FOOD FOR FUEL or FUEL FOR FOOD?

The interactions between Oil, Biofuels and Food

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Research question:

- Does biofuels production influence the relationship between crude oil and food prices?

- Time-series analysis to show that biofuel production strenghtens the cointegration between crude oil and agricultural commodity prices

Motivation:

Food for Fuel or Fuel for Food?

"Filling the 25-gallon tank of a SUV with pure ethanol requires over 450 pounds of corn…

… which contains enough calories to feed one person for a year."

(Runge, 2007)

Motivation: Food for Fuel or Fuel for Food?

How fuel has caused food prices to increase?

- **Supply side:**
- ***Energy prices****: fertilizers, mechanization, irrigation, transport*

- **Demand side:**
- ***Biofuels*** (direct and substitution effect)

Food for Fuel → Fuel for Food?

Interactions between Oil and Food Prices

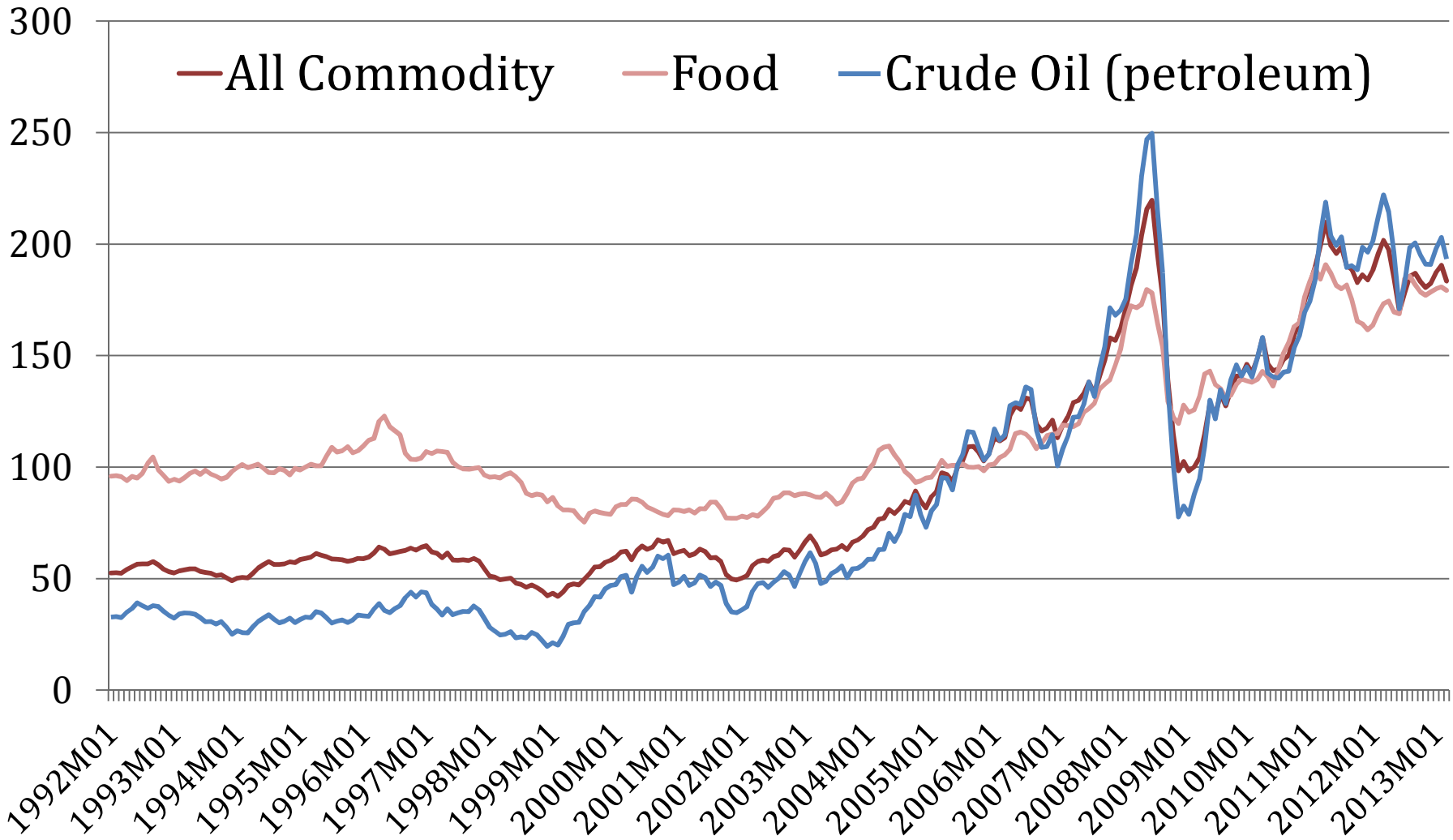
- Crude oil prices influence agricultural prices through 2 main channels:

$$P_{OIL} \xrightarrow{\text{input}} P_{FOOD}$$

$$P_{OIL} \rightarrow Q_{BIOFUEL} \rightarrow D_{FOOD} \rightarrow P_{FOOD}$$

- Separate the input effect from the effect of biofuels production
- Does biofuels production strengthen the cointegration oil-food?
- Policy implications

Food for Fuel → Fuel for Food?



