Spatial and Temporal Maize Price Analysis in East Africa

Sika Gbegbelegbe and Hugo de Groote
Socioeconomics Program, CIMMYT, Nairobi, Kenya

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Abstract

Maize is the major food crop and an important cash crop in East Africa, but yields have not increased in the last years. Maize prices fluctuate heavily both over time, causing price insecurity which hampers investment decisions, and over space which, combined with limited knowledge of that fluctuation, reduces opportunities to market surplus.

In this paper, temporal and spatial price volatility is analyzed, based on monthly maize prices from various markets in East Africa, including 28 markets in Kenya. The hypothesis that the market liberalization of the 1990s increased efficiency and decreased volatility in Kenya is also tested.

Preliminary results for Kenyan markets show a clear negative trend, indicating that real maize prices have decreased over time, on average 4% per year. Major factors in price variation are the differences between years, although a distinct one-season effect is demonstrated. Prices are clearly higher in the surplus zone during the high season, but lower otherwise. The coast has higher prices in the lower season.

Generally, it can be concluded that price volatility has been decreasing over the years. The liberalization, most likely, has played a positive effect on this trend.

Key words: Market liberalization, maize, price variation, spatial analysis

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1. Introduction

African agriculture improved dramatically in the 1960s and 1970s, due to strong public investment in research and extension, combined with market interventions such as guaranteed prices and subsidized inputs and credit (Stringer and Pingali, 2004). However, these interventions also had their limitations: government institutions often are not very efficient, and their interventions tend to be expensive and also tend to reduce the involvement of the private sector. Over time, government intervention in agricultural markets began to be seen as a major problem (Crawford et al., 2003). As a reaction, and strongly encouraged by the donor community, many countries adopted Structural Adjustment Plans (SAPs), starting in the 1980s. These SAPs focused on creating a conducive environment for private sector involvement, by liberalizing markets for agricultural inputs and outputs, letting market forces determine the prices of these products, and reduce government's role (Gisselquist and Grether, 2000; Gisselquist et al., 2002). The Kenyan government, faced with tight budgets and pressure from donors liberalized the maize marketing, lifting trade and transport controls, reducing the interventions of the marketing board, and liberalizing prices (Wangia et al., 2004). Other countries in there region, namely Uganda and Ethiopia, followed a strategy similar to that of Kenya by implementing SAPs.

Unfortunately, the liberalization of the agricultural sector in SSA did little to increase productivity. A synthesis of relevant research finds a consensus that economic performance of the region has lagged behind that of developing countries in other regions and that the reforms have fallen short of their expected outcomes (Kherallah et al., 2002). Often, reforms studied were only partially implemented and reversal was common. Others argue that, while liberalization is necessary to accelerate productivity, it is not sufficient. Proper distribution systems need to be in place, appropriate and efficient regulatory and legal frameworks need to be in place, and infrastructure, especially for transport infrastructure, is needed to decrease the transaction costs (Tripp, 2001; Tripp and Rohrbach, 2001).

Informal discussions in the different agro-ecological zones in Kenya revealed that farmers complain that price volatility is a major problem (De Groote et al., 2004). Maize is their most important food crop, and also an important cash crop. But prices fluctuate heavily over time, so farmers face price insecurity that hampers investment decisions, and over space, although they have little knowledge on the latter to guide them to market their surplus. Therefore, in this paper, the temporal and spatial price volatility is analyzed in various markets in Kenya, Uganda and Ethiopia; the hypothesis that the liberalization increased market efficiency and decreased volatility in Kenya is also tested.

2. Methodology

2.1. Conceptual framework

Before the liberalization, African governments generally maintained tight price and movement controls in the maize market. It was expected that the release of those controls could increase price volatility, at least in the short run. Over time, however, markets are expected to become more efficient, reducing the temporal volatility. Similarly, most African governments, used to have fixed and pan-territorial prices for major staples. The liberalization was expected to bring price corrections, reflecting cost of production and trade. When markets become more efficient, however, these prices are expected to stabilize. Many factors, other than the policy environment, influence prices. Some of the main factors include changes in supply brought by climatic conditions, changes in imports, food aid and governmental interventions in the market.

