Development and Recommendations of a Grain Sorghum Pricing Methodology – Institutions of Higher Learning

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Background

The objective of this project has been to develop and recommend a methodology for determining an expected market price for sorghum that more accurately reflects the actual national average price at harvest. The developed price methodology is both transparent and easily replicable. The developed price forecasting method is suitable for use in the national yield and revenue crop insurance programs for grain sorghum.

The project has considered prediction of harvest time prices both at planting time and harvest time, as predictions at both times are needed for operation of crop insurance programs. Both types of forecasts seek to predict the market price of grain sorghum at the time of harvest. Consistent with the current operation of the sorghum crop insurance programs, the planting time price prediction (referred to as the "base price") is made using only information available as of the end of February each year. The harvest time prediction ("harvest price") is made using information available as of the end of October each year.

Consistent with the current crop insurance pricing methodology, we consider forecast methodologies that are based on the market prices of contracts for December delivery of corn at the Chicago Board of Trade. Planting time predictions are based on the average daily settlement price of December corn futures level during the month of February. Harvest time predictions are based on the average daily settlement price of December corn futures level during the month of October. This system has the attractive feature of making use of forward-looking, market-based price forecasts, and being very easily calculated.

The research undertaken for this project consisted of two phases. First, we developed a historical time series of representative national average grain sorghum harvest time prices, for use as the series that we seek to predict. Second, we tested the accuracy of numerous competing models at predicting the harvest time sorghum price, for predictions made at both planting time and harvest time. After describing these two phases of the project, we describe how our recommended methodology can be used in the operation of grain sorghum crop insurance programs.

Phase I: Development of Representative Historical National Average Prices

In order to search for a well-performing price forecasting methodology, a representative price of sorghum at harvest series was developed. That is to say, the "right" answer to the forecasting problem was determined for use in evaluating competing forecasting methods in Phase II. This series that has been developed contains annual observations, corresponding to the frequency of harvest and frequency of crop insurance program operation.

Mathematically, the problem in this step of the project was to select, for each year t, a single price $\overline{p}_t$ that is a minimal average distance from the observed harvest prices $p_{r,t}$ in each region r:

$$(1) \qquad \min_{\overline{p}_t} \left| \sum_r w_{r,t} \left(p_{r,t} - \overline{p}_t \right) \right| .$$

The $w_{r,t}$ are weights for each region to reflect that region's importance in year t. The price $\overline{p}_t$ for each year is representative, in that it reflects, as closely as possible, the price received at harvest times for actual sorghum produced by geographically dispersed producers. We therefore employed quantities of sorghum produced in each region in each year, $q_{r,t}$ in forming the weights.

We employ six individual regional harvest-time spot price series, $p_{r,t}$. Four of these series are average prices in September for each year for four locations in Texas (North of the Canadian, South of Line, Triangle Area, and Houston Port). The other two series are September prices in New Orleans, Louisiana, and October prices in Kansas City, Missouri. Weekly price data for the four Texas locations were provided by Texas AgriLife Extension Service (available at http://agecoext.tamu.edu/resources/ basis-data/online.html), and the simple averages of all September observations in each year were calculated. Monthly Kansas City and New Orleans price series came from ERS/USDA, and the September and October observations, respectively, were extracted from those monthly series to form corresponding annual $p_{r,t}$ series. All six final annual price series are observed over the years 1979-2008, and are plotted in Figure 1.[1]

Weights $w_{r,t}$ were formed by calculating the proportion of total U.S. grain sorghum production that was produced in each of six regions in each year. The six regions are illustrated in Figure 2. The four Texas price series correspond to regions constituted by potions of Texas, New Mexico, and Oklahoma. New Orleans prices correspond to all of Louisiana, Arkansas, and Mississippi. Kansas City prices correspond to all of Kansas and Nebraska. All annual grain sorghum production data for the states Louisiana, Arkansas, Mississippi, Kansas and Nebraska, and county-level production data for Texas, New Mexico, and Oklahoma were collected from NASS/USDA for the years 1979-2008. The resulting weights for the six regions are plotted in Figure 3.

[1] The 2003 observation for New Orleans was not available.

Using the six $p_{r,t}$ series and corresponding $w_{r,t}$ series, the problem stated in (1) was solved for each year. The resulting final national representative harvest-time grain sorghum price time series $\overline{p}_t$ is shown in Figure 4.[2] This series was then used in Phase II of the project.

