International sorghum trade: United States beyond the Mexican dependency?

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Abstract

This research proposes the estimation of a partial equilibrium econometric and simulation international trade model for sorghum: United States and Mexico component. Sixteen equations were simultaneously estimated and validated as a system using seemingly unrelated regression. Results on parameter estimates agree with economic theory and a working model for simulation and forecast was obtained. Forecast scenarios suggest that the dependency of sorghum trade between US and Mexico will continue.

Key Words: Supply, Demand, NAFTA, International trade, Sorghum

Introduction

Grain sorghum is the third major coarse grain produced worldwide, only behind corn and barley. For the last 40 years, the United States (US) has been the world's highest producer of sorghum. However, as the total world's sorghum production increased from 54.8 to 63.1 M Mton from 1969 to 2008, the US contribution to that total declined from 33 to 18% (PS&D, 2008). In 2008, the US, Nigeria, India, and Mexico produced 18, 16, 11, and 10% of the world's total respectively, while all other countries produced the remaining 46% (PS&D, 2008).

During the 1960's and 1970's sorghum production in the US was intended to satisfy the animal feed industry demand; in the eighties, the perception that corn had superior nutritional characteristics and was better suited to fulfill livestock requirements, occasioned the feed industry to start substituting sorghum with corn in the animal rations. This shift in preference induced, on the long run, an increase in corn and a reduction in sorghum productions, closing the price gap between these grains, making corn an even better option instead of sorghum. Given those facts, the amount of sorghum available for industrial use or export has been growing. Regarding industrial use, albeit sorghum is a viable input for ethanol production this alternative has not been implemented to its potential, "Currently, in the US, feedstock for commercial ethanol production is 95% corn grain and 4% sorghum grain" (RFA, 2007) thus, industrial local demand for sorghum has not grown and therefore, has not positively impacted the local sorghum production. Domestically, about 80% of grain sorghum production is concentrated in Texas, Kansas and Nebraska. In TX, sorghum is a secondary crop to cotton; in Kansas and Nebraska sorghum competes with corn, wheat and soybeans for limited cropland. by 2008, even though sorghum yields have been constant, production was at a low 11.4 M Mton., while planted area underwent a cut down of 54%, with respect to that of 1969 (PS&D, 2008). In contrast, during the same period of time, the US exports of sorghum increased from 3.20 to 6.7 M Mton which represents a gain of 22 points on market share (from 54 to 76%; PS&D, 2008). The fact that sorghum is mainly produced in areas where it can be substituted, the low local industrial use, and the diminishing use of sorghum as a staple for the animal feed industry, have forced the US sorghum industry to be highly dependent on foreign markets. Furthermore, the amount of sorghum locally produced and used, has decreased to a point where the main objective of the production process seems to be international trade. Basically sorghum in the US became an exportable commodity.

In the case of Mexico, the initial boost of sorghum production was based on agricultural policies implemented during the 1940's and strengthened in the 1950's. During this time, new irrigation strategies were established, increasing the amount of land available for cropping. Additionally, the feed industry and the poultry and pork sectors grew at an accelerated rate (Caamal and Dorantes, 2004). Once sorghum production was consolidated on irrigated land, and with a still rising domestic demand for the grain, producers in dryland areas adopted the crop at the expense of corn. In the early 1990's, poultry and pork production underwent another rapid growth period thus, increasing the sorghum domestic demand even further and to a point where the national production was unable to satisfy it, making Mexican feed industry highly dependent on foreign markets. By 2008 Mexico was the third world's largest producer of sorghum; however, local production was only about 50% of the domestic demand. However, additional changes on the Mexican poultry sector, due to NAFTA and the expansion of US poultry companies into Mexico have contributed to the decline of the Mexican demand for sorghum.

Given the sorghum availability in the US, the need for Mexico to fulfill its demand for the grain, and the geographical proximity between these two countries, trade was the natural path to follow. Within a few years, the US became Mexico's only supplier of sorghum and Mexico became the main market for US sorghum, importing about 60% of the US sorghum available for international trade. In 2008, the US and Mexico were the first and fourth world's largest sorghum producers, respectively (PS&D, 2008). From 1969 to 2008, the US has been the largest exporter, while Mexico has moved back and forth from being the 15^{th} largest importer in 1969 to the world's largest importer of sorghum since 1986, when unilaterally, the Mexican government decided to liberalize the sorghum market (USDA, 2008). Furthermore, when NAFTA was signed, Mexico removed the seasonal 15% ad-valorem tariff for sorghum and established a 15 year tariff elimination schedule for corn, with a tariff-rate quota system and a high tariff out of quota of about 241% to US and Canada. Tariff rated quotas were imposed to corn to give Mexican sorghum and corn producers a period of adjustment to free trade. Sorghum producers would have the added advantage of delaying competition with corn in the feed industry. NAFTA also included a tariff schedule elimination for chicken and chicken legs of ten and 15 years, respectively. However, regardless the terms of the agreement, corn from the US entered the Mexican market without paying the high out of quota tariffs, causing a steeper decline on the Mexican sorghum demand. If complete substitution has not occurred at this time is due to the still significant corn-sorghum price gap.

In the context where international trade of sorghum being dominated by the relationship between Mexico and the US, a partial equilibrium econometric and simulation international trade model was constructed as the first step in the understanding of the sorghum production-utilization process. At this stage the objectives of such model were to estimate a medium-term baseline forecast until the year 2016 and to simulate alternative scenarios on variables identified as critical, such, as sorghum prices in both countries and the amount of sorghum that could be exported to Mexico.

Literature review

When reviewing scientific and technical literature to document this research, we found out that, although there are countless works that address production, use, distribution, and international trade of agricultural commodities, as well as, the development of theoretical and methodological tools on which sustain research results, detailed information for sorghum is either scarce or more than 10 years old. Generally, the main problem finding information is that sorghum is assigned to the “other coarse grains” category. This situation is surprising given the fact that in most of the international trade works consulted the US and Mexico are substantial elements on the models developed and sorghum is an economically important commodity traded between them. We speculate that perhaps the reason to not present sorghum information per se is due to the fact that its importance as a feed grain for rest of the world is low. This section, thus, would only give a sample of the research available.