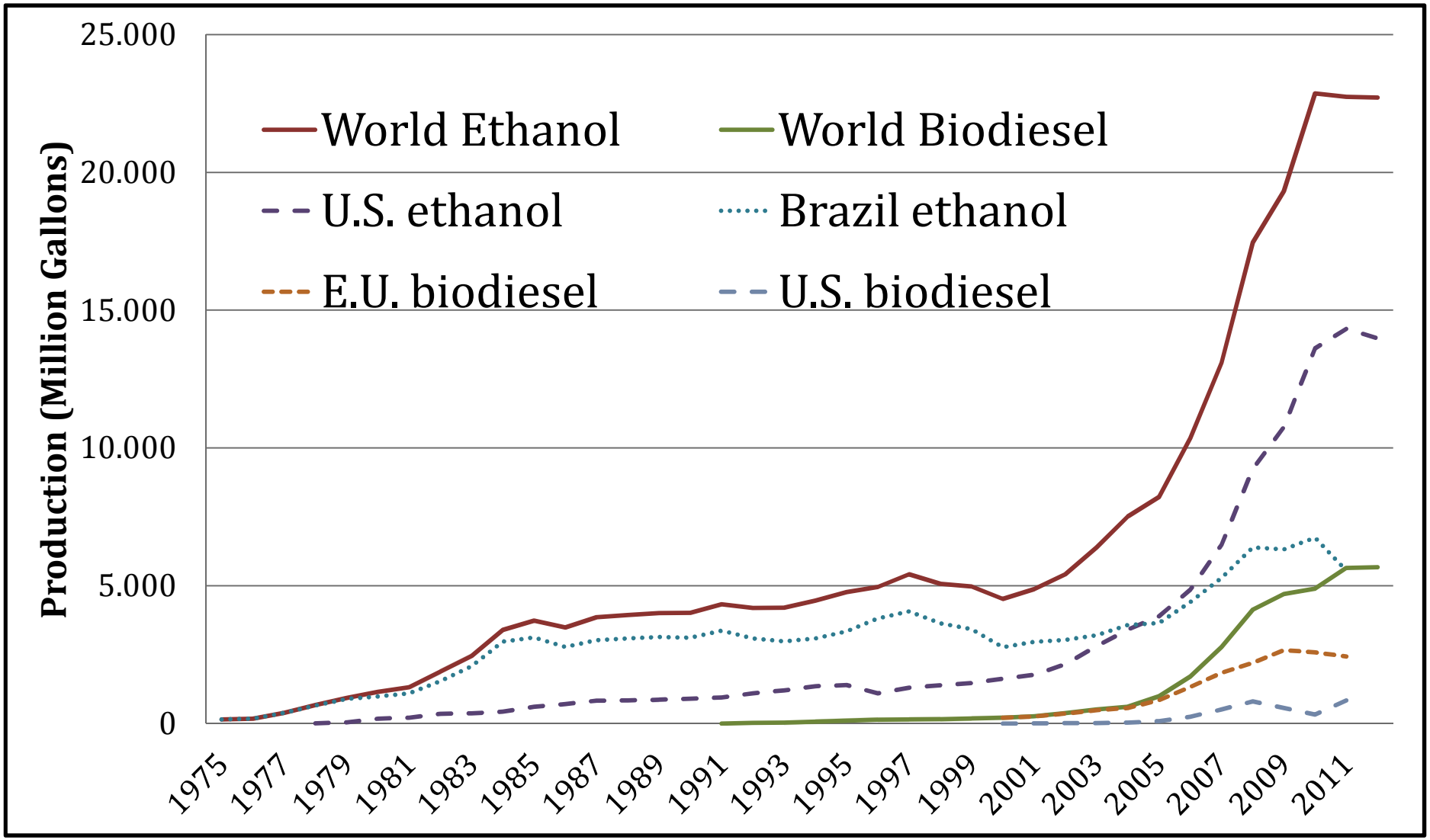
Source: *IMF*

Biofuels: the main sources

1st generation		2nd generation	3rd generation
Biodiesel	**Bioethanol**		
Palm oil	Corn	Willows	Algae
Rapeseed	Sugar cane	Poplars	
Sunflowers	Sugar beets	Grass	
Soybeans	Wheat	Agricultural waste products	
		Forestry waste products	

Source: UNEP (2009)

World Biofuels Production



Source: Dataset for Lester R. Brown, Full Planet, Empty Plates: The New Geopolitics of Food Scarcity (New York: W.W. Norton & Company, 2012), Earth Policy Institute.

Literature Review: Food for Fuel or Fuel for Food?

Author(s) and Title	Focus	Commodities	Methodology	Problems
Ahsan et al. 2012. "The Determinants of Food Prices in Pakistan".	Pakistan 1970-2010	Food Prices; Income (PC); Money Supply; Subsidies; Energy Prices; Domestic Supply.	Autoregressive Distributed Lag (ARDL) Model; Cointegration analysis; VECM	Pakistan No biofuels
Armah et al. 2009. "Drivers leading to higher food prices: biofuels are not the main factor".	US 1977-2007	Soybeans, CPI, Crude oil	Cross-correlation; "lead/lag" causality model	US
Baek and Woo. 2010. "Analyzing Factors Affecting U.S. Food Price Inflation".	US 1989-2008	Agricultural commodity prices, energy prices, (ethanol production) and exchange rates	Units root under structural breaks (Perron). Johansen multivariate co-integration analysis (Long Run) and vector error-correction (VEC) model (Short Run)	US Drop ethanol
Balcombe and Rapsomanikis. 2008. "Bayesian Estimation and Selection of Nonlinear Vector Error Correction Models: the Case of the Sugar-Ethanol-Oil Nexus in Brazil"	Brazil 2000-2006	Sugar, ethanol and oil prices	Generalized bivariate error correction models. Nonlinear adjustment processes. Bayesian Monte Carlo Markov Chain algorithm and Bayesian model selection methods.	Brazil No recent
Campiche et al. 2007. "Examining the Evolving Correspondence Between Petroleum Prices and Agricultural Commodity Prices".	2003-2007	Crude Oil Prices, Corn, Sorghum, Sugar, Soybeans, Soybean Oil, and Palm Oil Prices	Cointegration analysis; Vector error-correction Model (VECM)	No recent