Phase II: Evaluation of Forecasting Methods

The second stage of the project was to evaluate several price forecasting schemes. That is, we developed forecasts, $\hat{p}_t$, of the national average representative harvest-time prices $\overline{p}_t$. Numerous forecasting methodologies could have been considered, such as complex structural and time series econometric models, expert surveys, optimal compositions of multiple forecasts, etc. Complex econometric models cannot be fitted and evaluated with so few observations, however, and would also run a severe risk of data snooping. A historical record of expert survey would be difficult to obtain for sorghum prices, and objective expert opinion would not be easy to employ on an ongoing basis.

To ensure that forecasts are transparent and reproducible, and to avoid complexity, we considered simple transformations of observed settlement prices of corn futures contracts traded at the Chicago Board of Trade (CBOT). Eight forecasting methodologies were evaluated, which are presented in Table 1.

For base price forecasts (i.e., forecasts made at planting time), the F_t employed was the average settlement price of December corn futures during the month of February. For forecasts made at harvest time, the F_t employed was the average settlement price of December corn futures during the month of October. All futures data were obtained from the Thomsom Datastream Advance v.4.0 SP9 database. Daily settlement prices for all contracts were obtained,

[2] The national average representative harvest time price is not calculated for 2003 due to the missing New Orleans observation for that year.

and simple averages for the above-mentioned months were calculated to form the final annual series that were employed in fitting the models and generating forecasts.

The first model in the above Table 1 is the method currently employed in the sorghum crop insurance program, but with a re-fitted proportion parameter. The last three models have the attractive property of adapting to potentially evolving price bases between corn and sorghum, and employing zero fitted parameters, although unusual basis conditions in one year might result in poor forecasts in the subsequent year. In all cases, fitted parameters were obtained by minimizing the sum of squared prediction errors for the base price forecast and separately for the harvest price forecasts in the evaluations described below. That is to say, each of the eight models was applied to both the base time and harvest time price forecasting problems.

Ideally, evaluating the forecasting performance of several competing forecasting methodologies would consist of using one portion of the available historical data for fitting the models, and another portion of the data would be withheld for out-of-sample forecast evaluation. For this project, however, the limited number of available observations did not afford us this luxury, and all of the data were used for both model fitting and evaluation. Given this, simple measures of forecasting performance such as mean absolute prediction error or root mean squared prediction error could not be employed. This is because the in-sample fit of a model can be arbitrarily increased by increasing model complexity. However, the resulting models would have poor out-of-sample forecasting performance, as they will have simply been tailored to the historical period rather than having genuine predictive ability. To overcome this difficulty, we employed Schwarz information criterion to evaluate competing models:

(2) $$SIC = \ln\left(\frac{SSE}{T}\right) + \frac{k\ln(T)}{T}$$

where T is the total number of observations, k is the number of fitted parameters, and SSE is the sum of squared prediction errors. That is,

(3) $$SSE = \sum_t \left(\hat{p}_t - \overline{p}_t\right)^2$$

Models with lower *SIC* scores are preferred. The first term in the *SIC* rewards good fit, while the second term penalizes increasing model complexity.

All models were fitted using the standard ordinary least squares method.[3] The values of fitted parameters and the calculated values of *SIC* for the base (i.e., planting time) forecasting problem are presented in Table 2. The models are listed in order of increasing *SIC*, which is to say they are listed in order of best-performing to worst-performing. The values of fitted parameters and the calculated values of *SIC* for the harvest time forecasting problem are presented in Table 3, and the models are again ordered from best-performing to worst-performing.[4]

For individual models, fitted parameters are substantially different across forecasting problems (planting and harvest time). We therefore cannot recommend using parameters fitted for one problem for forecasting prices for the other problem (e.g., using a model fitted using planting time data for making a forecast at harvest time). We note that the fitted β parameter in models A and D is lower for the planting time models than the harvest time models in both cases, and that the δ parameter for models C and E is lower for the planting time models than the harvest time models in both cases. We therefore hypothesize that the differences in the fitted parameters is due to evolving risk premia in the December corn futures prices as the delivery

[3] Models C and E were linearized by taking the natural logarithm of both sides of those equations.
[4] Forecast errors for 1979 cannot be calculated for models F, G, and H due to the lack of a lagged (i.e., 1978) observation on which to base the models' parameters. The missing 2003 observation for the national average price precludes the calculation of forecast errors for any of the models for 2003, and precludes the calculation of forecast errors for models F, G, an H for 2004. To make *SIC* scores comparable across models, the *SIC* calculations for all models are based on 1980-2002 and 2005-2008.

horizon shortens. At planting time, all uncertainty regarding the upcoming crop remains to be resolved, and corn futures prices likely reflect the possibility of unfavorable growing conditions and a short crop. By harvest time, such uncertainty is largely resolved. We must therefore, on average, discount the corn futures observed at planting time by a greater amount than those observed at harvest time to generate unbiased forecasts.

