Agricultural Commodity Prices and Crude Oil Prices:

Long Relationship

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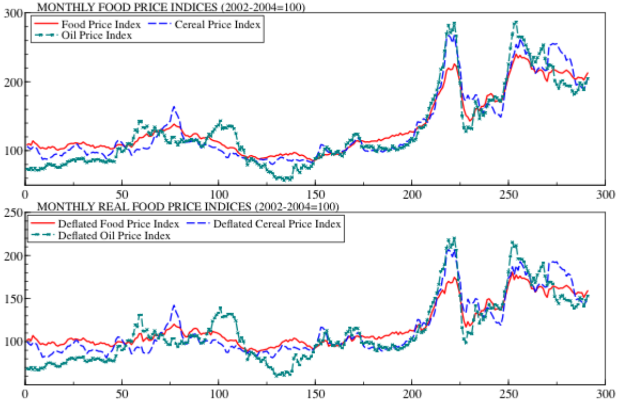
Why does it matters?



What do we know?

- Overwhelming number of studies on the effects of Energy Prices on Feedstock Price.
- Most studies concentrated in the U.S., Brazil and Germany.
- Predominant methodology used is Cointegration and VECM. However, most studies conduct the analysis in small sample periods using pair-wise analysis[1].
- Despite the number of studies the literature is not consistent in the results.

[1] See Campiche et al. (2007) where the authors find pair-wise (oil-feedstock) cointegration relationship over 2006-08.

Literature Review

- Saghaian (2010) finds evidence of cointegration between crude oil, ethanol, wheat, corn and soybean prices.
- While Zhang et al. (2010) find no evidence of cointegration between energy and agricultural commodity prices.
- Ciaian and Kancs (2011) find pair-wise cointegration by splitting the data into three periods with no formal argument[2].
- Natanelov et al. (2011) find that crude oil cointegration with feedstock to have vanished in recent years while at the same time argues that long-run causality flows from food commodities towards crude oil.
- Only recently Nazlioglu and Soytas (2012) used panel cointegration to determine that crude oil prices and exchange rates determine agricultural prices (Xrate is stronger link) as well as a LR between crude oil and agricultural prices.

[2] "The segmentation of the sample corresponds to roughly to structural breaks."

What is our contribution?

- No study so far has analyzed the long-run relationship at a global level using high frequency data at this length (1982-2012) using deflated prices.
- Include macroeconomic variables such as real interest rate, global demand and exchange rate to account for factors other than energy on agricultural commodities.
- Very few studies (if any) have addressed the complexity of modelling commodity prices using Cointegration-VAR while attempting to address the misspecifations and identification challenges the methodology outlines.

Methodology

General VAR Model

Johansen and Juselius (1990) and Johansen (1992)

General $p-dimensional$ VAR model in error correction form

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-1} + \mu_0 + \mu_1 t + \Psi D_t + \varepsilon_t, \quad \forall\ t = 1, 2, \ldots, T \tag{1}$$

Assumptions from Equation 1 indicate that the mean and actual realisation of the model follows a white noise process.

Methodology

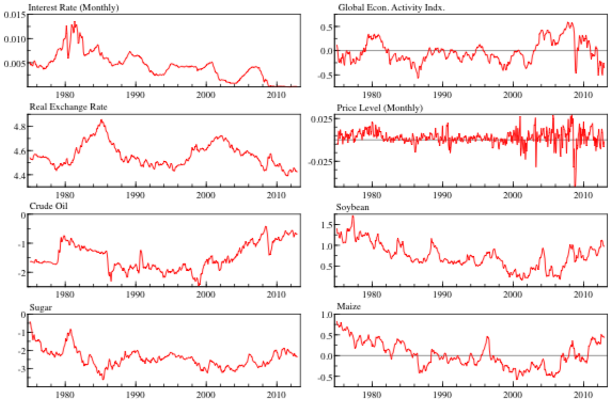
CVAR Definition

Assuming Equation (1) contains a mixture of stationary and non stationary components, then there exists $n \times r$ matrices α and β, each of them with rank 'r' such that $\Pi = \alpha\beta'$ and $\beta' X_t$ is stationary.