Author(s) and Title	Focus	Commodities	Methodology	Problems
Ciaian P., Kancs d. 2011. "Interdependencies in the energy-bioenergy-food price systems: A cointegration analysis."	Global 1994-2008	Crude oil; corn, wheat, rice, sugar, soybeans, cotton, banana, sorghum and tea	Vertical market integration model; Cointegration analysis (Johansen) with structural breaks; VECM; Granger causality tests	Period (1994 - 2008) Exogeneous breaks
Chen et al. 2010. "Modeling the relationship between the oil price and global food prices".	Global 1983-2010	Grain prices (corn, soybean and wheat); crude oil price	Estimate structural breakpoint (two-break minimum Lagrange Multiplier unit root test); Global Cropland Allocation Model; Autoregressive Distributed Lag (ARDL) Model	Period (1983-2010) No cointegration No separation
Du and McPhail. 2012. "Inside the Black Box: the Price Linkage and Transmission between Energy and Agricultural Markets"	US 2005-2011	Ethanol, gasoline and corn prices	Multivariate generalized autoregressive conditional heteroskedasticity (GARCH) model. IDH identification. Stuctural VAR (SVAR)	US No separation
Imai et al. 2008. "Food and oil prices"	Global. China. India. 1980-2007	Maize, Wheat, Rice, Oil, (Fruit, Vegetable), (Rainfall)	Unit-roots (ADF) tests; Co-integration tests (Johansen); Multi-variable vector autoregressive (VAR) model	No break test
Yu et al. 2006. "Cointegration and Causality Analysis of World Vegetable Oil and Crude Oil Prices"	Global 1999-2006	Soybean, Sunflower, Rapeseed and Palm Oils, World Crude Oil Price	Vector Error Correction Model (VECM); Directed Acyclic Graphs	Only seedcrops No recent
Zhang et al. 2010. "Food versus Fuel: what do prices tell us?"	Global (US) 1989-2008	Fuel (Crude oil, Gasoline, Ethanol); Agricultural (Maize; Soybean; Wheat; Sugar)	Cointegration estimation; Vector Error Correction Model (VECM); Granger causality tests	No recent. No relation and No causality found

What are the problems with the literature?

- No clear impact of biofuels (no break test, no separation input and biofuels channel)
- Check for biofuel impact (structural break, biofuels' commodities)
- Local (US, Pakistan, etc.) centered
- International model, because the impact of rising food prices is at global level, despite the concentration of biofuels production in a few countries
- No recent data

Data

Monthly World Data from the IMF (January 1980-October 2013) on:

- Energy: world crude oil price
- Food/Agricultural commodities:

  maize, sugar, wheat (ethanol);

  oil palm, rapeseed oil, soybean, sunflower oil (biodiesel)

Methodology:

How to address the effect of biofuels on oil-food link?

1) **Structural breaks:** Does biofuels production coincide with a break in crude oil-food prices relationship (Chow test)?
2) **Stationarity test/Unit roots**: Augmented Dickey-Fuller; Phillips Perron (Level and First Differences) Determine Lag Length: *n* (Bayesian-Schwarz; Hannan-Quinn & Akaike Information Criterion)
3) **Johansen Cointegration** test: food commodity-crude oil prices for the different time periods
4) **Granger causality** test: $P_o \rightarrow P_f$ or $P_f \rightarrow P_o$

1) **Structural Breaks:** Chow test

- The Chow breakpoint test confirms that it is convenient to divide the sample in three periods:

1. 1st period: January 1980 - December 1990 (negligible production of biodiesel)
2. 2nd period: January 1991 - December 2001
3. 3rd period: January 2002 - October 2013 (raise in biofuels production)

- The effect of biofuels on food-fuel relationship is absent in the 1st period, where only the input channel is at work, and very strong in the 3rd period

1) Results of Chow Test

	PMaize-POil	PSugar-POil	PWheat-POil	PPalmoil POil	PRapeoil POil	PSoybean POil	PSunoil POil
Chow Breakpoint Test: 1990M12							
F-statistic	1.051	2.036*	0.253	0.847	1.822*	0.356	0.859
Log likelihood ratio	6.449	12.400*	1.565	8.815	11.112*	2.175	5.276
Chow Breakpoint Test: 2001M12							
F-statistic	4.675*	0.730	0.848	0.906	3.223*	1.721*	2.459*
Log likelihood ratio	27.917*	4.489	5.209	9.431	19.458*	10.505*	14.930*

Note: The asterisk * indicates probability less than 0.10.
Source: Own elaboration.