2.2. The models

The standard procedure to analyze the temporal price variability is to regress the corrected price on a time indicator. Mathematically:

$$P_{it} = \alpha + \beta t + \varepsilon_{it}$$

where P_{it} is the adjusted maize price in location i at time t in consecutive months (January 1, 1994 = 1).

Since these price data are panel data, or combined cross-sectional and time series data, the appropriate model needs to correct for autocorrelation of the error terms over time and space by including dummies for both (Greene, 1991). For time, a combination of the trend and dummies for the months is used, and for space dummies for the markets. The model becomes:

$$P_{it} = \sum_i \alpha_i + \sum_m \mu_m + \beta t + \varepsilon_{it}$$

Where α_i is the coefficient for the binary variable of market I, and μ_m is the coefficient for the binary variable for month m. For this second regression, only those markets with few missing values were selected. Autocorrelation was tested using the Durban-Watson test. Seasonal variation was analyzed by comparing the coefficients of the monthly binary variables.

Spatial price variation was analyzed using the framework proposed by Rapsomanikis, Hallam and Conforti (2004) which involves the following steps (Figure 1):

1. Assess the order of integration of market price:
   - If tests results suggest different integration orders across the price series, there is no integration and Granger causality tests are performed
   - If results suggest I(0), estimate ADL and perform GC tests
   - If results suggests series are integrated of order k, I(k), proceed to step 2
2. Apply Johansen or Engle and Granger procedures to test co-integration:
   - If results suggests no co-integration, estimate ADL and perform GC tests
   - If results suggests co-integration, perform GC tests and move to step 3
3. Estimate VECM: assess speed of adjustment and test for long-run Granger causality; then, move to step 4
4. Estimate AECM: test for asymmetric price response and transmission

[FIGURE 1]

This analysis should be considered as preliminary. Formal tests for market integration would use more sophisticated models that include lagged prices and other factors that influence prices, including rainfall and production in the region, such as the Ravallion/Timmer model (Fackler and Goodwin, 2001). Ideally, the model should include quantities marketed and transport costs, data that are unfortunately not yet available.

2.3. Data

For the analysis on Kenyan markets, we used monthly maize prices collected by the Ministry of Agriculture, in 28 markets (although not consistently in the same markets every year), from January 1990 to December 2010 (150 months) (Figure 2). Maize prices for markets in Uganda and Ethiopia are from the Uganda Bureau of Statistics (UBOS) and the Central Statistical Office in Ethiopia, respectively.

[FIGURE 2]

To correct for inflation, nominal prices in Kenya, were multiplied by the Consumer Price Index (CPI), which is produced annually by the Central Bureau of Statistics (CBS). The annual CPI was converted into a monthly CPI using a linear approximation.

3. Preliminary Results

Here, we discuss preliminary results for Kenya. Some additional analysis will also be done for maize markets in Uganda and Ethiopia.

3.1. Evolution of prices over time (temporal variation)

Plotting the monthly maize prices over time clearly shows how the nominal price of maize has increased slowly over the years (Figure 3). The average price of maize was 1167 Kenya shillings (KSh) for a standard 90 kg bag, or 12.0 KSh/kg. Over the same period of 150 months, however, the CPI increased sharply, more than doubling in value.

As a result, the maize price in constant prices (2009 KShs/kg) decreased substantially. The trend, obtained by KShs/month (Table 1), is about almost half a shilling per year for nominal prices and about 1 shilling per year for the real prices.

[FIGURE 3]

[TABLE 1]

Correcting for the trend, the major source of variation is clearly between the different years, especially in the beginning. Maize prices in 1994 and 1997 are substantially above the trend, while 1995, 1996, 1998 and 2002 are substantially below. After the variation between years, there is also a clear seasonal pattern. Including binary variables for the major markets and monthly binary variables for February till December (keeping January as a base), results in significant price differences from May to August (Table 2). This reflects the supply of the major rainy season, from April to August.