The number of cointegration relationships is determined by the rank 'r' and the adjustment parameters in the error correction model are found in the α matrix and $\beta' X_t$ represents the r number of cointegration relations. The cointegration relationships determine the deviations front he long-run dynamics between the variables and the coefficients in α measure the rate of adjustments to any deviations from the long-run relationship.

Data Figures

Log Transformation



VAR Models

Assumptions

Interested in estimating 3 CVAR models:

Models

- **Model 1:** Maize ⇔ Oil and Macroeconomic Variables
- **Model 2:** Soybean ⇔ Oil and Macroeconomic Variables
- **Model 3:** Sugar ⇔ Oil and Macroeconomic Variables

Note that from Equation 1, the theoretical implications of the residuals imply:

- Multivariate Normality
- Independence (i.e. No Serial Autocorrelation)

Unrestricted VAR Models

Model Description

Lag Structure

The initial number of lags has been selected to three (i.e. $k = 3$) by minimizing the standard Schwarz (SC) and Hanna-Quinn (HQ) information criteria and of ‘no serial autocorrelation’.

Deterministic Components

Since the series present no linear trends, the only deterministic component in these models are the intercepts, which have been restricted to the cointegrating space.

Unrestricted VAR Models

Misspecification Tests - Model 1 (Maize)

Tests for Autocorrelation				
LM(1):	$\chi^2(36)$	=	37.252	[0.411]
LM(2):	$\chi^2(36)$	=	48.461	[0.080]
Test for Normality:	$\chi^2(12)$	=	712.825	[0.000]
Variables	**Mean**	**Std.Dev**	**Skewness**	**Kurtosis**
Δmz_t	0.000	0.051	0.413	7.020
Δo_t	0.000	0.072	0.225	5.395
Δy_t	0.000	0.054	-0.641	9.716
$\Delta^2 p_t$	0.000	0.008	-0.820	8.809
Δi_t	0.000	0.000	-1.885	17.447
Δxr_t	0.000	0.011	0.309	4.136
	ARCH(3)		**Normality**	
Δmz_t	3.020	[0.960]	107.381	[0.000]
Δo_t	15.539	[0.001]	55.145	[0.000]
Δy_t	27.168	[0.000]	194.341	[0.000]
$\Delta^2 p_t$	42.307	[0.000]	128.667	[0.000]
Δi_t	53.775	[0.000]	171.196	[0.000]
Δxr_t	1.573	[0.666]	16.845	[0.000]

Unrestricted VAR Models

Misspecification Tests - Model 2 (Soybean)

Tests for Autocorrelation				
LM(1):	$\chi^2(36)$	=	37.227	[0.412]
LM(2):	$\chi^2(36)$	=	50.382	[0.056]
Test for Normality:	$\chi^2(12)$	=	680.931	[0.000]
Variables	**Mean**	**Std.Dev**	**Skewness**	**Kurtosis**
Δsb_t	0.000	0.049	0.662	6.156
Δo_t	0.000	0.072	0.225	5.395
Δy_t	0.000	0.054	-0.641	9.716
$\Delta^2 p_t$	0.000	0.008	-0.820	8.809
Δi_t	0.000	0.000	-1.885	17.447
Δxr_t	0.000	0.011	0.309	4.136
	ARCH(3)		**Normality**	
Δsb_t	3.507	[0.320]	57.428	[0.000]
Δo_t	14.441	[0.002]	54.999	[0.000]
Δy_t	26.495	[0.000]	198.129	[0.000]
$\Delta^2 p_t$	49.532	[0.000]	118.008	[0.000]
Δi_t	54.666	[0.000]	168.300	[0.000]
Δxr_t	1.574	[0.665]	16.928	[0.000]

Unrestricted VAR Models

Misspecification Tests - Model 3 (Sugar)