2) Results of Stationarity

- The Augmented Dickey-Fuller & Phillips Perron tests performed on the variables in level cannot reject the null of a unit root at the conventional significance levels (with few exceptions)

- The series in level are considered not stationary

- The hypothesis of a unit root is rejected for all the series in first difference

3) Johansen Cointegration Test

- If the food and fuel price series are cointegrated, they are bound by some relationship in the long run, they "move together" over time

- Johansen (1991, 1995a) developed a methodology based on a vector error-correction model (VECM):

$$\Delta P_t = \Pi P_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta P_{t-i} + B x_t + \varepsilon_t$$

- The parameters of the VECM provide information both on the long-run and the short-run dynamics

3) Results of Johansen Cointegration test

	1st period		2nd period		3rd period	
	1980:01-1990:12		1991:01-2001:12		2002:01-2013:10	
	Max-Eigen		Max-Eigen		Max-Eigen	
	H_0: r=0	H_1: r=1	H_0: r=0	H_1: r=1	H_0: r=0	H_1: r=1
Oil-Maize	17.32*	2.39	6.17	3.85*	9.81*	0.01
	(0.03)	(0.70)	(0.59)	(0.05)	(0.09)	(0.95)
Oil-Sugar	7.47	4.32*	5.17	3.25*	10.43*	0.06
	(0.43)	(0.04)	(0.72)	(0.07)	(0.07)	(0.84)
Oil-Wheat	10.53	2.13	4.89	3.84*	18.76*	3.68
	(0.18)	(0.15)	(0.76)	(0.05)	(0.02)	(0.46)
Oil-PalmOil	11.54*	1.29	6.26	3.33*	19.54*	9.76
	(0.04)	(0.30)	(0.58)	(0.07)	(0.05)	(0.14)
Oil-RapeOil	7.76	4.76*	9.80	2.79*	24.62*	5.18
	(0.40)	(0.03)	(0.23)	(0.09)	(0.01)	(0.57)
Oil-Soybean	10.23	5.13	5.65	1.55	11.33*	0.04
	(0.31)	(0.27)	(0.66)	(0.21)	(0.05)	(0.87)
Oil-SunOil	10.46	5.83	17.63*	2.33	19.49*	5.55
	(0.29)	(0.20)	(0.01)	(0.13)	(0.01)	(0.23)

Notes: Johansen Trace and Max-Eigenvalue test statistics. MacKinnon-Haug-Michelis (1999) p-values are given in brackets. The asterisk (*) denotes rejection of the null hypothesis at the 10% significance level.

3) Results of Johansen Cointegration Test

- The cointegration between crude oil and food prices is stronger in the third period, coinciding with a raise in biofuels production

- These results confirm the hypothesis that biofuels strengthen the relationship between the price of crude oil and the price of agricultural commodities used for their production

3) Test for Multiple Cointegration between…
Ethanol commodities

PMaize-PSugar-PWheat-POil			
	1st period	2nd period	3rd period
	1980:01-1990:12	1991:01-2001:12	2002:01-2013:10
Hypothesized No. of CE(s)	Trace	Trace	Trace
r=0	30.938	57.505*	48.257*
r≤1	16.676	23.171	16.341
r≤2	9.206	6.569	7.554
r≤3	3.6	2.077	2.514

Notes: The asterisk * denotes rejection of the hypothesis at the 0.05 level

3) Test for Multiple Cointegration between…

Biodiesel commodities

PPalmoil-PRapeoil-PSoybean-Psunoil-POil			
	1st period	2nd period	3rd period
	1980:01-1990:12	1991:01-2001:12	2002:01-2013:10
Hypothesized No. of CE(s)	Trace	Trace	Trace
r=0	75.027*	88.167*	74.847*
r≤1	47.856	48.779	42.959
r≤2	29.797	18.138	23.064
r≤3	15.495	6.494	11.701
r≤4	3.841	2.139	4.0

Note: The asterisk * denotes rejection of the hypothesis at the 0.05 level

4) Results of Multiple Cointegration tests

- These results reflect some interdependencies among the food commodity prices and with crude oil price
- The price interactions depend on some degree of substitutability among them and with the crude oil price (Yu et al. 2006)
- The fact that the cointegration between the commodities does not change significantly over time contributes to rule out the possibility of a common factor other than the crude oil price affecting the food prices

4) Granger Causality

- Granger causality implies a chronological ordering of movements in the series

- A variable *x* is said to Granger-cause a variable *y* if, given the lagged values of *y*, lagged values of *x* are useful to predict *y* (Granger 1969)

4) Results of Granger causality Wald test

	1st period		2nd period		3rd period	
	1980-1990		1991-2001		2002-2013	
Direction of Causality	χ^2	**df**	χ^2	**df**	χ^2	**df**
POil → PMaize	8.823**	2	1.6	2	10.695***	2
PMaize → POil	5.158*	2	0.034	2	1.001	2
POil → PSugar	3.735	2	0.962	1	5.910**	2
PSugar → POil	6.078**	2	0.192	1	1.176	2
POil → PWheat	4.239	2	2.021	2	12.482***	2
PWheat → POil	1.371	2	0.083	2	2.645	2
POil → PPalmOil	2.398	2	18.601***	4	15.063***	2
PPalmOil → POil	4.292	2	3.884	4	0.374	2
POil → PRapeseedOil	0.638	2	4.672**	1	3.267	2
PRapeseedOil → POil	0.585	2	0.3	1	8.389**	2
POil → PSoybean	2.589	2	14.871	1	5.245*	2
PSoybean → POil	0.139	2	0.222	1	2.103	2
POil → PSunflowerOil	3.347	2	16.669***	1	7.622**	2
PSunflowerOil → POil	2.577	2	0.006	1	13.283***	2

Note: The arrow, →, indicates the direction of Granger-causality. The asterisks (***,**, *) denote significance at the 1%, 5% and 10% level, respectively.

