts were based on average growth from the previous ten years.

Baseline Forecast Results

Baseline forecast results for selected U.S. and Mexican rice market endogenous variables are presented in tables 5.2 and 5.3, respectively. U.S. rough rice production is expected to increase 2% annually over the forecast period, from just under 129 million cwt in 2000 to just under 181 million cwt in 2009 (table 5.2). U.S. rough exports to the ROW are projected to grow at an annual rate of 6%, while rough exports to Mexico are expected to remain relatively stable implying a 3% annual increase in total rough rice exports over the forecast period. Processing demand growth mirrored that of production and is forecast to increase from almost 113 million cwt in 2000 to just less than 158 million cwt in 2009. U.S. farm price is projected to remain relatively stable, increasing 2% annually from 2000 to 2009.

U.S. domestic demand is expected to grow from just over 52 million cwt in 2000 to approximately 89 million cwt in 2009. This increase can be attributed to a projected 1% annual decrease in milled rice price and an approximately 0.8% increase in population. Increased domestic demand is forecast to lead to a decrease in total milled rice exports. However, changes in exports by destination greatly differed. Milled rice exports to the ROW are expected to decrease 8% annually, while exports to Mexico are expected to increase dramatically from just over 1 million cwt in 2000 to almost 11 million cwt in 2009.

Mexican rough rice production are forecast to decrease from just under 8 million cwt in 2000 to almost 6 million cwt in 2009 (table 5.3). In addition, rough imports from the U.S. are expected to decrease from just over 12 million cwt in 2000 to just over 11 million cwt in 2009. Mexican farm price increases 5% annually over the forecast period. Due to projected increases in farm prices and decreases in production and imports, Mexican rough rice processing demand is forecast to decrease from approximately 20 million cwt in 2000 to just over 17 million cwt in 2009.

Mexican domestic demand increases 5% annually from approximately 15 million cwt in 2000 to a projected nearly 23 million cwt in 2009 in spite of a 6% annual increase in milled rice price. Domestic demand increases are attributable to increasing per capita income and population. Recall from an earlier discussion that the income elasticity of demand outweighs the price elasticity of demand in Mexico. Increases in domestic demand are met by large increases in imports from the U.S. that make up for the marginal decrease in milled rice production.

No-NAFTA Scenario

To isolate the effects of NAFTA from other market factors that may have had an effect on U.S. and Mexican rice markets since 1994, the model was simulated over the 1994 to 2009 period assuming NAFTA was not implemented. The counterfactual simulation of No-NAFTA assumed that Mexican rough and milled rice tariffs remained at their pre-NAFTA levels and that all other exogenous variables followed the paths described by the baseline. The effects of NAFTA are then determined by calculating the differences of the endogenous variables from the baseline forecast. The results are presented in tables 5.4 and 5.5 for Mexico and the U.S., respectively.

As one might expect, the effects of NAFTA are much greater in Mexico than in the U.S. In addition, the effects of NAFTA are much greater in the milled rice market than in the rough rice market in both countries. This result is due to the incremental nature of the tariff elimination schedule, which is much steeper in absolute terms in the milled market, decreasing two percentage points per year.

Mexican rough rice production, processing demand, imports, and farm price all decreased as a result of NAFTA (table 5.4). Moreover, the effects of NAFTA are magnified as the tariff level declines. Mexican rough rice production began decreasing in 1997 and is expected to be almost 18% less in 2009 than it would have been without NAFTA. The decrease in production is attributable to the decrease in farm price, which is projected to decrease 17% relative to the No-NAFTA scenario by 2003. One would normally expect a decrease in farm price to stimulate processing demand; however, the decrease in the milled rice price outweighed the decrease in farm price. As a result, milling margins declined, which led to decreased demand for processing. Imports from the U.S. declined marginally due to decreased processing demand although not nearly as much as rough rice production.
The effects of NAFTA in the Mexican milled market were as expected. Milled rice production decreased due to decreases in processing demand as explained above. Milled price decreased, which stimulated increases in both domestic demand and milled imports from the U.S. Like the Mexican rough rice market, the effects of NAFTA on the Mexican milled rice market are magnified over time due to the tariff phase-out schedule. Once the tariff rate becomes zero in 2003, changes from the No-NAFTA scenario are expected to level out and even decrease in most cases.

In the U.S., the effects of NAFTA were minimal with the exception of rough and milled rice exports to Mexico (table 5.5). U.S. rough production was basically unaffected. Processing demand increased slightly from 0.1% in 1994 to a projected 0.4% in 2009 as a result of higher milled and rough prices. As discussed above, changes in processing demand are determined by changes in milled and rough prices, and rough production. In the case of the U.S., milled prices increased more than farm prices, which led to the marginal increase in processing demand. Rough exports to Mexico showed the most difference from the No-NAFTA scenario, being 1.7% less in 1994 and an expected 4.9% less in 2009 as a result of NAFTA.