Meyers, et al. (1986) used a dynamic non-spatial equilibrium approach in order to determine baseline projections yields impacts and trade liberalization impacts for soybeans, wheat and other feed grains. Their model was able to estimate net imports and exports but not trade flows of commodities.

Rosegrant et al. (1995) developed and used the IMPACT model to forecast food projections to the year 2020. IMPACT includes “36 countries and regions (which account for virtually all of world food production and consumption), and 16 commodities, including all cereals, soybeans, roots and tubers, meats, milk, eggs, oils, oilcakes and meals.”

Hueth et al. (1995), used a partial equilibrium multi-market model (PEMM) to estimate implications of NAFTA on agricultural commodities. These authors developed an integral livestock-grain model for the US and Mexico that included supply and demand equations for all the commodities involved in both countries; however, trade equations were developed only for the livestock sector and not for grain crops.

Stout and Abler (2003) from ERS/Penn developed an applied partial equilibrium, multiple-commodity, multiple-region model of agricultural policy and international agricultural trade. It is a non-spatial, non-structural economic model that included 12 countries/ regions and 35 commodities. However, sorghum is not disaggregated from the “coarse grain” group.

Methodological approach

The model

In order to understand the complexity of agricultural production and distribution, and utilization worldwide, over time several large-scale economic models have been developed, used and research results published by well known and recognized national and international agencies. Examples of these models are: International Model for Policy Analysis of Agricultural Commodities and Trade IMPACT (IMPACT; IFPR, 1995). World Food Model (WFM; FAO, 1994), USDA Agricultural Baseline Projections to 2017 (USDA, 2008; most recent version); AGLINK (OECD, 2001), FAPRI (FAPRI, 2007; most recent), ATPSM (UNCTAD, 2005; most recent version). Each of the models cited above has been subjected to criticism in terms of the adequacy of the projections obtained. As the theoretical and methodological knowledge advances and new circumstances arise in the assumptions in which the models were based, adjustments could be made.

Overall, partial equilibrium models are criticized because they are often used to analyze changes in a small sector of the economy, generally a single industry and assume equality in demand and supply other things being equal, which can be perceived as unrealistic. In their aforementioned research Meyers et al. (1986) mentioned that since the models uses are partial equilibrium models, “they do not capture interactions among commodities.” However, the model proposed in this paper is a first attempt to look more closely to the factors affecting a single commodity. At this stage, from our point of view, the fact that sorghum trade between Mexico and the US comprises the majority of world’s trade of the grain justifies the assumption that production, consumption and trade of sorghum on other countries have a low contribution in the explanation of the sorghum dynamic.

The estimated partial equilibrium econometric model consisted of 16 equations estimated simultaneously and validated as a system using seemingly unrelated regression (SUR). The model can be separated into equations of demand and supply of sorghum for each country and equations used to link both countries (Fig. 1).

The equations of the model were specified as follows:

(1) $QSF^{US}_{t} = f\,(PS^{US}_{t}, PC^{US}_{t}, Year^{US}_{t})$,

(2) $PAS^{TX}_{t} = f\,[PS^{US}_{t-1}, PAS^{TX}_{t-1}, (HACo^{TX}_{t} / PACo^{TX}_{t})\ CRP^{US}]$,

(3) $PAS^{OS}_{t} = f\,(PS^{US}_{t-1}, PAS^{OS}_{t-1}, CRP^{US})$,

(4) $PAS^{US}_{t} = PAS^{TX}_{t} + PAS^{OS}_{t}$,

(5) $VolS^{US}_{t} = PAS^{US}_{t} * (PAS^{US}_{t} / HAS^{US}_{t}) * Yield^{US}_{t}$,

(6) $QSS^{US}_{t} = VolS^{US}_{t} + StocksS^{US}_{t-1}$,

(7) $QSD^{US}_{t} = QSF^{US}_{t} + QSOU^{US}_{t} + StocksS^{US}_{t} + QXSROW^{US}_{t}$,

(8) $ExSup^{US}_{t} = QSS^{US}_{t} – QSD^{US}_{t}$,

(9) $PS^{MX}_{t} = f\,(PS^{US}_{t})$,

(10) $QSF^{MX}_{t} = f\,[(PS^{MX}_{t} / PC^{MX}_{t}), CProd^{MX}_{t}, Y1991^{MX}, Y1999^{MX}]$,

(11) $PAS^{MX}_{t} = f\,(PS^{MX}_{t-1}, PAS^{MX}_{t-1}, Y1981^{MX}, Deval^{MX})$,

(12) $VolS^{MX}_{t} = PAS^{MX}_{t} * (PAS^{MX}_{t} / HAS^{MX}_{t}) * Yield^{MX}_{t}$,

(13) $QSS^{MX}_{t} = VolS^{MX}_{t} + StocksS^{MX}_{t}$,

(14) $QSD^{MX}_{t} = QSF^{MX}_{t} + QSOU^{MX}_{t} + StocksS^{MX}_{t}$,

(15) $ExDem^{MX}_{t} = QSD^{MX}_{t} - QSD^{MX}_{t}$,

(16) $MKTEq = ExSup^{US}_{t} – ExDem^{MX}_{t}$.

Where:

Superscripts US TX, OS, and MX and subscripts t and t-1 refer to United States, Texas, other states, Mexico, current and preceding yr, respectively; QSF = amount of sorghum used for feed (thousands Mton); PS = average Gulf Coast FOB sorghum price (in US thousand dollars $Mton^{-1}$; in MX thousand pesos $Mton^{-1}$); PC = average corn farmer price (in US thousand dollars $Mton^{-1}$; in MX thousand pesos $Mton^{-1}$); Year = time trend; PAS = planted area with sorghum (thousand ha); HACo = cotton harvested area (thousand ha); PACo = planted area with cotton (thousand ha); CRP = dummy for the Conservation Reserve Program; VolS = volume of sorghum produced (thousand Mton); HAS = sorghum harvested area (thousand ha); Yield = amount of sorghum produced per unit of land (Mton ha^{-1}); QSS = amount of sorghum available (thousand Mton); StocksS = amount of sorghum in storage at the end of the year (thousand Mton); QSD = amount of sorghum needed (thousand Mton); QSOU = amount of sorghum used in industry; QXSROW = amount of sorghum exported to the rest of the world (excluded exports to Mexico); ExSup = amount of sorghum available for exports to Mexico (thousand Mton); CProd = chicken production (million Mton); Y1991 = dummy variable for the year 1991; Y1999 = dummy variable starting in the year 2002; Y1981 =

dummy variable starting on the year 1981; Deval = dummy variable for the peso devaluation of 1994/95; ExDem = amount of sorghum imported by Mexico (thousand Mton); MKTEq = market equilibrium.