4) Results of Granger Causality

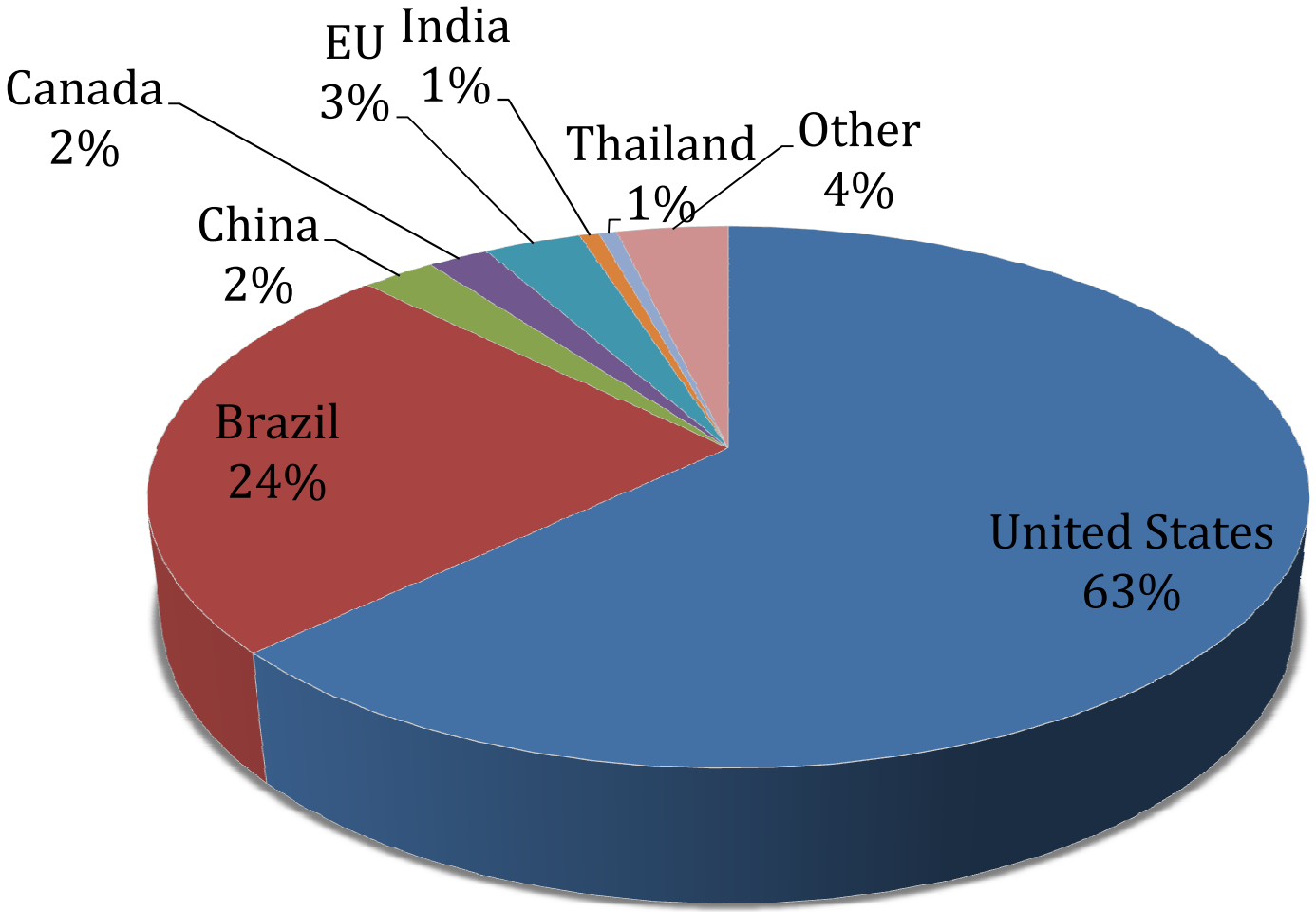
- In the period 2002-2013 crude oil price Granger-causes the prices of food commodities used to produce biofuels

Conclusions

- Our results show that, in the last decade, biofuels production has contributed to strengthen the relationship between high crude oil prices and agricultural commodity prices, with a one-direction Granger-causality going from fuel to food
- Our work provides further evidence for the necessity to reshape the incentives to biofuels production
- A growing literature is proving that the fight against poverty and hunger is not independent from biofuels policy