U.S. milled rice production increased as a result of increased processing demand. Domestic demand decreased due to increases in the U.S. milled price. As a result, less milled production remained in the domestic market. Exports to Mexico grew to satisfy increased Mexican import demand. The increases in milled rice exports to Mexico seem quite large at first glance. However, exports to Mexico represent a small portion of total U.S. milled rice exports. Thus, small absolute changes (in terms of quantity) lead to large percentage changes.

No-Devaluation Scenario

At the end of 1994, the inaugural year of the NAFTA agreement, Mexico experienced an economic crisis as a result of peso devaluation. The value of the Mexican peso dramatically decreased along with national income. The devaluation began in December 1994 and carried

through 1995. Saddled with a weaker peso and lower income, Mexico's purchasing power was dramatically reduced. Because the economic crisis coincided with the beginning of NAFTA, numerous groups blamed the agreement for the decline in exports to Mexico. In order to disentangle the effects of the devaluation from those of NAFTA and other market influences, the baseline was simulated under the counterfactual of No-Devaluation while allowing all other exogenous variables to follow the paths described by the baseline. The No-Devaluation scenario assumed that the peso devaluation and associated effects on the Mexican real GDP were a three-year shock to the system. Thus, for the years of 1994 through 1996, the exchange rate and GDP were assumed to grow at the rates at which they were forecast to grow by FAPRI a year *before* the devaluation actually occurred. Because the devaluation was largely unanticipated, the FAPRI pre-devaluation forecasts of the dollar-peso exchange rate and the real Mexican GDP did not include any major adjustments during the subsequent three-year period. The result is a shift in the values of the exchange rate and the real Mexican GDP in those three years which was the most plausible assumption. The effects of the economic crisis were determined by analyzing simulated differences from the baseline forecast. The effects of the Mexican economic crisis on the rice Markets of the U.S. and Mexico are presented in tables 5.6 and 5.7 for Mexico and the U.S., respectively.
Like the effects of NAFTA, the effects of the crisis were greater in Mexico than in the U.S., and greater in the milled rice market regardless of country. Mexican farm price increased as a result of the crisis, which led to increased rough rice production (table 5.6). By 2009, production is expected to be almost 140% greater than would have been expected had the Mexican economic crisis not occurred. Processing demand decreased from 1994 through 1996 then began increasing throughout the remainder of the forecast period. Rough imports from the U.S. decreased to almost 18% below the No-Devaluation scenario by 1995. By 2000, increased processing demand is anticipated to temper the reduction in imports to an almost steady 8% below the No-Devaluation level.

In the Mexican milled rice market, decreased per capita income coupled with the large increase in milled price caused Mexican domestic demand to drop almost 25% relative to the No-Devaluation level in 1995. In response to decreased demand and increased milled rice production, Mexican milled rice imports from the U.S. plummeted 63% in 1995, dropped to a level just under 90% less than the No-Devaluation scenario in 1997 and are expected to be 45% lower in 2009 as a result of the economic crisis.

Effects of the crisis on the U.S. rough rice market were less severe. U.S. rough production and processing demand were virtually unaffected. Rough exports to Mexico were significantly less than No-Devaluation levels from 1995 through 2000 after which they are likely to be around 8% below the No-Devaluation levels. U.S. farm price decreased over the period from 0.3% less than the No-Devaluation level in 1999 and is expected to be just over 12% less than the No-Devaluation level in 2009.

The milled rice market was more affected by the crisis than the rough rice market. Milled price was increasingly lower as a result of the crisis, which lead to an increase in U.S. domestic demand. U.S. milled rice exports to Mexico were the most affected by the Mexican economic crisis. After an initial increase, milled rice exports to Mexico were 56% less in 1995, and are likely to remain below the No-Devaluation level for the remainder of the forecast period. Milled rice production was relatively unaffected by the economic crisis.

Comparison of the Relative Effects of NAFTA and the Mexican Peso Devaluation

To accurately compare the relative effects of NAFTA and the Mexican peso devaluation on rice trade between the U.S. and Mexico, the impacts of each scenario must be measured from a common base. To accomplish this, the model was simulated assuming that neither NAFTA nor the devaluation took place. This simulation was termed the null base forecast. The differences between the baseline forecast and the null base forecast are a measure of the combined effects of both NAFTA and the devaluation. In a purely linear model, the combined effects of NAFTA and the devaluation would simply be the sum of their individual effects. However, the Mexican rough rice price transmission equation was specified to be linear in logs. As a result, the sum of the individual effects is larger than the combined effects. Fortunately, the differences were small and the calculated relative effects are approximately equal to the true relative effects.