[TABLE 2]

This seasonal variation is better understood when compared to the month with the lowest prices, October, and plotting the monthly price differences (Figure 4). A strong seasonal trend is clearly visible, although basically with only one season. Prices are lowest in November, shortly after the harvest. They rise slowly from November till April, followed by another sharp price increase in May. Price stays high in June and July, but drop quickly over August and September. The short rainy season (October to December) does not seem to have much impact on prices, other than a small increase in December.

[FIGURE 4]

3.2. Price differences between markets (spatial variation)

3.2.2 Kenyan maize markets versus international maize markets

Maize prices in Nairobi, Mombasa, and selected international markets are integrated of order one (Table 3). However, the maize price series in Nairobi does not seem to be co-integrated with the price of white maize in SAFEX or with the price of maize US no 2, from the US Gulf (Table 3). These results suggest no integration between maize markets in Nairobi and in international markets. Some additional Granger causality tests and the estimation of the ADL model indicate some Granger causality from Nairobian markets to SAFEX with lags 9 and 11 (Table 3). Such results imply that shocks to maize prices in Nairobi are passed through to maize prices in SAFEX some months later; however, the effects of these shocks are not strong enough to drive maize prices in SAFEX. The results also imply no relationship between maize prices in Nairobi and the price of maize US no 2 (Table 3).

Maize markets in Mombasa are also not integrated with international maize markets (Table 3). However, the results suggest some Granger causality from Mombasa to Safex with a lag of 4 months: this means that shocks to maize prices in Mombasa are passed through, albeit not strongly to maize prices in SAFEX, about 4 months later. The results also imply that the price of maize US no 2 Granger-causes maize prices in Mombasa for lags

[TABLE 3]

3.2.3 Market Integration between maize markets in Kenya

Maize prices in all markets under study are integrated of order one: augmented Dickey-Fuller and Philips Perron tests with and without drift indicate that the price series are non-stationary in their levels but they are stationary in their first-difference (Table 4). The Engle and Granger procedure also indicated that all maize markets under study were co-integrated of degree CI(1,1) on a pairwise basis, except for Eldoret and Nairobi.

The Granger causality tests were performed for the co-integrated price series (Table 4). The results related to maize markets in Nairobi relative to other markets in Kenya implied Granger causality in at least one direction. The estimation of the Vector Error Correction Models (VECM) implied that maize prices in Mombasa take about 1.7 months to fully adjust to the maize price changes in Nairobi: the coefficient of the error correction term is 0.6 and is significant at the 5% threshold level. The estimated coefficients in the VECM also imply that maize prices in Mombasa are affected by the maize price shocks that occurred 5 months earlier in Nairobi. However, the test of long-run Granger causality also indicates a bilateral Granger causality between maize prices in Nairobi and Mombasa: in the long-run, maize prices in Nairobi and Mombasa affect each other.

The results also indicate full price transmission between maize markets in Nairobi and Nakuru, with prices in Nakuru being affected by prices in Nairobi in the short term (Table 4). Long-run Granger causality test also indicate that maize prices in Nairobi Granger-cause maize prices in Nakuru and not vice versa. These results imply that maize prices in Nakuru strongly depend on maize prices in Nairobi. A similar conclusion applies for maize markets in Nairobi and Kisumu; however, in this case, maize prices in Nairobi strongly depend on maize prices in Kisumu.

The Granger causality tests implied unilateral Granger causality between maize prices in Mombasa and each of the other Kenyan markets (Table 4). The results related to estimating the VECM for maize prices in Mombasa and Nakuru suggest a slow adjustment to the long-run relationship between maize prices in the two markets: the coefficient of the error correction term is insignificant. Moreover, maize prices in Mombasa are affected by maize price shocks that occur in Nakuru 9 months earlier. However, long-run Granger causality tests imply that maize prices in Mombasa and Nakuru affect each other in the long run.