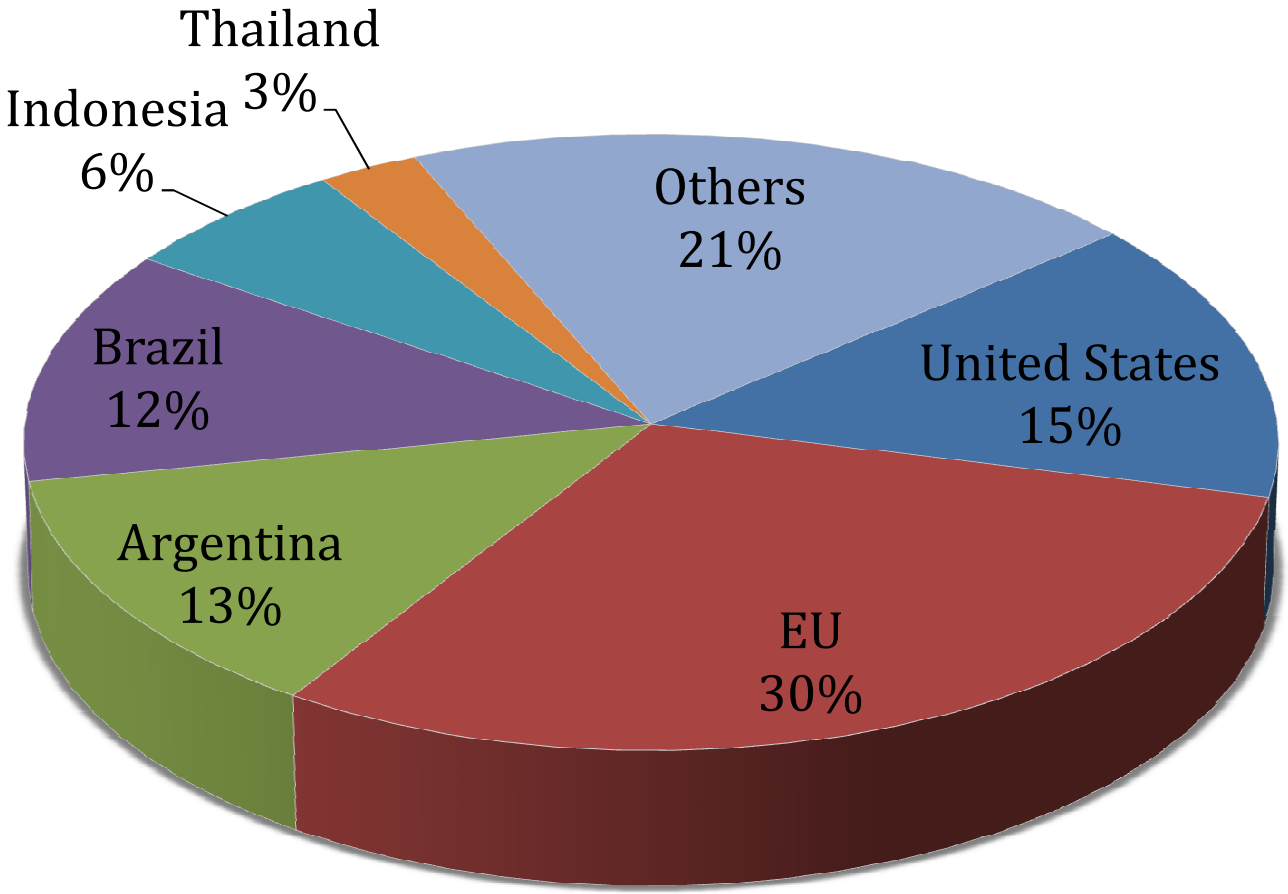
Thank you for your attention!

Ethanol Production, 2011 (Million Gallons)



Source: author elaboration on EPI data

Biodiesel production, 2011 (Million Gallons)



Source: author elaboration on EPI data

Biofuels: issues

- Food security

- GHG emission
- Land conversion
- Deforestation
- Soil erosion
- Water footprint
- Lower biodiversity
- Nitrogen runoff
- Displacement of local people