The combined effects of NAFTA and the Mexican peso devaluation on U.S.-Mexico rice trade are presented along with their approximate relative contributions in table 5.8. The table is divided into sections for Mexican rough and milled rice imports from the U.S. that are subdivided into past effects (1994-1999) and the likely effects over the next decade (2000-2009).

Rough Rice Trade

NAFTA and the devaluation induced economic crisis in Mexico together decreased Mexican rough rice exports from the U.S. from 1994 through 1999. The relative impacts of NAFTA were magnified over this period due to the incremental nature of the tariff reduction. NAFTA was responsible for 18% of the decrease in rough rice imports in 1994. By 1999, NAFTA accounted for 31% of the rough rice trade reduction. From 1994 to 1999, the impacts of the crisis were much greater than those of NAFTA. The economic crisis contributed 78% of the total reduction in rough rice imports with NAFTA responsible for the remaining 22%.

Over the forecast period (2000-2009), NAFTA is expected to have about the same impact on the reduction of Mexican rough rice imports from the U.S. as does the economic crisis. NAFTA was responsible for 41% of the anticipated reduction in rough rice trade in 2000, but accounted for 50% in 2009. The relative effects of the devaluation, on the other hand, are expected to diminish over the forecast period.

Milled Rice Trade

From 1994 through 1999, the economic crisis had a much larger relative effect on milled rice trade between the U.S. and Mexico than did NAFTA. Both NAFTA and the crisis increased trade in 1994. However, the devaluation greatly decreased trade post-1994. By 1999, the devaluation was responsible for 126% of the decrease in Mexican milled rice imports from the U.S. NAFTA actually mitigated the effects of the economic crisis. Had NAFTA not been enacted, Mexican milled rice imports would have been 26% less from 1994 through 1999 than they actually were. This result is contrary to the assertions of many anti-NAFTA activists in the U.S. who held NAFTA responsible for decreased U.S. exports to Mexico.

Similar to the period from 1994 to 1999, the Mexican economic crisis is expected to have the greatest impact on Mexican milled rice imports from the U.S over the next decade. However, NAFTA is expected to further diminish the impact of the crisis. Mexican milled rice imports are expected to neutralize 30% of the negative effects of the crisis in 2000 and 37% by 2009.

Mexican GDP Growth Scenario

One of the key factors complicating an analysis of the effects of NAFTA on U.S.-Mexico rice trade is that Mexican per capita incomes were growing in most years leading to increased demand for rice and, therefore, increased Mexican imports of U.S. rice. The estimated income elasticity estimated for Mexican rice demand suggests that increases in Mexican per capita income have large positive impacts on Mexican rice demand. The grow in incomes along with the stagnation of domestic rice production in Mexico over time likely pushed Mexico to look to the U.S. to fill the increasing domestic demand for rice to some extent. To measure the extent to which Mexican income growth has impacted Mexican imports of U.S. rice, the real Mexican GDP was conservatively assumed to grow at an annual rate 1% lower than their baseline values over the historical and forecast period and the model was then re-simulated over that period. Measuring from the new, simulated values of endogenous values back to their baseline values provides an indication of the contribution of Mexican income growth to the actual and forecast level of U.S. rice exported to Mexico over the actual and forecast periods. Thus, the measured changes in rice trade as well as in U.S. and Mexican supply and demand for rice from their simulated back to their baseline values presented in tables 5.9 and 5.10 for Mexico and the U.S., respectively, provide an indication of the impact of the growth in income that occurred over the historical period and likely to occur over the forecast period on U.S. and Mexican rice markets.

The simulation results suggest that the effects of the growth in the real Mexican GDP was and is expected to continue to be minimal in the rough rice market of Mexico (table 5.9). Both Mexican farm price and production increase only marginally. The Mexican farm price would likely have been only 0.3% greater in 2000 than would have been the case without the actual growth in real GDP that occurred and only 2.4% greater in 2009 than would be the case at a lower rate of growth in real GDP than assumed in the forecast baseline. Mexican rough rice production is measured to be 2.3% greater in 2009 than the would be the case at a lower assumed rate of real GDP growth. Processing demand and rough imports from the U.S. would be basically unaffected.

The actual rate of real GDP growth that occurred and was assumed for the forecast period implied a large impact on Mexican domestic rice demand compared to what would have occurred at a slightly lower rate of actual and forecast real Mexican GDP growth. Because the Mexican production of milled is relatively unaffected by the actual and forecast growth in Mexican real GDP, the large increase in Mexican rice demand resulting from the actual and forecast growth in Mexican GDP is met with large increases in milled imports from the U.S. The simulation results imply that the actual and likely growth in Mexican GDP is responsible for boosting milled rice imports from the U.S. by at least 30% on average in each year over the simulation period than would have been the case otherwise.