We also note that no single model performed consistently best or close to best for both forecasting problems. We are therefore unable to recommend a single type of model (A, B, …) for making both types of forecasts. We recommend instead that the best performing model from each problem be used. We recommend that model C be used for making planting time forecasts and that model A be used for making harvest time forecasts.

Application of the Recommended Pricing Methods

The recommended pricing method for planting time, model C, can be applied as follows. First, the settlement prices for December corn futures contract traded at the Chicago Board of Trade must be collected for every trading day in February. Second, the simple average of those settlement prices must be calculated; we denote this average $F_{t,Feb}$. Third, the forecast price is calculated as

(4) $$\hat{p}_{t,Planting} = F_{t,Feb}^{0.858025}.$$

Here, we provide additional digits of precision for the fitted δ parameter relative to Table 2.

The recommended pricing method for harvest time, model A, can be applied as follows. First, the settlement prices for December corn future contract contracts traded at the Chicago Board of Trade must be collected for every trading day in October. Second, the simple average of those settlement prices must be calculated; we denote this average $F_{t,Oct}$. Third, the forecast price is calculated as

$$\hat{p}_{t,Harvest} = 0.941205 * F_{t,Oct} . \quad (5)$$

Here, we provide additional digits of precision for the fitted β parameter relative to Table 3.

Table 1: Forecasting Methods

Forecasting method	Formula	Number of fitted parameters
A	$\hat{p}_t = \beta F_t$	1
B	$\hat{p}_t = \alpha + F_t$	1
C	$\hat{p}_t = F_t^{\delta}$	1
D	$\hat{p}_t = \alpha + \beta F_t$	2
E	$\hat{p}_t = \gamma F_t^{\delta}$	2
F	$\hat{p}_t = \beta_{t-1} F_t$, $\beta_{t-1} \equiv \overline{p}_{t-1} / F_{t-1}$	0
G	$\hat{p}_t = \alpha_{t-1} + F_t$, $\alpha_{t-1} \equiv \overline{p}_{t-1} - F_{t-1}$	0
H	$\hat{p}_t = F_t^{\delta_{t-1}}$, $\delta_{t-1} \equiv \ln(\overline{p}_{t-1}) - \ln(F_{t-1})$	0

Table 2: Fitted Parameters and Model Scores for Forecasts made at Planting Time

Model	α	β	γ	δ	*SIC*
C				0.858***	-1.711
D	0.624*	0.649***			-1.610
E			1.084	0.780***	-1.603
A		0.862***			-1.600
B	-0.247**				-1.379
F					-0.968
G					-0.941
H					-0.917

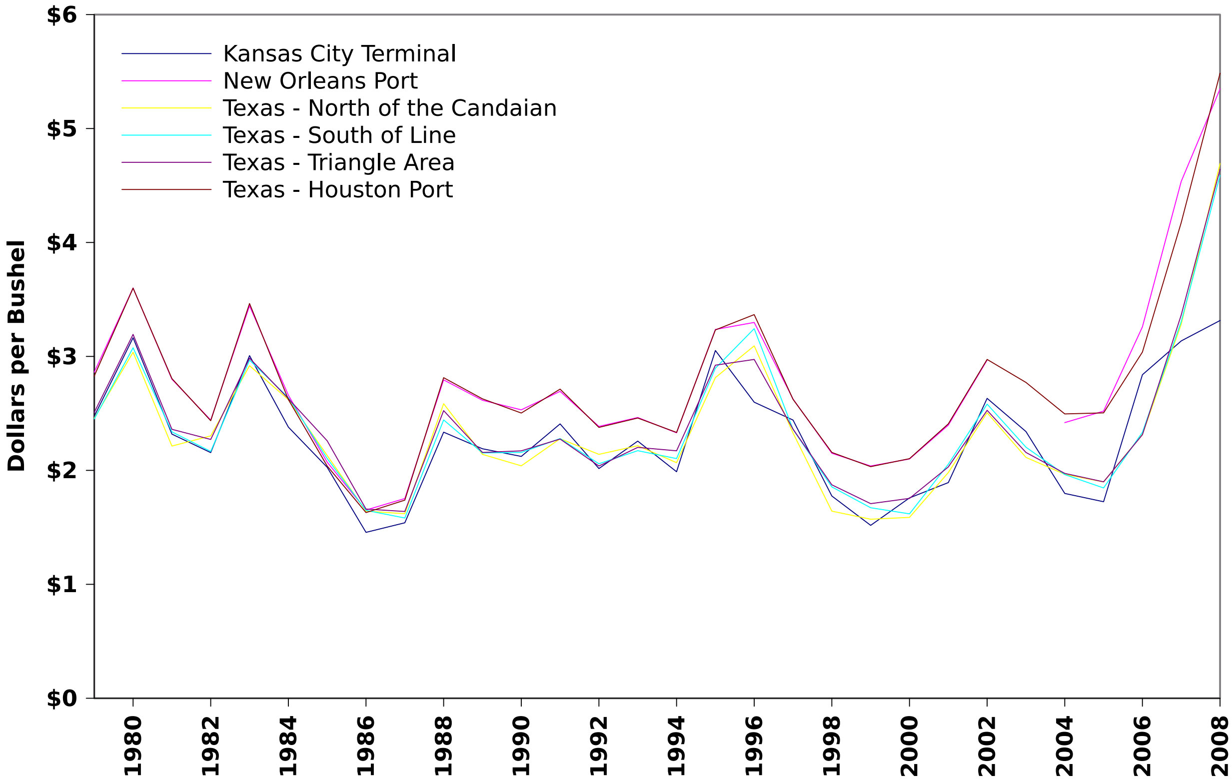
* Significantly different from zero (α, β, and δ) or from unity (γ) at the 10% level.
** Statistically significant at the 5% level.
*** Statistically significant at the 1% level.