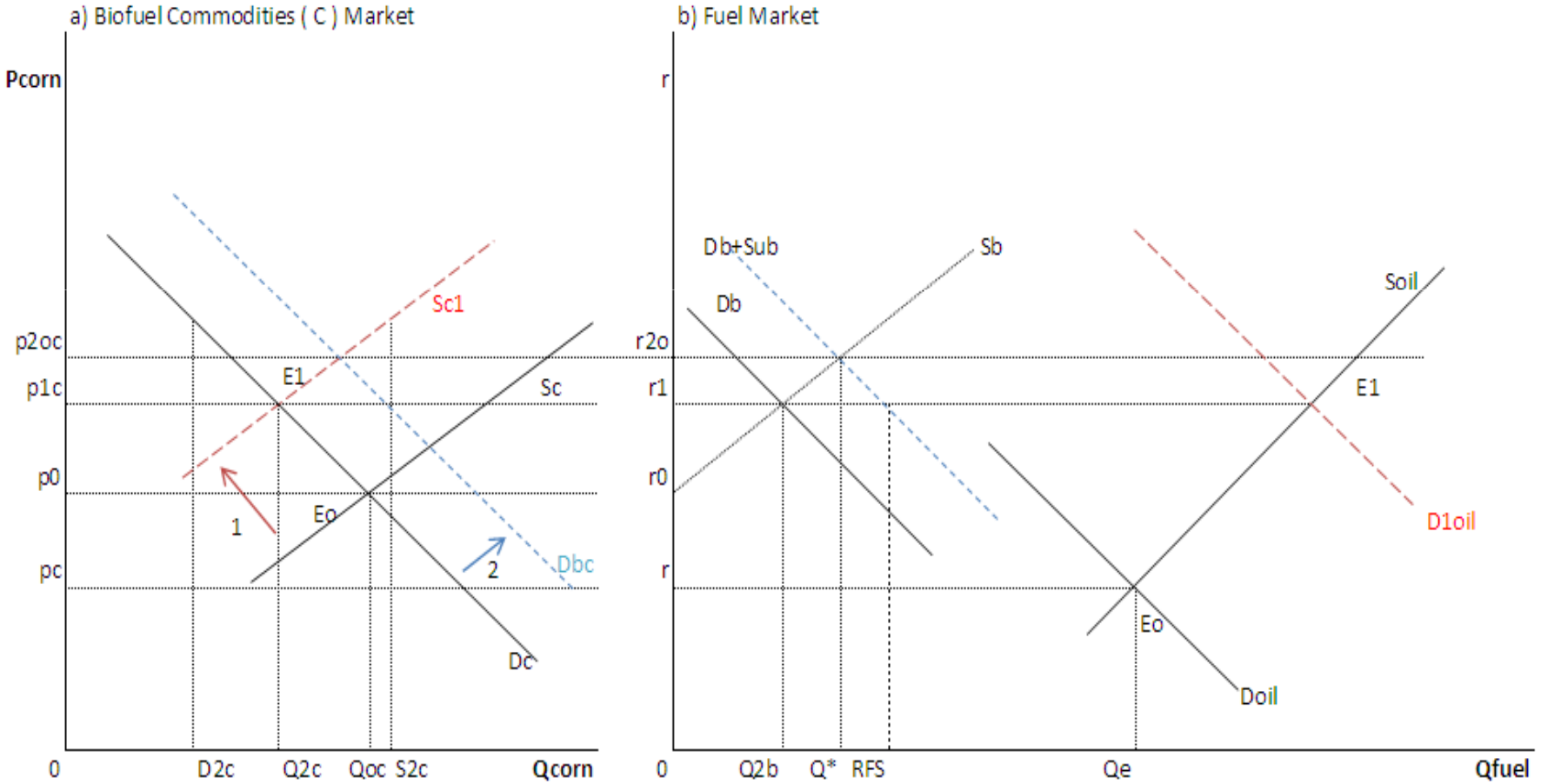
Biofuels policy

- Biofuel production is heavily subsidized and supported by the governments of the main biofuel producers (USA, EU and Brazil). They have variously adopted:
- *Energy legislations* forcing mandatory quantity of biofuels (Renewable Fuel Standard in US, Renewable Energy Directive in EU, ...)
- Production *subsidies* or *tax credit* to gasoline blenders
- *Tariffs* on imported ethanol
- *Regulations*, such as the blend wall or the oxygenate substitution (demanding ethanol as replacement for MTBE).
- If we prove the trade-off between biofuels production and food security issues in many developing countries, it might be the case of rethinking energy policy supporting biofuel.

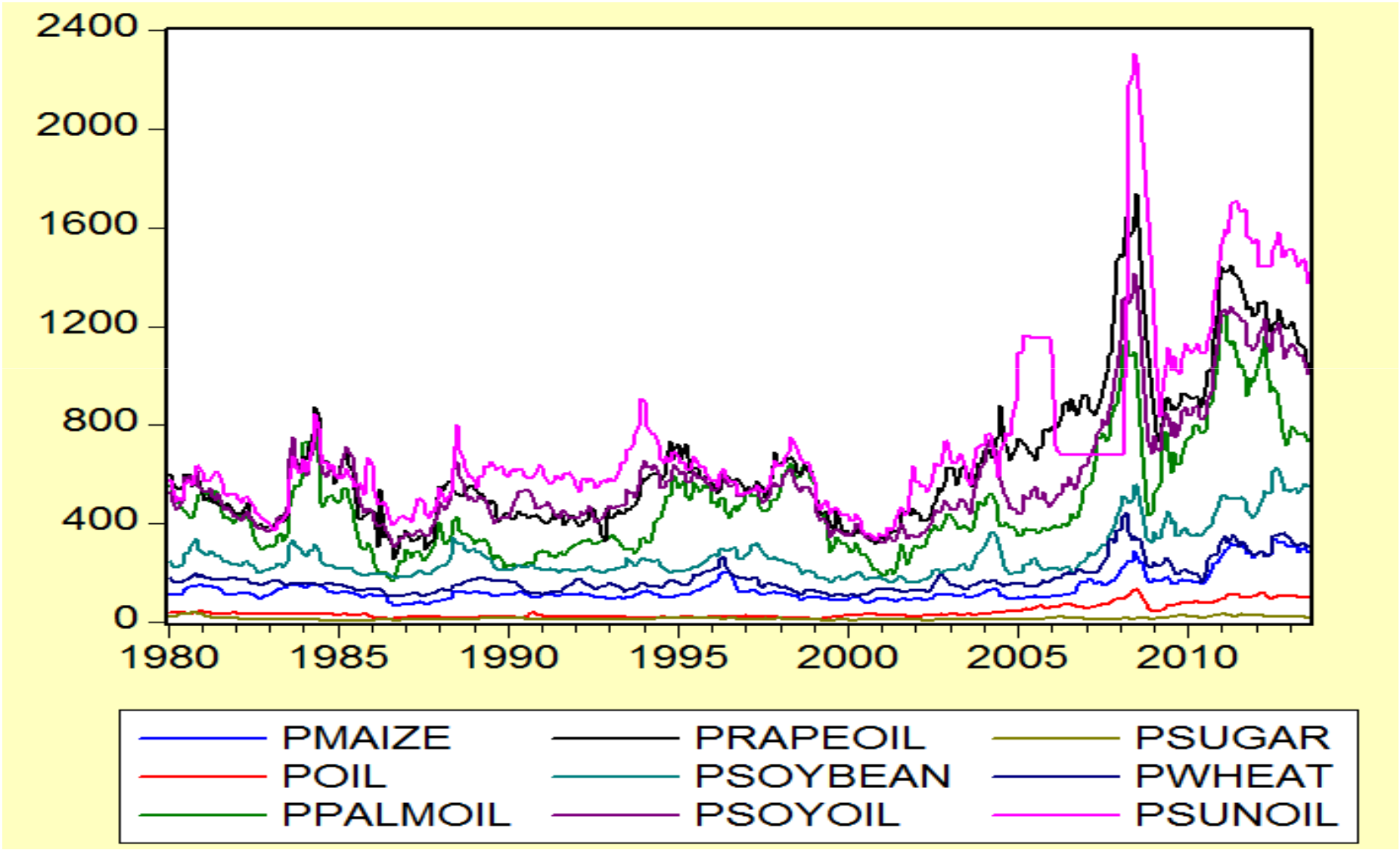
Fuel to Agricultural price transmission:

a) Investigating price interdependency:

Shock in the oil price



Oil and Food Monthly Prices (1980-2013)



Source: Own elaboration on IMF data

2) Results of Stationarity (ADF)

Augmented Dickey-Fuller (ADF) Unit Root test results

	1st period 1980:01-1990:12		2nd period 1991:01-2001:12		3rd period 2002:01-2013:10	
Prices	**Level (with constant)**	**1st Difference**	**Level (with constant)**	**1st Difference**	**Level (with constant)**	**1st Difference**
Oil	-1.98 (2)	-8.07*** (1)	-2.07 (0)	-11.62*** (0)	-2.06 (1)	-7.3*** (0)
Maize	-2.10 (1)	-8.60*** (0)	-2.45* (1)	-7.21*** (0)	-1.34 (0)	-9.77*** (0)
Sugar	-1.60 (0)	-10.39*** (0)	-1.69 (0)	-10.78*** (0)	-1.86 (1)	-9.38*** (0)
Wheat	-1.51 (1)	-9.05*** (0)	-2.19 (1)	-8.50*** (0)	-2.14 (1)	-9.31*** (0)
Palm Oil	-2.15 (3)	-9.04*** (1)	-2.03 (4)	-5.51*** (2)	-2.14 (1)	-7.36***(0)
RapeseedOil	-2.56 (0)	-12.77*** (0)	-1.81 (0)	-11.77*** (0)	-2.46 (2)	-5.57*** (1)
Soybean	-2.70* (1)	-8.99*** (0)	-1.58 (1)	-9.30*** (0)	-1.88 (1)	-8.32*** (0)
SunflowerOil	-3.31** (1)	-8.95*** (1)	-2.02 (1)	-7.99*** (1)	-2.89** (1)	-7.13*** (0)

Note: Single (*), double (**) and triple (***) asterisks denote significance at the 0.10, 0.05 and 0.01 levels, respectively. Lag lengths are indicated on brackets and calculated with the Schwarz-Information Criteria.

2) Results of Stationarity (PP)

Phillips-Perron (PP) Unit Root test results

	1st period		2nd period		3rd period	
Prices	**Level (with constant)**	**1st Difference**	**Level (with constant)**	**1st Difference**	**Level (with constant)**	**1st Difference**
Oil	-1.80 (6.4)	-6.78*** (2.7)	-2.07 (1)	-11.62***(0.5)	-1.76 (6.4)	-7.3*** (0.6)
Maize	-1.97 (4.3)	-8.60*** (0.7)	-2.06 (6.1)	-7.21*** (0.3)	-1.52 (3.2)	-9.77*** (0.6)
Sugar	-1.68 (2.5)	-10.42***(1.5)	-1.79 (1.7)	-10.78***(0.1)	-1.59 (3.6)	-9.38*** (0.6)
Wheat	-1.54 (3.6)	-9.05*** (0.8)	-1.97 (4.4)	-8.50*** (0.9)	-1.72 (3.7)	-9.38*** (0.8)
Palm Oil	-2.14 (4.6)	-8.44*** (1.9)	-1.44 (3.6)	-9.1*** (1.3)	-1.89 (6.3)	-7.45*** (1.3)
RapeseedOil	-2.47 (1.6)	-12.77***(0.2)	-1.81 (0.6)	-11.77*** (0.3)	-2.06 (4.3)	-8.73*** (1.5)
Soybean	-2.48 (3.9)	-8.99*** (0.4)	-1.33 (3.4)	-9.30*** (0.8)	-1.69 (4.9)	-8.32*** (0.1)
SunflowerOil	-2.72** (3.8)	-9.21***(1.2)	-1.82 (4.5)	-8.36*** (1.3)	-2.45 (6.8)	-7.2*** (1.1)

Note: Single (*), double (**) and triple (***) asterisks denote significance at the 0.10, 0.05 and 0.01 levels, respectively. Spectral estimation method: kernel sum-of-covariances estimator with Bartlett weights. Bandwidths are indicated in brackets and selected with the Andrews method.