The endogenous variables in the system were QSF^{US}_{t}, PS^{US}_{t}, PAS^{TX}_{t}, PAS^{OS}_{t}, PAS^{US}_{t}, $VolS^{US}_{t}$, QSS^{US}_{t}, QSD^{US}_{t}, $ExSup^{US}_{t}$, PS^{MX}_{t}, QSF^{MX}_{t}, PAS^{MX}_{t}, $VolS^{MX}_{t}$, QSS^{MX}_{t}, QSD^{MX}_{t}, $ExDem^{MX}_{t}$, the remaining variables were either lagged values of the endogenous variables or exogenous to the system.

Since in both countries the main domestic use for sorghum is in the feedstock industry, the amount of sorghum used as feed was estimated (EQ. 1 and 10) and used afterwards to calculate the total amount of sorghum demanded (EQ.7 and 14), which also included sorghum amounts destined for other uses, stocks at the end of the year, and in the case of the US (EQ. 7) amount of sorghum exported to the rest of the world. In the Mexican equation (EQ. 10) the ratio of sorghum price to corn price was used to represent the effect of price difference on the quantity of sorghum used as feed in Mexico.

On the supply side, for both countries, the area planted with sorghum was estimated (EQ. 2, 3, 4, and 11). In the case of the US the sorghum planted area was divided in two regions: Texas and southern states (EQ. 2), where sorghum is a secondary crop to cotton, and the rest of US states (EQ. 3); in the Texas equation, the ratio of cotton area harvested to cotton area planted was used to represent the effect of cotton loses on the sorghum planted area. Estimates from the planted area equations were used afterwards to calculate volume of sorghum produced (EQ. 5 and 12), and total supply of sorghum, which also included stocks at the beginning of the year (EQ. 6 and 13).

In order to connect the US and Mexican supply and demand models a price translation equation (EQ. 9), is introduced. In this equation the price of sorghum in Mexico depends on the grain's Gulf Coast FOB price and the exchange rate. Since Mexico liberalized the market of sorghum in 1986 and yet the US has been the only supplier to the Mexican market, the equilibrium price of sorghum in the US and Mexico should be highly correlated.

In order to achieve equilibrium, excess supply of sorghum in US (EQ. 8) and excess demand of sorghum in Mexico (EQ. 15) were calculated and set to be equal (EQ. 16).

Data sources

Time series from 1970-2007 for all variables were used to estimate the model. Mexican and United States variables were obtained from official institutions: PS&D (2008), SAGARPA (2008), FAO-STATS (2008), ERS-USDA (2008), and FATUS (2008). Prices of sorghum and corn for both countries were deflated to prices of 2002. Projections for exogenous variables were obtained from official sources (FAPRI, SAGARPA, etc) when available or were constructed by the researcher. Forecasted scenarios were chosen based direct suggestions of the national sorghum producers association and researcher's interests.

Forecast scenarios

The scenarios were set as follow:

1) Increases of US sorghum yield: Increase of US sorghum yield by 5% annually was suggested by the Sorghum Producers Association;

2) Changes on domestic demand for industrial use of sorghum: FAPRI projected an annual increase of industrial demand for sorghum of 7% annually. Projected values were obtained increasing or decreasing FAPRI's annual projection by 100 and 50%.

3) Changes on ROW sorghum demand: Projections were based on a sustained increase of US sorghum exports to the European Union in order to explore the possibility of expanding US sorghum to new markets.

Empirical results

Medium-term baseline

Parameter estimates are presented in Table 1. Estimated results of all equations have the expected sign and are significant.

The demand side of the model in both countries was estimated as the amount of sorghum used as feed. For estimation purposes, the price variable in the Mexican equation was defined as the ratio of sorghum to corn price. Demand for other uses, and stocks at the end of the year were exogenous variables. Total demand for sorghum was calculated adding the estimated amount for feed use, the demand for other uses, and the stocks at the end of the year. In the total demand equation for the US, demand from the rest of the world, also an exogenous variable, was included. As for the estimated parameters, feed demand, in both countries responded to prices of both sorghum and corn, as expected. Furthermore, chicken production and policy dummies were also significant parameters in the Mexican equation.

Results suggest that if the sorghum price increases demand would decrease. In Addition, sorghum demand in Mexico would change depending on chicken production. This result is particularly important due to rearrangements that would occur in the Mexican poultry sector when NAFTA previsions stop in 2008.

The supply side on both countries was modeled by the estimation of sorghum planted area. In the US, as sorghum is a secondary crop to cotton, it was assumed, that sorghum planted area would be a function of the harvested cotton area as a percentage of the area planted, in regions where cotton production is important. Thus, two sorghum planted area equations were specified: area planted in Texas and other southern states and planted area on the rest of the country. Total demand was obtained adding up the area planted in Texas and other southern states and the area planted in the rest of the US. In Mexico, total area planted is derived directly from the estimated equation. For both countries, yields, and harvested area as a percentage of area planted were considered exogenous. Volume produced was determined as planted area times the ratio area harvested to area planted times yield. As in the case of the demand equations, stocks were also considered exogenous to the model and were included in the equation for estimation purposes. Total supply was then calculated as volume produced plus stocks at the beginning of the year.