Tests for Autocorrelation				
LM(1):	$\chi^2(36)$	=	31.300	[0.692]
LM(2):	$\chi^2(36)$	=	41.293	[0.250]
Test for Normality:	$\chi^2(12)$	=	611.754	[0.000]
Variables	**Mean**	**Std.Dev**	**Skewness**	**Kurtosis**
Δs_t	0.000	0.080	0.144	3.928
Δo_t	0.000	0.072	0.246	5.276
Δy_t	0.000	0.054	-0.641	9.826
$\Delta^2 p_t$	0.000	0.008	-1.027	8.887
Δi_t	0.000	0.000	-1.704	16.177
Δxr_t	0.000	0.011	0.288	4.061
	ARCH(3)		**Normality**	
Δs_t	4.098	[0.251]	12.901	[0.002]
Δo_t	12.836	[0.002]	50.404	[0.000]
Δy_t	29.589	[0.000]	197.658	[0.000]
$\Delta^2 p_t$	51.601	[0.000]	100.807	[0.000]
Δi_t	56.021	[0.000]	181.077	[0.000]
Δxr_t	1.332	[0.722]	15.377	[0.000]

Correcting Misspecifications

According to Juselius (2006), we can achieve a well statistically specified model by modifying some of the initial specifications of the unrestricted VAR by:

- including intervention dummies (account for significant institutional changes)
- conditioning on weakly exogenous variables
- parameter constancy of the model (e.g. structural shifts)
- splitting or changing the sample period
- checking the information set by adding new variables
- checking the adequacy of the measurements of the chosen variables
- increasing the lag length (in the presence of serial autocorrelation)

Intervention and Structural Shifts

Identification Process

Periods of instability and structural changes were identified by detecting those residuals larger than three standard deviations ($\pm 3\hat{\sigma}$) as well as checking its relevance with the economic calendar.

These periods coincide with major price fluctuations in the commodity markets (e.g. Boom 2003-07), significant monetary policy interventions (e.g. Greenspan 2003) as well as the recent global financial crisis of 2007/08.

Type	Year	Month	Events
Maize			
Transitory	1988	June	Drought Midwest U.S.
Transitory	1996	September	Drought Midwest U.S.
Transitory	2008	June	Peak of the 2007/08 price shock
Transitory	2012	July	Drought Midwest U.S.
Shift	2003	April	U.S. Monetary Expansion
Soybean			
Transitory	1983	August	Drought Midwest U.S.
Transitory	1988	June	Drought Midwest U.S.
Transitory	1993	July	Flooding Midwest U.S.
Transitory	2012	July	Drought Midwest U.S.
Shift	2004	August	U.S. Monetary Expansion & Energy Policy Act of 2003/04
Sugar			
Transitory	1983	May	Drought in South Africa
Oil			
Transitory	1986	February	Collapse of Oil Prices
Transitory	1990	August	Gulf war
Inflation			
Transitory	2008	August	Financial Crisis 2008
Index of Glob.Econ.Actv.			
Transitory	2009	January	Financial crisis 2008
Transitory	2012	January	Eurozone Debt Crisis

Weakly Exogenous Variables

Model 1 - Maize

Rank	DGF	5% C.V.	mz_t	o_t	y_t	Δp_t	xr_t	i_t
1	1	3.841	2.655	0.155	7.575	83.203	0.565	0.000
			[0.103]	[0.693]	[0.006]	[0.000]	[0.452]	[0.996]
2	2	5.991	7.146	7.426	20.000	104.543	5.521	4.011
			[0.028]	[0.024]	[0.000]	[0.000]	[0.063]	[0.135]
3	3	7.815	10.228	10.706	34.094	114.159	5.654	7.322
			[0.017]	[0.013]	[0.000]	[0.000]	[0.130]	[0.062]
4	4	9.488	13.191	11.013	38.394	115.385	5.654	11.190
			[0.010]	[0.026]	[0.000]	[0.000]	[0.227]	[0.025]
5	5	11.070	16.707	12.722	41.870	118.324	7.601	15.019
			[0.005]	[0.026]	[0.000]	[0.000]	[0.180]	[0.010]

Model 2 - Soybean

			sb_t	o_t	y_t	Δp_t	xr_t	i_t
1	1	3.841	2.613	88.546	6.126	0.280	0.501	0.367
			[0.106]	[0.000]	[0.013]	[0.597]	[0.479]	[0.545]
2	2	5.991	5.713	99.262	8.558	5.929	4.217	3.804
			[0.057]	[0.000]	[0.014]	[0.052]	[0.121]	[0.149]
3	3	7.815	5.928	105.308	16.573	8.177	4.265	4.461
			[0.115]	[0.000]	[0.001]	[0.042]	[0.234]	[0.216]
4	4	9.488	11.105	110.439	21.834	11.837	5.746	4.695
			[0.025]	[0.000]	[0.000]	[0.019]	[0.219]	[0.320]
5	5	11.070	15.652	113.066	25.762	11.847	9.106	8.601
			[0.008]	[0.000]	[0.000]	[0.037]	[0.105]	[0.126]