Table 3: Fitted Parameters and Model Scores for Forecasts made at Harvest Time

Model	α	β	γ	δ	*SIC*
A		0.941***			-3.596
F					-3.552
H					-3.490
E			0.921	1.019***	-3.485
D	-0.058	0.963***			-3.485
C				0.935***	-3.477
B	-0.090				-3.429
G					-3.389

* Significantly different from zero (α, β, and δ) or from unity (γ) at the 10% level.
** Statistically significant at the 5% level.
*** Statistically significant at the 1% level.

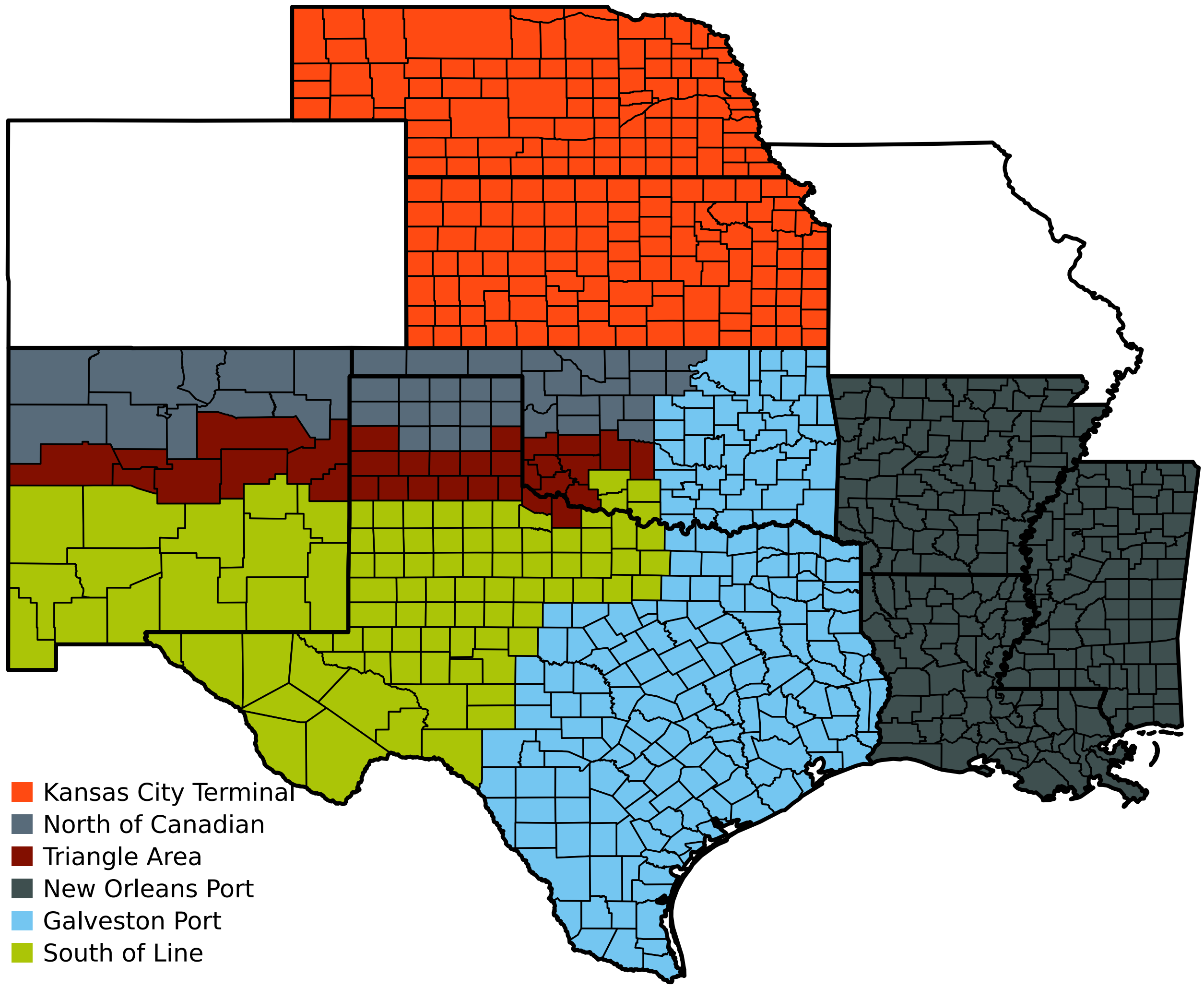
Figure 1: Time Series of Regional Harvest Time Grain Sorghum Prices