As expected, planted area in TX responded to changes in previous sorghum price and area previously planted with sorghum, CRP program and the ratio of cotton area harvested to area planted. The parameter associated with the ratio of cotton area harvested to area planted had a negative sign and was significant, reinforcing the idea that sorghum is a secondary crop in those areas. Planted area in the rest of the US also responded to previous sorghum planted area and CRP, but not to previous sorghum price. The CRP dummy was included in the US equations to account for cropping land availability. Planted area in Mexico depended on previous sorghum price and dummy variables for policy or external factors, such as the 1994-95 peso's devaluation. Previously planted area was not significant, which suggest that, in Mexico, sorghum production responds to changes in prices and is also sensitive to changes in policies and external economic factors.

For demand-supply equilibrium, excess demand from the Mexican equations and excess supply from the US equations were calculated as the difference between demand and supply in each country. Since the US are the solely supplier of sorghum to the Mexican market, excess demand is also the total amount of sorghum imported from the US; consequently, excess supply is the amount of sorghum exported from the US to Mexico. Exports to the rest of the world were included in the US supply equation. Mexican farm price was significantly dependent on the Gulf's coast FOB price, as expected. Equilibrium was achieved at the price where excess demand equated excess supply, as they were defined above.

After estimation the model was solved to obtain the baseline values of the endogenous variables. Figs. 2 to 16 show the results of the model in the full set of 16 endogenous variables.

The estimated model, appears to simulate adequately the bilateral trade of sorghum between the US and Mexico; however, there are still issues that need to be explored. A better understanding and inclusion of policy variables affecting sorghum in both countries is one potential improvement. Additionally, including other countries into the model would help to expand the model and to gain a better understanding on the international sorghum trade.

Forecast scenarios

Results of the forecast are shown in table 2 to 14. Forecast results suggest that increases in sorghum yields and demand of the rest of the world as well as decreases in industrial demand will decrease sorghum prices in both countries, and raise Mexican imports. The opposite occurs when industrial demand goes from 7% to 14% annual growth rate.

Final remarks

The working model obtained in this first step of a larger objective of constructing a international trade model for sorghum could be a useful tool to help decision makers in the grain sorghum production-industry. As for the title of this work, according with the scenarios forecast, it seems that the US sorghum industry will still depend on the Mexican market. Since chicken production prove to be a significant factor affecting Mexican sorghum demand, it would be useful to explore how and to what extent changes in the Mexican poultry sector will affect the sorghum bilateral trade. Furthermore, expanding the model to other countries could also affect the dependent relationship between the US and Mexico. Finally, the reiteration, the model is still in development and is susceptible to improvement.

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Table 1. Parameter estimates, standard errors, and t -values of the medium term baseline forecast of the US-Mexico component of a sorghum international trade model

Parameter	Estimate	STD Error	t - value
	Sorghum used as feed in US		
Constant	690624.90	79924.40	8.64
PS^{US}_{t} †	-1600290.00	36144.20	-4.43
PC^{US}_{t} †	123588.80	32633.30	3.79
$Year^{US}_{t}$	-340.48	39.87	-8.54
	Planted area with sorghum in Texas and other southern states		
Constant	2218.23	465.9	4.76
PS^{US}_{t-1} †,‡	3521.94	1451.7	2.43
PAS^{TX}_{t-1} †,‡	0.44	0.09	4.77
$(HACo^{TX}_{t} / PACo^{TX}_{t})$ †	-1524.93	403.90	-3.78
CRP^{US} †	-496.36	178.60	-2.78
	Planted area with sorghum in the rest of the US		
Constant	2001.64	490.7	4.08
PS^{US}_{t-1} †,‡	1653.83	1769.5	0.93
PAS^{OS}_{t-1} †,‡	0.43	0.09	4.58
CRP^{US} †	-713.04	231.90	-3.08
	Price of sorghum in Mexico		
Constant	-0.07	0.29	-0.24
PS^{US}_{t} †	2.05	0.21	9.48
	Sorghum used as feed in Mexico		
Constant	8051.13	1038.70	7.75
$(PS^{MX}_{t} / PC^{MX}_{t})$ †	-7050.42	1422.70	-4.96
$CProd^{MX}_{t}$ †	3.78	0.31	12.30
$Y1991^{MX}$ †	1643.48	831.30	1.98
$Y1999^{MX}$†	-2070.82	628.20	-3.30
	Planted area with sorghum in Mexico		
Constant	515.07	225.90	2.28
PS^{MX}_{t-1} †,‡	180.56	53.48	3.38
PAS^{MX}_{t-1} †,‡	-0.089	0.11	-0.80
$Y1981^{MX}$†	636.05	141.50	4.50
$Deval^{MX}$†	825.15	114.90	7.18

†Superscripts US TX, OS, and MX and subscript t refer to United States, Texas, other states, Mexico, and current yr, respectively.

‡Subscript t-1 refers to preceding yr.

Table 2. Baseline, forecast and FAPRI sorghum prices in the US and Mexico and excess demand when sorghum yields increase 5% annually

Year	Sorghum yield annual increase		
	Baseline 1%	Forecast 5%	FAPRI
US Sorghum Price in thou. Dollars $Mton.^{-1}$			
2008	0.093	0.084	0.14
2009	0.091	0.081	0.14
2010	0.089	0.077	0.14
2011	0.083	0.069	0.14
2012	0.082	0.066	0.13
2013	0.076	0.058	0.13
2014	0.075	0.055	0.13
2015	0.073	0.052	0.13
2016	0.068	0.045	0.13
Mexican Sorghum Price in thou. Pesos $Mton.^{-1}$			
2008	1.74	1.57	1.40
2009	1.71	1.51	1.40
2010	1.67	1.44	1.40
2011	1.55	1.28	1.40
2012	1.53	1.23	1.30
2013	1.42	1.08	1.30
2014	1.39	1.03	1.30
2015	1.37	0.97	1.30
2016	1.27	0.83	1.30
Mexican sorghum excess demand			
2008	1199.10	2024.86	1644.14
2009	1124.34	2199.12	1554.12
2010	1296.87	2617.63	1604.32
2011	1890.53	3471.29	1610.47
2012	1970.79	3821.56	1615.14
2013	2526.99	4683.09	1676.39
2014	2584.59	5031.22	1722.26
2015	2620.62	5410.59	1756.46
2016	3247.06	6376.84	1815.03