Weakly Exogenous Variables

Model 3 - Sugar

			s_t	o_t	y_t	Δp_t	xr_t	i_t
1	1	3.841	0.343	119.285	5.298	1.686	0.710	0.498
			[0.558]	[0.000]	[0.021]	[0.194]	[0.400]	[0.480]
2	2	5.991	15.762	120.214	5.325	1.687	1.298	1.035
			[0.000]	[0.000]	[0.070]	[0.430]	[0.523]	[0.596]
3	3	7.815	19.732	123.252	12.465	1.748	1.300	1.125
			[0.000]	[0.000]	[0.006]	[0.626]	[0.729]	[0.771]
4	4	9.488	25.620	128.403	18.237	3.319	3.943	3.298
			[0.000]	[0.000]	[0.001]	[0.506]	[0.414]	[0.509]
5	5	11.070	28.547	128.409	21.039	3.585	8.000	6.816
			[0.000]	[0.000]	[0.001]	[0.611]	[0.156]	[0.235]

Correcting Misspecifications

Model 1 VAR(2) (Accounting for instability and W.E.)

Tests for Autocorrelation				
LM(1):	$\chi^2(16)$	$=$	23.197	[0.109]
LM(1):	$\chi^2(16)$	$=$	22.468	[0.129]
Test for Normality:	$\chi^2(8)$	$=$	156.680	[0.000]
Test for ARCH:				
LM(1):	$\chi^2(100)$	$=$	310.411	[0.000]
LM(1):	$\chi^2(200)$	$=$	459.478	[0.000]
Variables	**Mean**	**Std.Dev**	**Skewness**	**Kurtosis**
Δmz_t	0.000	0.047	0.006	3.685
Δo_t	0.000	0.067	-0.244	3.584
Δy_t	0.000	0.048	0.008	5.148
$\Delta^2 p_t$	0.000	0.007	-0.169	5.749
	ARCH(2)		**Normality**	
Δmz_t	6.394	[0.041]	7.980	[0.019]
Δo_t	30.613	[0.000]	7.136	[0.028]
Δy_t	29.435	[0.000]	49.719	[0.000]
$\Delta^2 p_t$	49.298	[0.000]	69.938	[0.000]

Correcting Misspecifications

Model 2 VAR(2) (Accounting for instability and W.E.)

Tests for Autocorrelation				
LM(1):	$\chi^2(16)$	=	21.270	[0.168]
LM(1):	$\chi^2(16)$	=	25.795	[0.057]
Test for Normality:	$\chi^2(8)$	=	178.885	[0.000]
Test for ARCH:				
LM(1):	$\chi^2(100)$	=	391.922	[0.000]
LM(1):	$\chi^2(200)$	=	564.341	[0.000]

Variables	**Mean**	**Std.Dev**	**Skewness**	**Kurtosis**
Δsb_t	0.000	0.042	0.207	3.637
Δo_t	0.000	0.067	-0.279	3.598
Δy_t	0.000	0.049	0.131	5.148
$\Delta^2 p_t$	0.000	0.007	-0.293	6.195
	ARCH(2)		**Normality**	
Δsb_t	0.542	[0.763]	7.592	[0.022]
Δo_t	43.968	[0.000]	7.733	[0.021]
Δy_t	27.656	[0.000]	60.975	[0.000]
$\Delta^2 p_t$	31.422	[0.000]	82.496	[0.000]

Correcting Misspecifications

Model 3 VAR(2) (Accounting for instability and W.E.)