Prices

Year	Kansas City Terminal	New Orleans Port	Texas-North of Candaian	Texas-South of Line	Texas-Triangle Area	Texas-Houston Port
1979	2.4752	2.8616	2.4584	2.4514	2.5088	2.828
1980	3.164	3.6008	3.0366	3.0758	3.1934	3.5994
1981	2.3184	2.8	2.2134	2.338	2.3604	2.8056
1982	2.156	2.4416	2.30272	2.16608	2.27136	2.436
1983	3.0072	3.444	2.91872	2.968	2.9848	3.46416
1984	2.38	2.66	2.6208	2.639	2.6292	2.6222
1985	2.0272	2.072	2.1308	2.1042	2.2596	2.0384
1986	1.456	1.652	1.6422	1.6492	1.6604	1.6296
1987	1.54	1.7528	1.6198	1.582	1.6394	1.7388
1988	2.3352	2.7944	2.58496	2.44272	2.52448	2.81344
1989	2.1896	2.6152	2.1406	2.1532	2.1574	2.6278
1990	2.1224	2.5312	2.0398	2.1574	2.1714	2.5032
1991	2.408	2.6936	2.2778	2.2792	2.275	2.7132
1992	2.016	2.3856	2.1406	2.058	2.0384	2.3772
1993	2.2568	2.464	2.21648	2.1728	2.20192	2.45952
1994	1.988	2.3296	2.06752	2.10336	2.17168	2.33296
1995	3.052	3.2368	2.814	2.8966	2.9232	3.2326
1996	2.5984	3.2984	3.0926	3.2438	2.9736	3.367
1997	2.4416	2.6264	2.3282	2.3604	2.3618	2.6236
1998	1.7752	2.1504	1.6422	1.855	1.8732	2.1574
1999	1.5176	2.0384	1.57136	1.67216	1.708	2.0328
2000	1.7584	2.1	1.5876	1.6184	1.7542	2.1028
2001	1.8928	2.3968	1.981	2.0538	2.03	2.408
2002	2.632	2.968	2.506	2.5816	2.527	2.9736
2003	2.3408		2.114	2.2036	2.1574	2.772
2004	1.7976	2.4192	1.9656	1.96336	1.97344	2.49536
2005	1.7248	2.52	1.8984	1.84576	1.89952	2.5046
2006	2.8392	3.2592	2.3156	2.3338	2.3128	3.038
2007	3.136	4.536	3.283	3.3054	3.3642	4.1748
2008	3.3152	5.348	4.6928	4.5892	4.6424	5.4852

Figure 2: Spatial Aggregation of Grain Sorghum Production for Weighting Observed Market Prices



Counties in Each Region

Kansas City Terminal

All Kansas
All Nebraska

New Orleans Port

All Louisiana
All Arkansas
All Mississippi

North of Canadian

Texas

Carson, Dallam, Gray, Hansford, Hartley, Hemphill, Hutchinson, Lipscomb, Moore, Ochiltree, Potter, Roberts, Sherman

Oklahoma

Alfalfa, Beaver, Blaine, Canadian, Cimarron, Custer, Dewey, Ellis, Garfield, Grant, Harper, Kay, Kingfisher, Major, Noble, Roger Mills, Texas, Woods, Woodward