Table 3. Baseline, forecast and FAPRI sorghum prices in the US and Mexico and excess demand when industrial sorghum demand increases, 3.5 7 and 14%

	Industrial sorghum demand annual increase			
Year	Baseline 7%	Forecast 3.5%	Forecast 14%	FAPRI%
US Sorghum Price in thou. Dollars $Mton.^{-1}$				
2008	0.093	0.089	0.099	0.14
2009	0.091	0.088	0.097	0.14
2010	0.089	0.086	0.095	0.14
2011	0.083	0.080	0.088	0.14
2012	0.082	0.079	0.087	0.13
2013	0.076	0.073	0.081	0.13
2014	0.075	0.072	0.080	0.13
2015	0.073	0.071	0.078	0.13
2016	0.068	0.065	0.073	0.13
Mexican Sorghum Price in thou. Pesos $Mton.^{-1}$				
2008	1.74	1.68	1.86	1.40
2009	1.71	1.65	1.82	1.40
2010	1.67	1.62	1.78	1.40
2011	1.55	1.49	1.65	1.40
2012	1.53	1.48	1.63	1.30
2013	1.42	1.37	1.52	1.30
2014	1.39	1.35	1.49	1.30
2015	1.37	1.32	1.47	1.30
2016	1.27	1.22	1.36	1.30
Mexican sorghum excess demand				
2008	1199.10	1491.58	614.15	1644.14
2009	1124.34	1436.20	500.61	1554.12
2010	1296.87	1607.25	676.12	1604.32
2011	1890.53	2202.07	1267.46	1610.47
2012	1970.79	2286.10	1340.16	1615.14
2013	2526.99	2847.44	1886.11	1676.39
2014	2584.59	2912.29	1929.18	1722.26
2015	2620.62	2956.89	1948.06	1756.46
2016	3247.06	3590.45	2560.27	1815.03

Table 4. Baseline, forecast and FAPRI sorghum prices in the US and Mexico and excess demand when sorghum demand for the rest of the world is maintained at 2007 levels

Year	Baseline	Forecast	FAPRI
US Sorghum Price in thou. Dollars $Mton.^{-1}$			
2008	0.093	0.11	0.14
2009	0.091	0.10	0.14
2010	0.089	0.10	0.14
2011	0.083	0.096	0.14
2012	0.082	0.094	0.13
2013	0.076	0.088	0.13
2014	0.075	0.086	0.13
2015	0.073	0.085	0.13
2016	0.068	0.079	0.13
Mexican Sorghum Price in thou. Pesos $Mton.^{-1}$			
2008	1.74	2.06	1.40
2009	1.71	1.98	1.40
2010	1.67	1.93	1.40
2011	1.55	1.79	1.40
2012	1.53	1.77	1.30
2013	1.42	1.65	1.30
2014	1.39	1.62	1.30
2015	1.37	1.58	1.30
2016	1.27	1.47	1.30
Mexican sorghum excess demand			
2008	1199.10	-343.39	1644.14
2009	1124.34	-419.88	1554.12
2010	1296.87	-199.86	1604.32
2011	1890.53	408.62	1610.47
2012	1970.79	489.84	1615.14
2013	2526.99	1037.65	1676.39
2014	2584.59	1087.91	1722.26
2015	2620.62	1116.01	1756.46
2016	3247.06	1738.67	1815.03