Tests for Autocorrelation				
LM(1):	$\chi^2(16)$	=	22.437	[0.130]
LM(1):	$\chi^2(16)$	=	23.65	[0.097]
Test for Normality:	$\chi^2(8)$	=	277.592	[0.000]
Test for ARCH:				
LM(1):	$\chi^2(100)$	=	381.802	[0.000]
LM(1):	$\chi^2(200)$	=	528.8581	[0.000]
Variables	**Mean**	**Std.Dev**	**Skewness**	**Kurtosis**
Δs_t	0.000	0.077	0.040	3.490
Δo_t	0.000	0.068	-0.144	3.540
Δy_t	0.000	0.052	-0.362	7.428
$\Delta^2 p_t$	0.000	0.007	-0.622	7.360
	ARCH(2)		**Normality**	
Δs_t	1.887	[0.389]	4.671	[0.097]
Δo_t	30.667	[0.000]	5.767	[0.021]
Δy_t	33.464	[0.000]	128.64	[0.000]
$\Delta^2 p_t$	35.864	[0.000]	100.942	[0.000]

Preferred Specifications

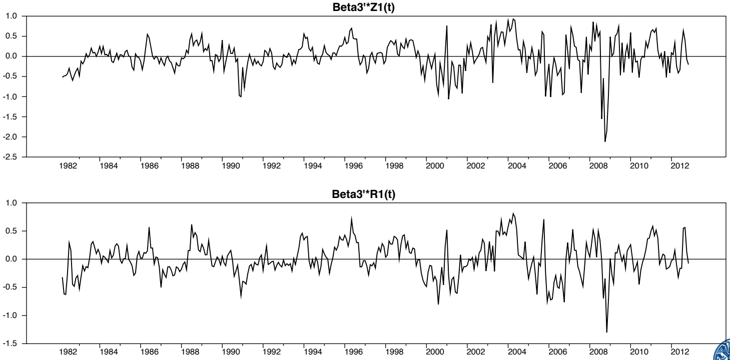
Models 1 - 3

The preferred specification is a VAR(2) with the interventions dummies and shifts dummies (April 2003 and August 2004 for maize and soybean respectively) restricted to the CI-Space as well as conditioning the real exchange rate and nominal short-run interest rate as weakly exogenous in the model with the intercept as the only deterministic components.
Model 3 is the same as above with the exception that no structural shift has been detected.

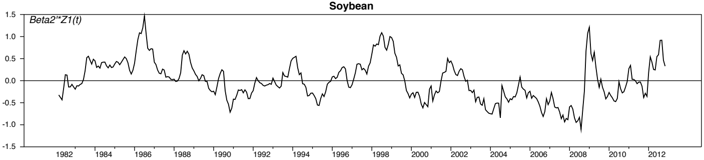
Model 1 - Maize

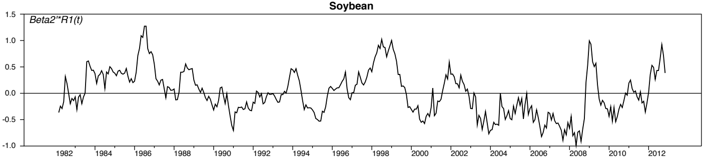
$p-r$	r	λ_i	$\tau(p-r)$	$\tau_{Bart.}(p-r)$	$C_{.95}$	P-*Value*	P-*Value*
4	0	0.343	223.228	218.247	71.302	0.000	0.000
3	1	0.100	67.613	66.187	48.621	0.000	0.000
2	2	0.058	28.482	27.815	30.667	0.080	0.095
1	3	0.017	6.193	6.058	15.039	0.622	0.638
Model 2 - Soybean							
4	0	0.322	195.005	190.718	71.550	0.000	0.000
3	1	0.063	51.255	50.209	48.556	0.027	0.034
2	2	0.051	27.024	26.053	29.738	0.106	0.133
1	3	0.020	7.616	7.349	14.984	0.465	0.494
Model 3 - Sugar							
4	0	0.345	211.461	207.012	53.358	0.000	0.000
3	1	0.087	54.933	53.863	35.371	0.000	0.000
2	2	0.049	21.196	20.760	20.874	0.040	0.047
1	3	0.007	2.529	2.451	8.327	0.690	0.707