A similar conclusion applies to maize prices in Mombasa and Eldoret (Table 4). The econometric results imply that maize prices in Mombasa are affected by maize prices in Eldoret with a lag of 1, 2 and 7 months. However, maize prices in the two towns Granger-cause each other in the long run.

The Granger causality tests on maize prices in Mombasa and Kisumu showed no Granger causality, even if the series were co-integrated of degree CI(1,1) (Table 4). In addition, the results related to estimating the VECM for these two price series indicated no relationship between the price series. The results implying co-integration between the two prices series might stem from the fact that maize markets in Kisumu affect the ones in Nairobi while maize markets in Nairobi affect the ones in Mombasa, as shown in the earlier results.

The Granger causality tests on the relationship between maize prices in Nakuru and each of Eldoret and Kisumu suggested bilateral or unilateral Granger causality (Table 4). The estimation results related to the VECM linking maize prices in Nakuru and Eldoret indicate a slow adjustment to the long-run equilibrium between maize prices in the two markets. In the short- and medium-term, maize prices in Nakuru affect maize prices in Eldoret. However, in the long-run, the two price series Granger-cause each other. A similar conclusion applies the maize prices in Nakuru and Kisumu. Maize prices in Nakuru affect maize prices in Kisumu in the short- to medium-term. However, the two price series affect one another in the long-run.

The Granger causality tests between Eldoret and Kisumu implied a bilateral Granger causality (Table 4). However, the estimation of the VECM for the two price series indicated that there is no relationship between the two price series. Maize markets in Nakuru are integrated with maize in each of Eldoret and Kisumu, as explained earlier. Hence, it should not be surprising for Eldoret and Kisumu to be co-integrated, as shown in the test results. However, the subsequent tests, including the VECM estimation has shown no relationship.

Even if maize prices in maize prices in Nairobi and Eldoret are not co-integrated, some additional tests were conducted to assess whether the price series are linked to one another in any way. The Granger causality tests implied that there is Granger causality from Eldoret to Nairobi in the short-term (same month and also at lags of 1 and 2 months) (Table 4). Moreover, the estimation of the Autoregressive Distributive Lag model implied that shocks to maize prices in Eldoret are partly transmitted to maize prices in Nairobi within the same month or one month later.

3.3. Combining temporal and spatial analysis

To determine if maize markets have become more integrated, the spatial and temporal dimensions of price variation were combined in the analysis. In particular, the evolution of price differences between major markets over time was analyzed (Table 5). The mean difference (MD in the Table 5) between the major consumer market, Nairobi, and the coast has evolved over the study period from positive (higher price in Nairobi) to negative (higher prices in Mombasa). The mean squared difference (MSD), an indicator of variance between the two markets, has declined over the years. This is confirmed by the results of regression of MSD over time (lower part of Table 5).

The mean price difference between Nairobi and the supply markets (Kitale and Eldoret), on the other hand, have remained relatively constant, with a distinct peak in 2002.

The price differences between Nairobi and the major market in Western Kenya (Kisumu) have also been reduced over time. To analyze the difference with a deficit area Garissa), the available data are not sufficient. Comparing the prices between the major import harbor (Mombasa) and the most important Western consumption market (Kisumu), also indicates a reduction in variability. The reduction in price differences with the production zone (Eldoret) is less distinct, but the regression still shows it is significant.

4. Conclusions

The analysis of temporal variation shows that real maize prices have decreased over time in Kenya. Major factors in price variation are the differences between years, although a distinct one-season effect is demonstrated. Prices are clearly higher in the surplus zone during the high season, but lower otherwise. The coast has higher prices in the lower season. Price volatility has been decreasing over the years, and most likely market liberalization has played a positive effect on this trend.