New Mexico

Colfax, Harding, Los Alamos, McKinley, Mora, Rio Arriba, San Juan, Sandoval, Santa Fe, Taos, Union

Triangle Area

Texas

Armstrong, Briscoe, Castro, Childress, Collingsworth, Deaf Smith, Donley, Hall, Hardeman, Oldham, Parmer, Randall, Swisher, Wheeler, Wilbarger

Oklahoma

Beckham, Caddo, Grady, Greer, Harmon, Jackson, Kiowa, Tillman, Washita

New Mexico

Bernalillo, Cibola, Curry, Guadalupe, Quay, San Miguel, Torrance, Valencia

South of Line

Texas

Andrews, Archer, Bailey, Baylor, Borden, Brewster, Clay, Cochran, Coke, Cottle, Crane, Crockett, Crosby, Culberson, Dawson, Dickens, Ector, El Paso, Fisher, Floyd, Foard, Gaines, Garza, Glasscock, Hale, Haskell, Hockley, Howard, Hudspeth, Irion, Jack, Jeff Davis, Jones, Kent, King, Knox, Lamb, Loving, Lubbock, Lynn, Martin, Midland, Mitchell, Montague, Motley, Nolan, Palo Pinto, Parker, Pecos, Presidio, Reagan, Reeves, Runnels, Schleicher, Scurry, Shackelford, Stephens, Sterling, Stonewall, Sutton, Taylor, Terrell, Terry, Throckmorton, Tom Green, Upton, Val Verde, Ward, Wichita, Winkler, Wise, Yoakum, Young

Oklahoma

Comanche, Cotton, Jefferson, Stephens

New Mexico

Catron, Chaves, De Baca, Dona Ana, Eddy, Grant, Hidalgo, Lea, Lincoln, Luna, Otero, Roosevelt, Sierra, Socorro