Cointegration Relations - Model 1

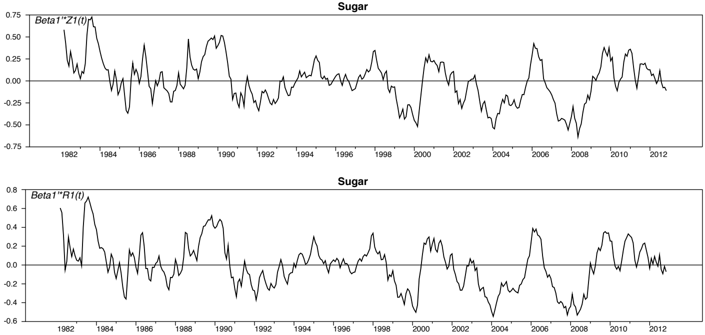


Cointegration Relations - Model 2



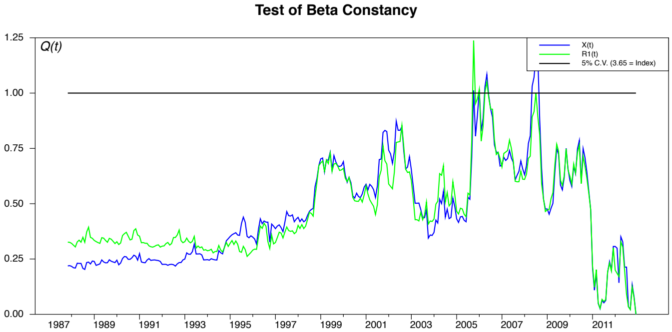


Cointegration Relations - Model 3



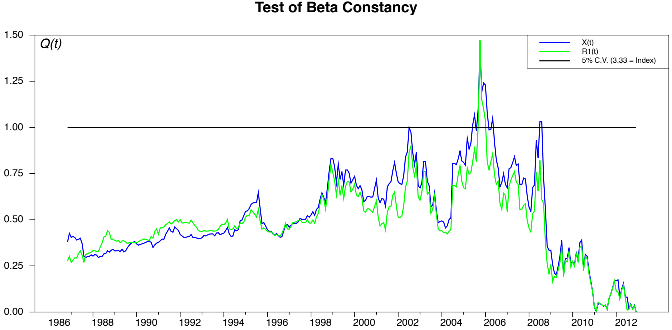
Recursively calculated constancy test of $\tilde{\beta}$

Figure : Model 1 - $\tilde{\beta}$ is estimated on the full sample 1982:01 - 2012:12.



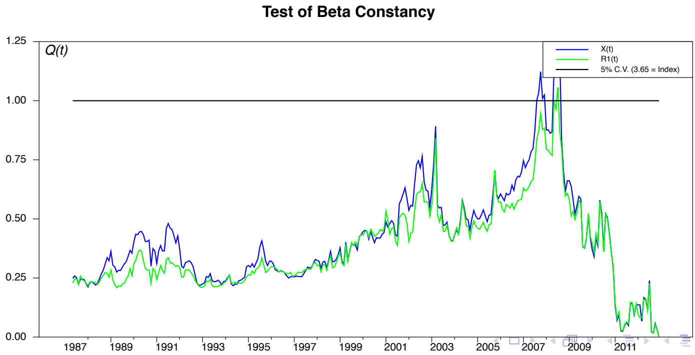
Recursively calculated constancy test of $\tilde{\beta}$

Figure : Model 2 - $\tilde{\beta}$ is estimated on the full sample 1982:01 - 2012:12.



Recursively calculated constancy test of $\tilde{\beta}$

Figure : Model 3 - $\tilde{\beta}$ is estimated on the full sample 1982:01 - 2012:12.



Model 1 - Identified long-run structures (P-values in brackets).

Model 1 - Maize (β')

	mz_t	Δp_t	y_t	o_t	xr_t	i_t	Ds_{2003}	μ_0
$\hat{\beta}_1$	0.000 [NA]	1.000 [NA]	0.000 [NA]	0.000 [NA]	0.000 [NA]	0.000 [NA]	0.000 [NA]	−0.002 [−3.301]
$\hat{\beta}_2$	0.000 [NA]	0.000 [NA]	1.000 [NA]	0.317 [3.588]	0.000 [NA]	0.000 [NA]	−0.490 [−5.525]	0.676 [4.227]
$\hat{\beta}_3$	1.000 [NA]	38.621 [5.382]	0.000 [NA]	−0.889 [−5.049]	1.415 [2.848]	−38.621 [−5.382]	0.625 [3.428]	−1.341 [−4.305]