However, to isolate the effect of the liberalization, the analysis needs to be widened to include other factors known to influence prices, in particular climatic conditions and its effect on production, maize imports and the effect of international maize prices.

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FIGURES

Figure 1. A Conceptual Approach for testing for Market Integration

Figure 2. Kenya's Agro-ecological Zones and the Location of Markets with Available Maize Price Data

Figure 3. Evolution of Maize Prices in Kenya (1994-2006)

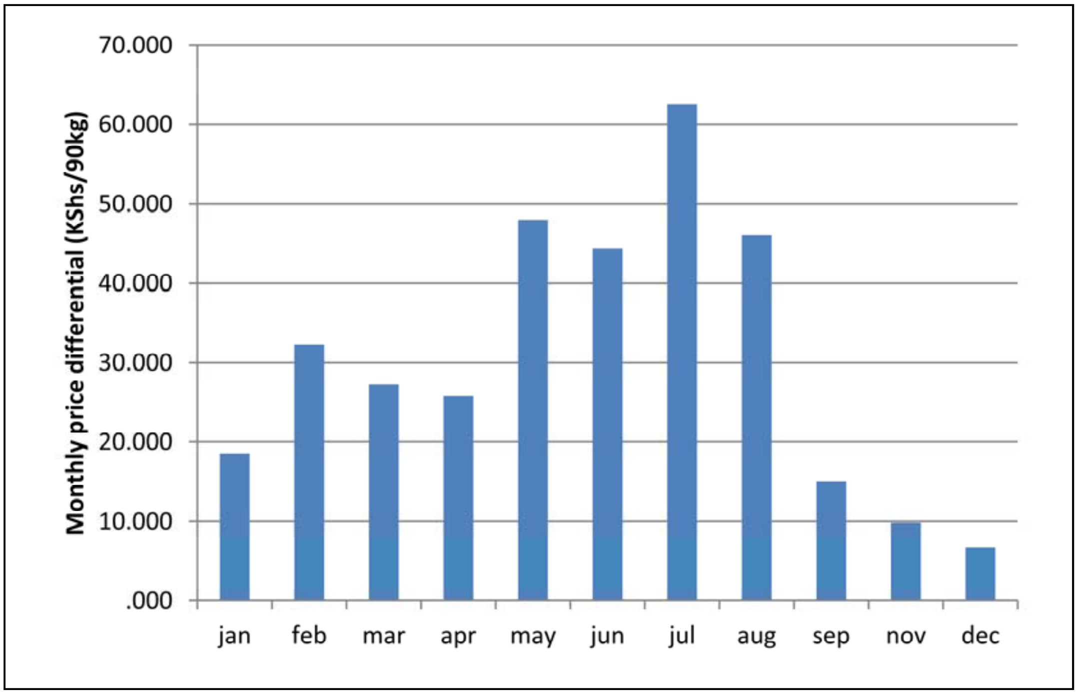

Figure 4. Seasonal Variation of Maize Prices in Kenya

TABLES

Table 1. Estimation of trends of maize prices in Kenya (1991-2011)

Variable	Nominal Price (KShs/kg)			Real price (2009 KShs/kg)		
	Estimated coefficients	Std. Error	Sig.	Estimated coefficients	Std. Error	Sig.
Constant	7.084	.261	.000	39.093	.498	.000
Month (January 1999=1)	.056	.002	.000	-.093	.003	.000
R2	.466			.400		
St. err. Estimate	4			8		
N	1091			1091		

Note: nominal maize prices have increased substantially, from 1991 to 2011, an increase of 0.056 KShs/month; however, real prices have decreased, by 0.093 KShs/kg/month, or US$ 1.2/ton/month.