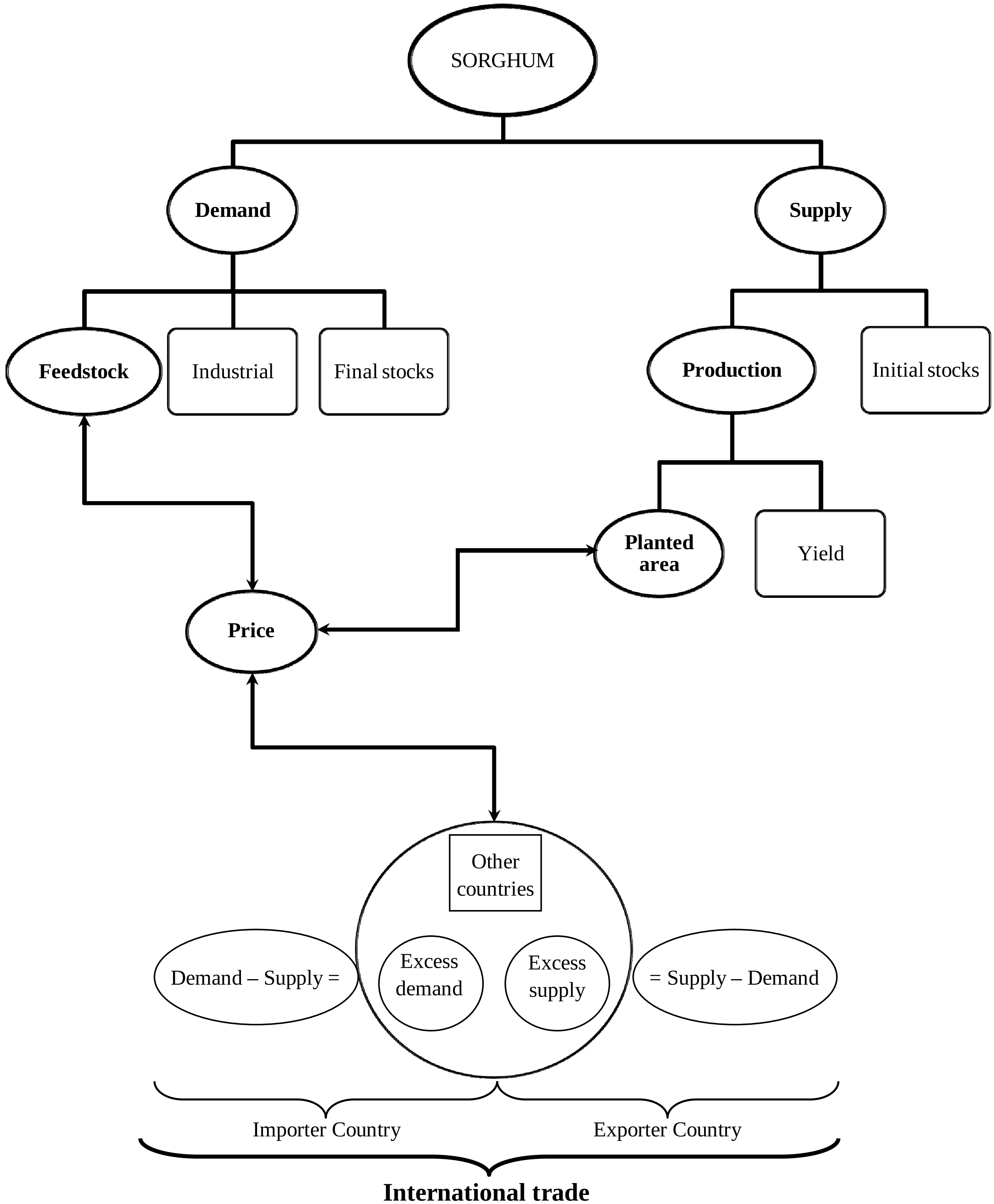

Fig. 1 International trade model

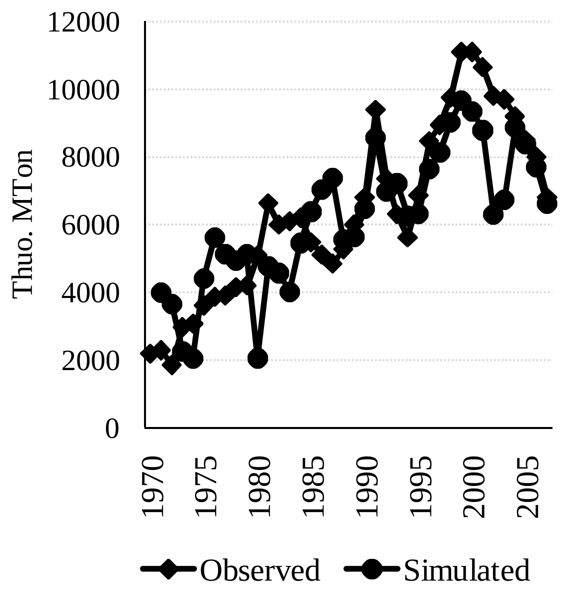

Fig. 2. Observed and simulated amount of sorghum used as feed in Mexico.

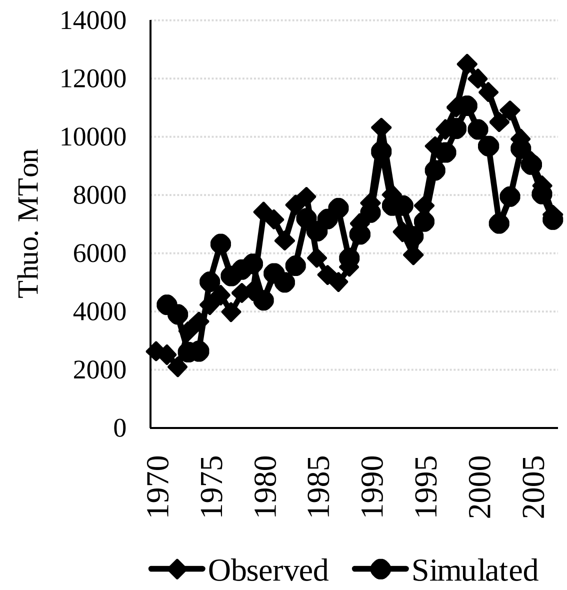

Fig. 3. Observed and simulated total sorghum demand in Mexico.

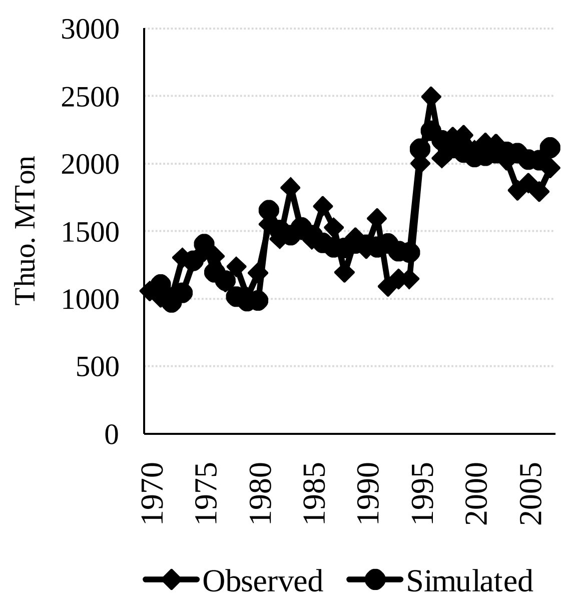

Fig. 4. Observed and simulated sorghum area planted in Mexico.

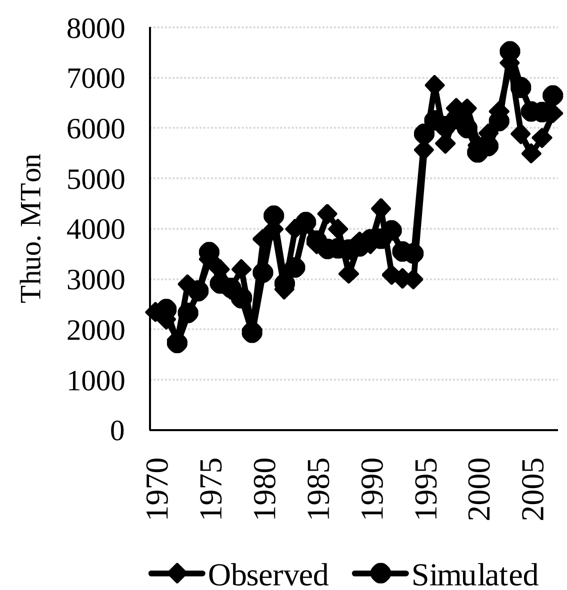

Fig. 5. Observed and simulated amount of sorghum produced in Mexico.