	α_1	α_2	α_3
Δmz_t	0.602 [0.997]	0.010 [0.632]	−0.041 [−3.492]
$\Delta^2 p_t$	−0.772 [−8.728]	0.004 [1.519]	0.002 [0.935]
Δy_t	2.376 [3.864]	−0.101 [−6.112]	−0.023 [−1.950]
Δo_t	−1.506 [−1.759]	−0.002 [−0.097]	0.037 [2.235]

Test of Restricted Model: $\chi^2(3) = 8.011$ [0.237]
Test of Homogeneity Maize-Oil: $\chi^2(7) = 4.447$ [0.727]

Model 2 - Identified long-run structures (P-values in brackets).

Model 2 - Soybean β'

	sb_t	Δp_t	y_t	o_t	xr_t	i_t	Ds_{2004}	μ_0
$\hat{\beta}_1$	0.000	1.000	−0.007	0.000	0.000	0.000	0.000	−0.002
	[NA]	[NA]	[−3.440]	[NA]	[NA]	[NA]	[NA]	[−4.562]
$\hat{\beta}_2$	1.000	0.000	0.000	−0.937	2.089	0.000	0.899	−2.223
	[NA]	[NA]	[NA]	[−4.662]	[3.582]	[NA]	[3.925]	[−6.268]

	α_1	α_2
Δsb_t	−0.826	−0.036
	[−2.248]	[−3.904]
$\Delta^2 p_t$	−0.687	0.001
	[−11.069]	[0.871]
Δy_t	1.095	0.013
	[2.462]	[1.184]
Δo_t	−0.265	0.036
	[−0.447]	[2.411]

Test of Restricted Model: $\chi^2(6) = 7.624[0.267]$
Test of Homogeneity Soybean-Oil: P-Value [0.364]

Model 3 - Identified long-run structures (P-values in brackets).

Model 3 - Sugar β'

	s_t	Δp_t	y_t	o_t	xr_t	i_t	C
β_1	1.000	0.000	0.000	0.000	2.545	0.000	2.690
	[*NA*]	[*NA*]	[*NA*]	[*NA*]	[6.504]	[*NA*]	[62.269]
β_2	0.000	1.000	0.000	0.000	0.000	0.000	-0.002
	[*NA*]	[*NA*]	[*NA*]	[*NA*]	[*NA*]	[*NA*]	[-4.395]
β_3	0.000	0.000	1.000	0.000	0.000	0.000	0.000
	[*NA*]	[*NA*]	[*NA*]	[*NA*]	[*NA*]	[*NA*]	[*NA*]
	α_1	α_2	α_3				
Δs_t	-0.096	0.366	-0.005				
	[-5.660]	[0.567]	[-0.280]				
$\Delta^2 p_t$	0.001	-0.764	0.004				
	[0.701]	[-12.300]	[2.359]				
Δy_t	-0.014	1.352	-0.061				
	[-1.189]	[3.098]	[-4.687]				
Δo_t	-0.006	-0.750	0.004				
	[-0.423]	[-1.315]	[0.215]				

Test of Restricted Model: $\chi^2(9) = 3.450[0.944]$

Summary Results

Model 1 - Maize

- One-to-one long-run relation with real oil prices.
- Adjustment coefficient is about 4% (consider oil).
- Since April 2003 real maize prices have (on average) been about 70% higher than the previous period.
- Long-run relationship is stable and no apparent break in the CI parameters is present.
- Permanent shocks to crude oil real prices are transmitted to maize and by a factor of 0.67.
- By the end of the food price crisis in 2008 the LR relationship was unstable (See Vacha et al. (2013)).

Summary Results

Model 2 - Soybean

- One-to-one long-run relation with real oil prices.
- Adjustment coefficient is about 3% (consider oil).
- Since April 2004 real maize prices have (on average) been about 130% higher than the previous period.
- Long-run relationship is stable and no apparent break in the CI parameters is present.
- Permanent shocks to crude oil real prices are transmitted to soybeans by a factor of 0.67.
- By the end of the food price crisis in 2008 the LR relationship was unstable (See Vacha et al. (2013)).

Summary Results

Model 3 - Sugar

- No Long-run relation with crude oil.

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