Table 2. Regression of Maize Prices (1999 KShs/kg) on Time, Months and Locations

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	445.582	14.330		31.095	.000
	month_cont	-1.207	.044	-.624	-27.592	.000
	Nakuru	12.817	9.719	.038	1.319	.188
	Kisumu	42.678	9.755	.126	4.375	.000
	Nairobi	54.114	9.563	.164	5.659	.000
	Mombass	66.842	9.665	.200	6.916	.000
	month01	18.549	15.247	.039	1.217	.224
	month02	32.342	15.169	.068	2.132	.033
	month03	27.263	15.132	.058	1.802	.072
	month04	25.846	15.131	.055	1.708	.088
	month05	48.001	15.515	.097	3.094	.002
	month06	44.414	15.568	.089	2.853	.004
	month07	62.522	15.355	.129	4.072	.000
	month08	46.054	15.642	.092	2.944	.003
	month09	15.109	15.317	.031	.986	.324
	month10	9.832	15.280	.020	.643	.520
	month11	6.704	15.634	.013	.429	.668

Table 3. Test results related to market integration between international and Kenyan maize markets

Order of integration[1]			Granger causality[2]		ADL estimation	
	Nairobi	Mombasa	Nairobi	Mombasa	Nairobi	Mombasa
White maize (SAFEX)	-	No	GC	GC	Pass through is 2-way	Pass through from Mombasa to SAFEX: lag 4
Maize US no 2	No	-	GC	GC*	No pass through	Pass through from Maize US no 2 to Mombasa: lags 1, 4

1: Augmented Dickey Fuller and Philips-Perron tests (with and without drift) were conducted on level and first-difference time series to assess order of integration; the results implied that all price series were I(1). The Engle and Granger procedure was the applied to assess whether the series were CI(1,1)

2: Granger causality tests were applied to series (first-differenced series); GC for Nairobi and wmsafex implies that there is statistically significant (threshold of 5%) Granger causality from Nairobi to the price of white maize on SAFEX; GC* for Mombasa and Musa implies that there is statistically significant Granger causality from the price of white maize US no 2 to maize prices in Mombasa

Table 4: Test Results related to market integration between maize markets in Kenya

	Order of integration[1]					**Granger causality tests**[2]				
	Nairobi	Mombasa	Nakuru	Eldoret	Kisumu	Nairobi	Mombasa	Nakuru	Eldoret	Kisumu
Nairobi	-	CI(1,1)	No	No	CI(1,1)	-	No	GC-4,12	GC-0, 1, 2	GC-0, 1, 6
Mombasa	CI(1,1)	-	CI(1,1)	CI(1,1)	CI(1,1)	GC-5	-	GC-9,11	No	No
Nakuru	CI(1,1)	CI(1,1)	-	CI(1,1)	CI(1,1)	GC-1,10	No	-	GC-0, 1	GC-0, 1, 2, 3, 4, 5
Eldoret	No	CI(1,1)	CI(1,1)	-	CI(1,1)		GC-3,4	GC-0, 2, 3	-	GC-4
Kisumu	CI(1,1)	CI(1,1)	CI(1,1)	CI(1,1)	-	No	No	No	GC-1	-
VECM estimation										
	VECM estimation: adjustment to long-run equilibrium (months)[3]					**VECM estimation: selected lagged terms**[4]				
	Nairobi	Mombasa	Nakuru	Eldoret	Kisumu	Nairobi	Mombasa	Nakuru	Eldoret	Kisumu
Nairobi	-				3.57	-				PT: lags 6
Mombasa	1.67	-	Insignificant	Insignificant		PT: lags 5	-	PT: lags 9	PT: 1, 2, 7	No relation
Nakuru	2.13		-			PT: 4, 10		-		
Eldoret			Insignificant	-				PT: 2, 3, 10	-	No relation
Kisumu			Insignificant		-		No relation	PT: 1, 2	No relation	-

1: Augmented Dickey Fuller and Philips-Perron tests (with and without drift) were conducted on level and first-difference time series to assess order of integration; the results implied that all price series were I(1). The Engle and Granger procedure was the applied to assess whether the series were CI(1,1)
2: Granger causality tests were applied to series (first-differenced series); GC-5 for Mombasa and Nairobi implies that there is statistically significant (threshold of 5%) Granger causality from Nairobi to Mombasa at lag 5
3: Results are related to the VECM estimation linking any two series; '1.67' for Nairobi and Mombasa implies that the long-run equilibrium between maize prices in Nairobi and Mombasa is restored 1.67 months after a shock
4: Results are related to the VECM estimation linking any two series; 'PT: lags 5' for Mombasa and Nairobi implies that there is price transmission (PT) and that shocks to maize prices in Nairobi are passed through to maize prices in Mombasa 5 months later.