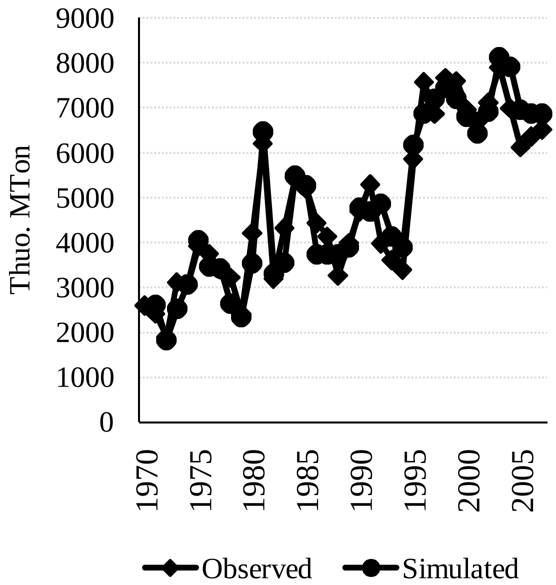

Fig. 6. Observed and simulated total sorghum supply in Mexico.

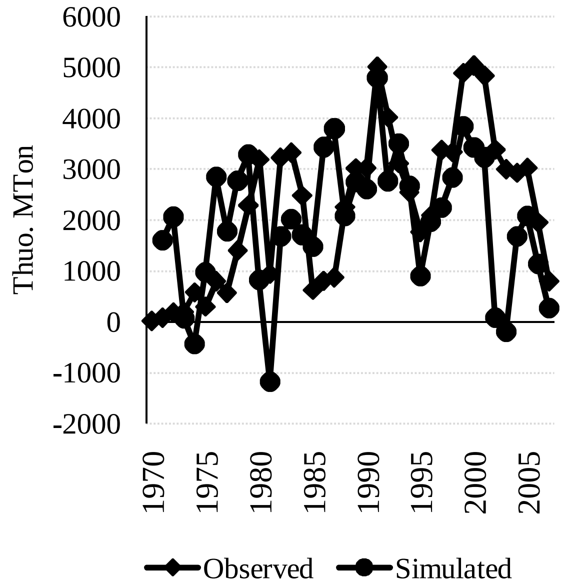

Fig. 7. Observed and simulated Mexico's excess demand for sorghum.

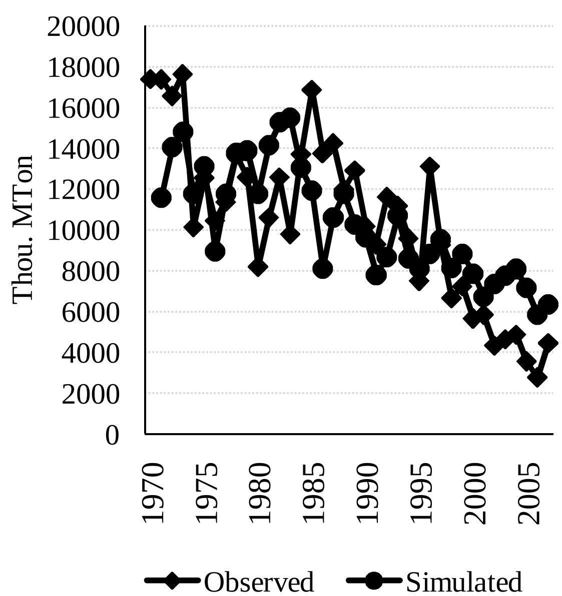

Fig. 8. Observed and simulated amount of sorghum used as feed in the United States.

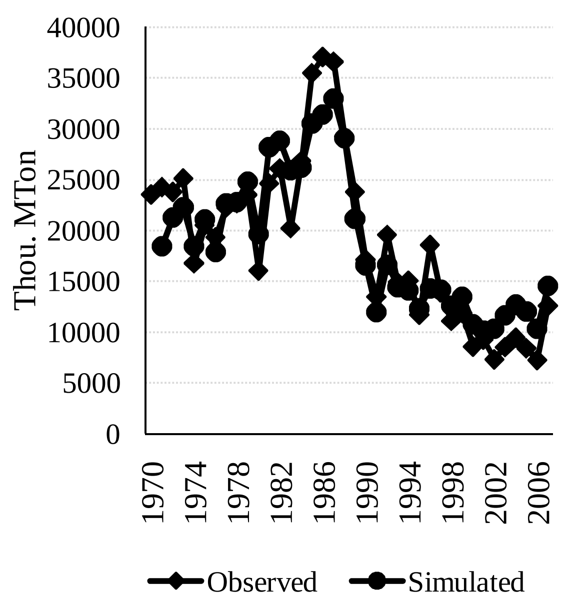

Fig. 9. Observed and simulated total sorghum demand in the United States.

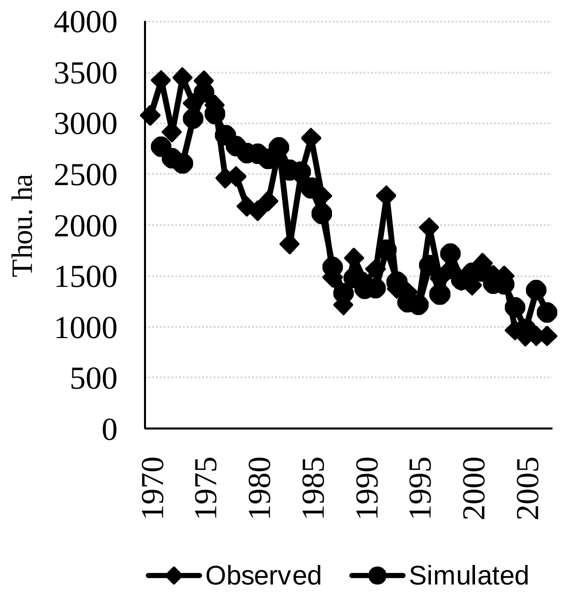

Fig. 10. Observed and simulated sorghum planted area in TX and other southern states.