Galveston Port

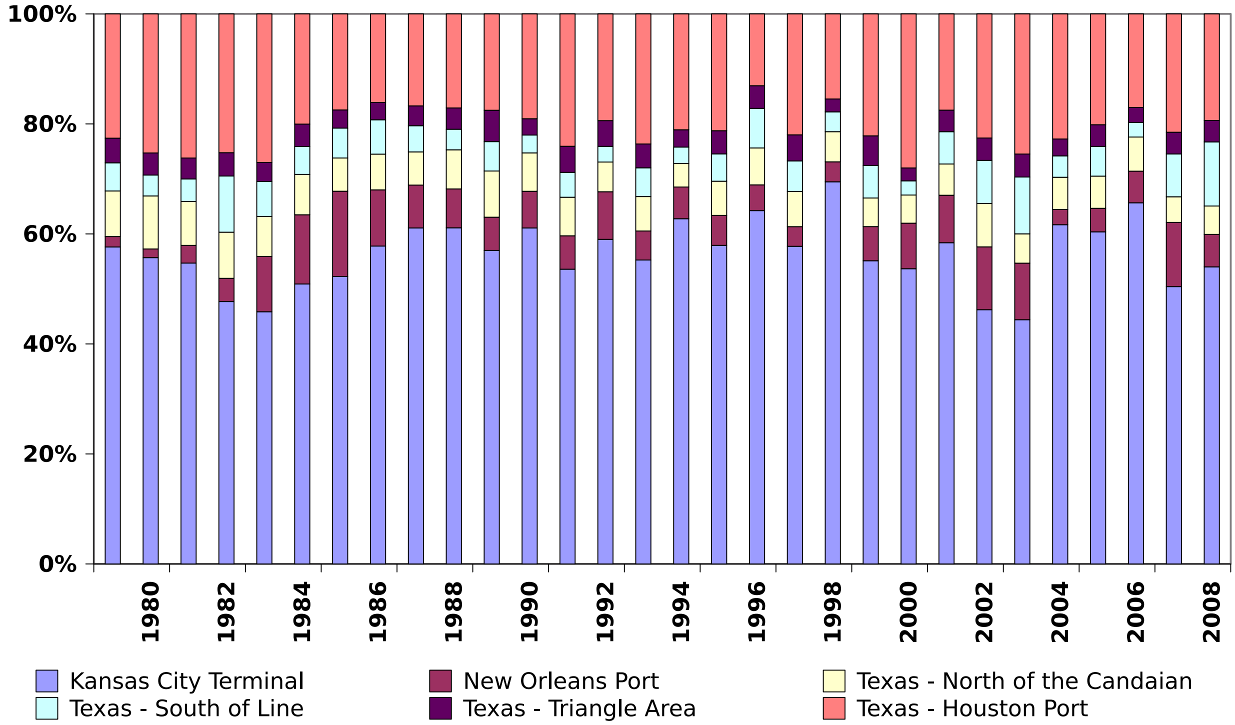
Texas

Anderson, Angelina, Aransas, Atascosa, Austin, Bandera, Bastrop, Bee, Bell, Bexar, Blanco, Bosque, Bowie, Brazoria, Brazos, Brooks, Brown, Burleson, Burnet, Caldwell, Calhoun, Callahan, Cameron, Camp, Cass, Chambers, Cherokee, Coleman, Collin, Colorado, Comal, Comanche, Concho, Cooke, Coryell, Dallas, Delta, Denton, DeWitt, Dimmit, Duval, Eastland, Edwards, Ellis, Erath, Falls, Fannin, Fayette, Fort Bend, Franklin, Freestone, Frio, Galveston, Gillespie, Goliad, Gonzales, Grayson, Gregg, Grimes, Guadalupe, Hamilton, Hardin, Harris, Harrison, Hays, Henderson, Hidalgo, Hill, Hood, Hopkins, Houston, Hunt, Jackson, Jasper, Jefferson, Jim Hogg, Jim Wells, Johnson, Karnes, Kaufman, Kendall, Kenedy, Kerr, Kimble, Kinney, Kleberg, Lamar, Lampasas, La Salle, Lavaca, Lee, Leon, Liberty, Limestone, Live Oak, Llano, McCulloch, McLennan, McMullen, Madison, Marion, Mason, Matagorda, Maverick, Medina, Menard, Milam, Mills, Montgomery, Morris, Nacogdoches, Navarro, Newton, Nueces, Orange, Panola, Polk, Rains, Real, Red River, Refugio, Robertson, Rockwall, Rusk, Sabine, San Augustine, San Jacinto, San Patricio, San Saba, Shelby, Smith, Somervell, Starr, Tarrant, Titus, Travis, Trinity, Tyler, Upshur, Uvalde, Van Zandt, Victoria, Walker, Waller, Washington, Webb, Wharton, Willacy, Williamson, Wilson, Wood, Zapata, Zavala

Oklahoma

Adair, Atoka, Bryan, Carter, Cherokee, Cleveland, Choctaw, Coal, Craig, Creek, Delaware, Garvin, Haskell, Hughes, Johnston, Latimer, Le Flore, Lincoln, Love, Logan, Marshall, Mayes, McClain, McCurtain, McIntosh, Murray, Muskogee, Nowata, Okfuskee, Oklahoma, Okmulgee, Osage, Ottawa, Pawnee, Payne, Pittsburg, Pontotoc, Pottawatomie, Rogers, Seminole, Sequoyah, Tulsa, Wagoner, Washington