The simulation results also suggest that the primary effect of past and future growth in real Mexican GDP is likely to be an increase in U.S. milled rice exports to Mexico along with a boost in the U.S farm and milled prices of rice (table 5.10). In essence, the results suggest that an increase in Mexican incomes translates almost directly into increased U.S. exports of milled rice which comes primarily out of U.S. rice consumption rather than from increased U.S. rice production or processing. At the same time, the results suggest that even though Mexican income growth has a slightly negative impact on U.S. rough rice exports, the increase in the price of rough rice is sufficient to generate an increase in the value of U.S. rough rice exports to Mexico.

Summary and Conclusions

The general objective of this study was an analysis of the implications of NAFTA for the rice industries of the U.S. and Mexico. The basic tool of analysis was a 27 equation, nonspatial price equilibrium model of the U.S. and Mexican rice industries and trade. Given the characteristics of U.S. and Mexican rice markets and their interaction through trade and the availability of data, only long grain rice was considered in the analysis although the rice markets in each country were split into the interrelated sub-markets of rough and milled rice in order to analyze the market and trade effects of the declining tariff differential between the two types of rice. Government programs, which have heavily influenced rough rice production in the U.S. and Mexico, were integrated into the model utilizing implicit revenue functions for each country.

Validation of the model through historical simulation indicated that the model tracks the behavior of U.S. and Mexican rice markets over the historical period extremely well with few turning point errors. In addition, the model is stable to shocks in key exogenous variables, returning to equilibrium following the shocks within a reasonable period of time in directions consistent with expectations and economic theory.

To analyze the effects of the tariff elimination under NAFTA on U.S. and Mexican rice markets and trade, a ten-year baseline forecast was first established with the model. The baseline provided estimates of the values of the endogenous variables over the next decade assuming NAFTA remained in effect and all other exogenous variable follow paths devoid of extreme events (weather, etc.) and consistent with past market behavior. Then the model was used to simulate four scenarios: (1) No NAFTA; (2) No Devaluation; (3) No NAFTA or Devaluation; and (4) Lower GDP Growth over the historical and forecast time period.

In general, the simulation results under the four scenarios suggest that the combined effects of NAFTA and the 1994-95 peso devaluation on U.S. exports of both rough and milled rice to Mexico have had and are expected to be negative. In the case of U.S. milled rice exports, however, the results suggest that NAFTA has had and will continue to have a large positive effect, offsetting to a great extent the large negative effect of the devaluation. Thus, despite the fact that U.S. milled rice exports to Mexico have actually declined since NAFTA was implemented, NAFTA has helped boost the level of those exports, contrary to the concerns expressed by some in the U.S. rice industry. The primary reason for the decline has been the devaluation of the Mexican peso and the accompanying economic crisis in Mexico.

This study also finds that perhaps more important that either NAFTA or the Mexican economic crisis of the mid-1990s for the future of U.S. rice exports to Mexico is the annual rate of economic growth in Mexico. Just a 1% increase in the real Mexican per capita GDP would generate an annual increase of 30% in U.S. milled rice exports to Mexico as well as higher U.S.

farm and milled rice prices. At the same time, Mexican domestic demand would likely increase reaching a level almost 20% above the baseline in 2009.

Other key conclusions from the simulation analysis include the following:

- The devaluation is the major reason why U.S. rice exports to Mexico have not switched from rough to milled form as many researchers had predicted and many in the U.S. rice industry expected.

- Rough rice exports were 20% lower than they would have been in 1995 if the Mexican peso devaluation had not occurred while U.S. milled rice exports to Mexico were 56% less in 1995 and 84% less in 1999 as a result of the devaluation.

- From 1994 through 1999, NAFTA accounted for 22% of the total reduction in U.S. rough rice exports to Mexico with the devaluation accounting for the remaining 78%.

- Had the devaluation not occurred, U.S. milled rice exports to Mexico would have been expected to surpass rough rice exports by 2003 (rough basis) and would have been expected to be about twice as large by 2009.
- U.S. milled rice exports to Mexico are likely to be over twice as large in 2003 as might have been the case if NAFTA not been implemented. By 2009, milled rice exports to Mexico are likely to be 30% greater than otherwise as a result of NAFTA.

- NAFTA has had a negative effect on the rough rice market of Mexico. Mexican farm prices, production, and quantity demanded for processing all decreased as a result of the agreement.

- The peso devaluation, on the other hand, has had and is expected to have an overwhelmingly positive impact on Mexican rice production at the expense of the consumption of rice in Mexico. Mexican farm prices of rice since the 1995 have been more than double what they would have been largely as a result of the devaluation.

- Mexican rough rice production is expected to increase roughly 3 million cwt above what would have been expected had the devaluation not occurred over the next decade.

- The Mexican peso devaluation has had the effect of depressing Mexican milled rice demand which has retarded the growth in Mexican milled rice imports from the U.S.