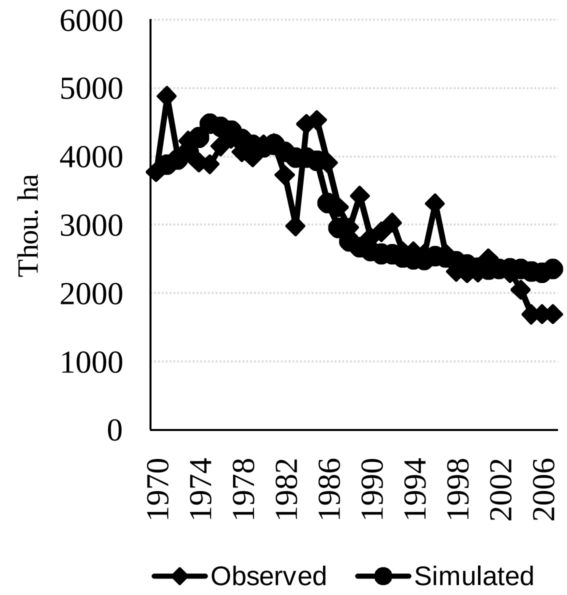

Fig. 11. Observed and simulated sorghum planted area in the rest of the United States.

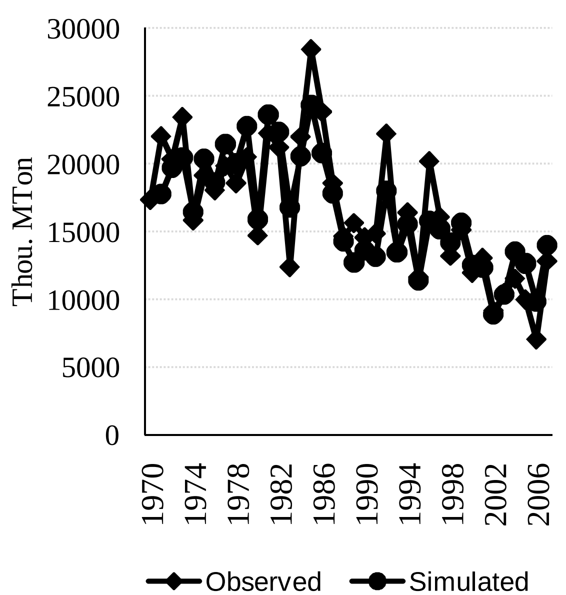

Fig. 12. Observed and simulated amount of sorghum produced in the United States.

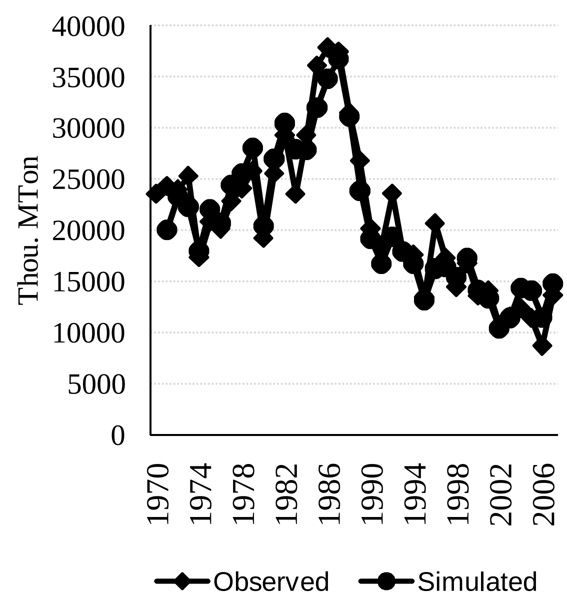

Fig. 13. Observed and simulated total sorghum supply in the United States.

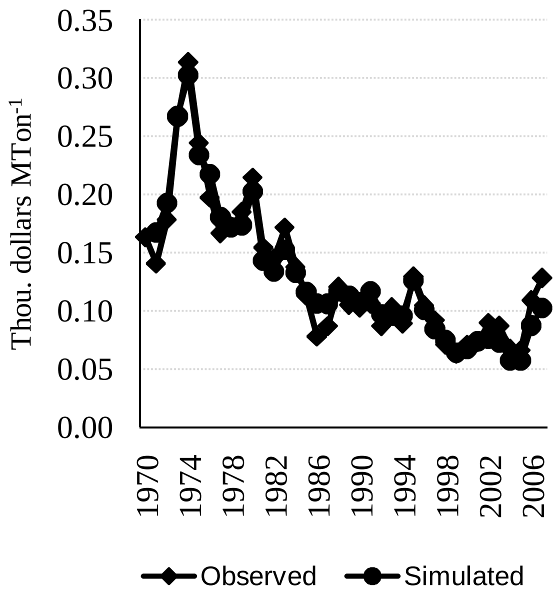

Fig. 14. Observed and simulated sorghum prices in the United States.

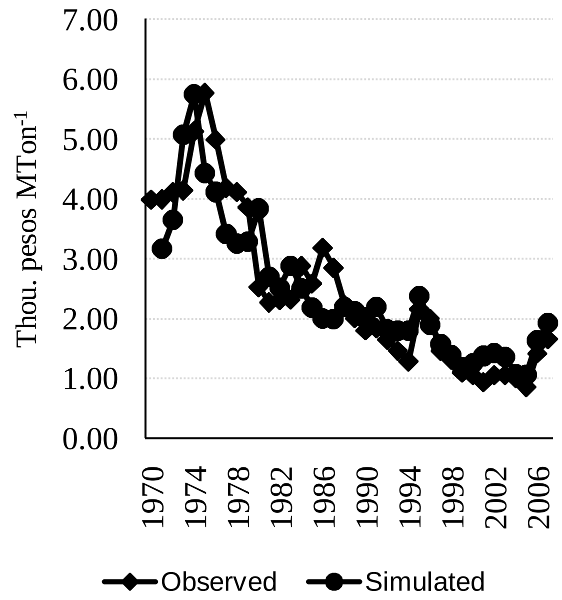

Fig. 15. Observed and simulated sorghum prices in Mexico.