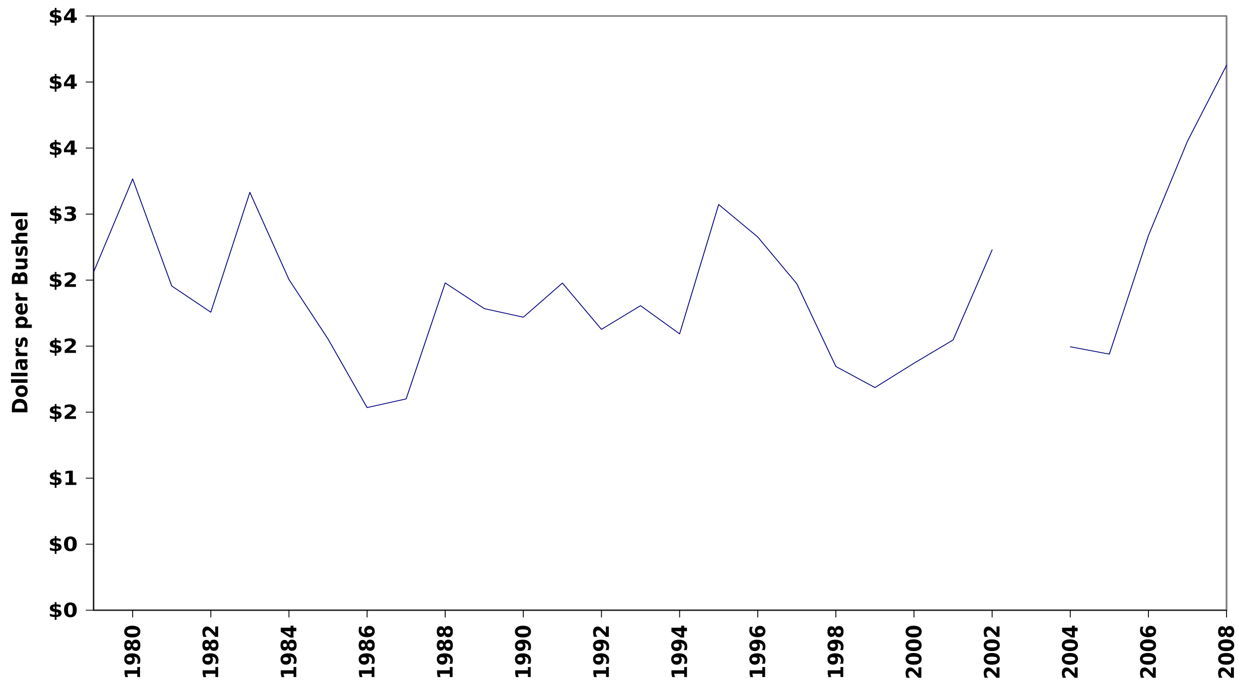
Figure 3: Time Series of Region Weights



Weights

Year	Kansas City Terminal	New Orleans Port	Texas-North of Candaian	Texas-South of Line	Texas-Triangle Area	Texas-Houston Port
1979	0.576284	0.018892	0.082906	0.051208	0.044753	0.225957
1980	0.556877	0.015783	0.096373	0.037942	0.040242	0.252783
1981	0.546954	0.032192	0.079725	0.041067	0.038043	0.262019
1982	0.477003	0.04224	0.083847	0.102125	0.042468	0.252318
1983	0.45853	0.100533	0.072709	0.063444	0.034562	0.270221
1984	0.508992	0.12583	0.073357	0.050743	0.040709	0.200369
1985	0.522578	0.155001	0.060436	0.054339	0.033073	0.174574
1986	0.577904	0.102194	0.06491	0.062532	0.031342	0.161117
1987	0.610877	0.077878	0.060351	0.04763	0.036059	0.167204
1988	0.611129	0.070666	0.071125	0.037321	0.038802	0.170958
1989	0.56997	0.060379	0.084013	0.053425	0.056989	0.175225
1990	0.61085	0.066619	0.069827	0.032426	0.029721	0.190557
1991	0.535822	0.060781	0.070038	0.045278	0.047405	0.240677
1992	0.590113	0.086568	0.05398	0.028496	0.046825	0.194019
1993	0.552549	0.052781	0.062546	0.052308	0.04334	0.236475
1994	0.627657	0.057596	0.042656	0.029919	0.03154	0.210632
1995	0.57917	0.054489	0.062103	0.049734	0.042153	0.212352
1996	0.64236	0.046819	0.067106	0.071916	0.041264	0.130536
1997	0.577451	0.035742	0.06402	0.055511	0.047431	0.219844
1998	0.694777	0.036278	0.05482	0.036044	0.023397	0.154683
1999	0.551253	0.062035	0.051991	0.059212	0.053835	0.221675
2000	0.536758	0.082727	0.051185	0.025849	0.023423	0.280058
2001	0.584029	0.086241	0.056836	0.058753	0.039144	0.174997
2002	0.462252	0.114222	0.078748	0.078454	0.040678	0.225646
2003	0.444046	0.102768	0.053338	0.103261	0.041784	0.254803
2004	0.616771	0.027636	0.058546	0.038947	0.030674	0.227426
2005	0.603809	0.042722	0.058479	0.054047	0.039484	0.201458
2006	0.656619	0.057424	0.062067	0.02655	0.027132	0.170209
2007	0.504204	0.116729	0.046602	0.077853	0.039449	0.215162
2008	0.540137	0.058987	0.051588	0.116571	0.038894	0.193821

Figure 4: National Representative Harvest-time Grain Sorghum Price



Prices

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1998	1.7752	2.1504	1.6422	1.855	1.8732	2.1574
1999	1.5176	2.0384	1.57136	1.67216	1.708	2.0328
2000	1.7584	2.1	1.5876	1.6184	1.7542	2.1028
2001	1.8928	2.3968	1.981	2.0538	2.03	2.408
2002	2.632	2.968	2.506	2.5816	2.527	2.9736
2003	2.3408		2.114	2.2036	2.1574	2.772
2004	1.7976	2.4192	1.9656	1.96336	1.97344	2.49536
2005	1.7248	2.52	1.8984	1.84576	1.89952	2.5046
2006	2.8392	3.2592	2.3156	2.3338	2.3128	3.038
2007	3.136	4.536	3.283	3.3054	3.3642	4.1748
2008	3.3152	5.348	4.6928	4.5892	4.6424	5.4852