Table 5. Analysis of the Difference between Maize Prices in Major Towns in Kenya (1999 KShs/kg, 1994-2006)

		From Nairobi to										From Mombassa to			
		Mombassa		Eldoret		Kitale		Kisumu		Garissa		Kisumu		Eldoret	
		MSD	MD	MSD	MD	MSD	MD	MSD	MD	MSD	MD	MSD	MD	MSD	MD
Means	1994	4.24	1.39	2.34	-1.12	12.59	-3.19	4.84	-1.40	139.14	11.64	16.07	-2.79	9.88	-2.51
	1995	4.30	1.89	5.42	-2.27	7.74	-2.71	1.80	-1.25	.	.	10.92	-3.13	18.51	-4.15
	1996	2.40	1.47	6.83	-2.51	6.85	-2.47	0.18	-0.15	18.08	4.12	2.96	-1.62	17.02	-3.98
	1997	0.96	0.56	5.22	-0.45	7.38	-1.20	4.13	1.45	11.41	-2.81	9.24	2.21	10.49	0.31
	1998	0.54	-0.23	3.44	-1.31	3.56	-1.41	2.71	1.18	.	.	4.56	1.41	3.43	-1.01
	1999	1.15	0.46	7.02	-2.57	7.15	-2.19	3.08	-1.40	.	.	4.61	-1.87	10.65	-3.04
	2000	1.57	-0.35	5.05	-2.04	9.77	-2.88	1.39	-0.88	.	.	1.53	-0.53	4.93	-1.69
	2001	0.26	-0.04	7.72	-2.73	.	.	0.55	-0.59	.	.	0.72	-0.55	7.51	-2.70
	2002	1.79	-0.73	11.54	-3.21	12.84	-3.46	0.86	-0.53	.	.	0.87	0.20	6.06	-2.36
	2003	1.81	-1.02	2.55	-1.13	3.19	-1.45	4.12	0.05	.	.	3.22	1.12	1.64	-0.11
	2004	0.69	-0.20	1.90	-1.24	.	.	0.35	0.17	.	.	1.53	0.56	1.83	-0.81
	2005	0.20	-0.28	3.70	-1.89	.	.	0.26	-0.14	.	.	0.45	0.14	2.58	-1.57
	2006	0.21	-0.29	4.39	-2.07	.	.	1.17	-0.68	5.55	-2.36	0.50	-0.39	3.17	-1.78
	Overall	1.67	0.20	5.27	-1.87	8.13	-2.34	2.00	-0.30	44.23	3.17	4.62	-0.40	7.91	-1.95

N	N	135	135	139	139	84	84	143	143	25	25	145	145	141	141
Regression	(Constant)	3.937	***			11.573	***					11.184	***	16.87	***
coefficients		(0.419)				(1.358)						(1.156)		(1.217)	
	Time													-	
(st dev.)		-0.024	***			-0.019						-0.089	***	0.102	***
		(0.004)				(0.0187)						(0.012)		(0.013)	
	High													-	
	season	-1.23	**			-5.949	***					0.042		3.792	***
		(0.394)				(1.434)						(1.088)		(1.143)	
	N	134				83						144		140	
	R2	0.221382				0.184						0.2628		0.333	
	St error														
	estimate	2.228941				6.4494						6.4157		6.663	

MSD= Mean squared difference between constant maize prices

MD= Mean difference between constant maize prices