The Pacific Food System Outlook 2006-07

Long-run linkage between fuels' and commodities' prices: A co-integration approach

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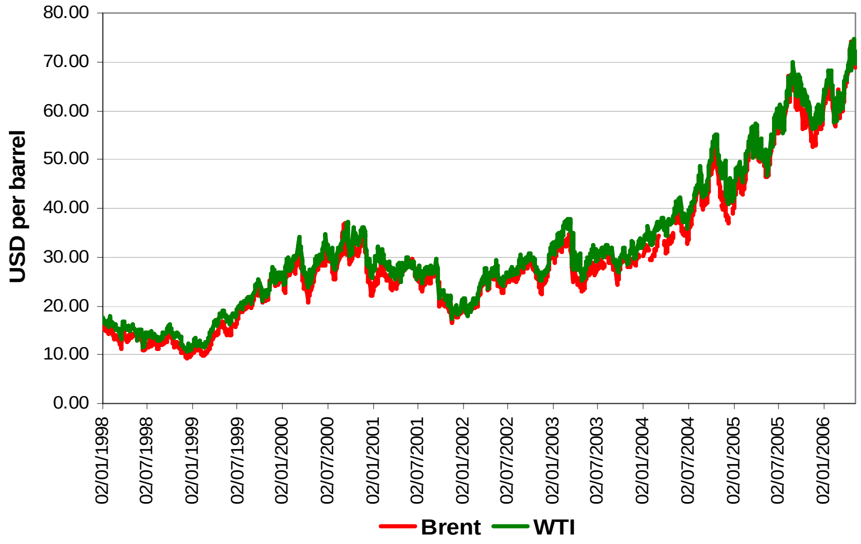
- **Fossil fuels *vs* Biofuels**
- **Testing co-integration between fuels' and commodities' prices**
- **Conclusions and Perspectives**

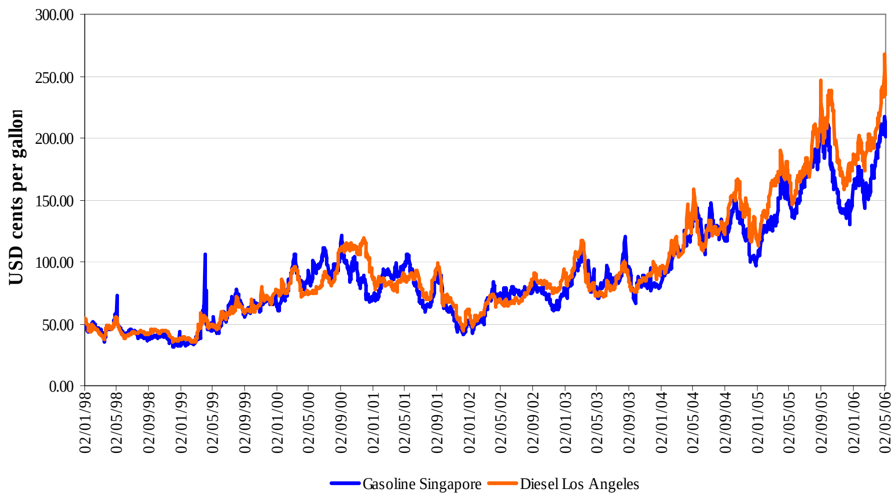
The world prices of oil and its derivatives have reached historical records during the last years, which has increased the incentives to search for alternative sources of energy, such as biofuels (ethanol, biodiesel)

Figure 1. World reference oil prices 1998-2006



Source of data: US Government Energy Information Administration.

Figure 2. World reference prices of two oil derivatives 1998-2006



Source of data: US Government Energy Information Administration.

Ethanol

•The research about bioenergy production began in the 19th century when the ethanol motor was invented by Samuel Morey (1826), Nicholas Otto (1860), and Henry Ford (1896).

•When Henry Ford designed the Model T, it was his expectation that ethanol, made from renewable biological materials would be a major automobile fuel. However, gasoline emerged as the dominant transportation fuel in the early 20th century, because of the ease of operation of gasoline engines with the materials then available for engine construction, and a growing supply of cheaper petroleum from oil field discoveries.

•Ethanol is an alcohol made from renewable resources like sugar cane, corn, sugar beet, wheat, etc. Ethanol is used as an automotive fuel by itself and can be mixed with gasoline to form what has been called "gasohol"

Ethanol worldwide

- Over 1 billion gallons of ethanol are blended with gasoline every year in the United States. Most of US ethanol is made from corn, and American output of maize-based ethanol is rising by 30% a year.
- Some Canadian provinces promote ethanol use as a fuel by offering subsidies of up to 45 cents per gallon of ethanol.
- In France, ethanol is produced from grapes that are of insufficient quality for wine production.
- Prompted by the increase in oil prices in the 1970s, Brazil introduced a program to produce ethanol for use in automobiles in order to reduce oil imports. Brazilian ethanol is made mainly from sugar cane. Pure ethanol (100% ethanol) is used in approximately 40 percent of the cars in Brazil. The remaining vehicles use blends of 24 percent ethanol with 76 percent gasoline. Brazil consumes nearly 4 billion gallons of ethanol annually. In addition to consumption, Brazil also exports ethanol to other countries.
- Sweden has used ethanol in chemical production for many years. As a result, Sweden’s crude oil consumption has been cut in half since 1980.
- India is initiating the use of ethanol as an automotive fuel.
- China, though late to start, has already built the world's biggest ethanol plant, and plans another as big.

In Brazil, ethanol and sugar share the same input: sugar cane

- Brazil is the main producer of ethanol, sugar cane and sugar in the world.

Table 1. Main ethanol producers in the world

Country	2004	2003
1. Brazil	15338	14428
2. USA	13950	10900
3. China	3650	3400
4. India	2000	190
5. France	830	817
6. Russia	760	745
7. Spain	420	304
8. South Africa	409	404
9. UK	400	410
10. Saudi Arabia	340	350
11. Ukraine	290	284
12. Thailand	280	250
13. Germany	270	280
14. Canada	245	204
15. Italy	210	240

Figures quotes are in millions of liters. Source: F.O. Licht, *WORLD ETHANOL & BIOFUELS REPORT*, V2 N. 19 June 6, 2004.

Table 2. Main producers of sugar cane in the world

1999-2003

World Production of Sugar Cane (1999 - 2003)					
	1999	2000	2001	2002	2003
Brasil	333,848	327,705	345,942	363,721	386,232
China	78,108	69,299	77,966	92,203	92,370
India	295,730	299,230	295,956	297,208	289,630
Pakistan	55,191	46,333	43,606	48,042	52,056
Tailandia	52,813	49,563	60,013	74,258	64,408
Mexico	46,880	44,100	47,250	45,635	45,127
Peru	6,900	7,750	8,000	9,100	9,550
Others	397,759	401,627	395,827	408,002	393,880
Total	1,267,229	1,245,607	1,274,560	1,338,169	1,333,253

Table 3. Main producers of sugar in the world

2002-2005

Main producers	2002'2003	2003'2004	2004'2005
BRAZIL	25.3	26.8	30.4
CHINA	-	11.3	10.9
INDIA	21.7	-	14.0

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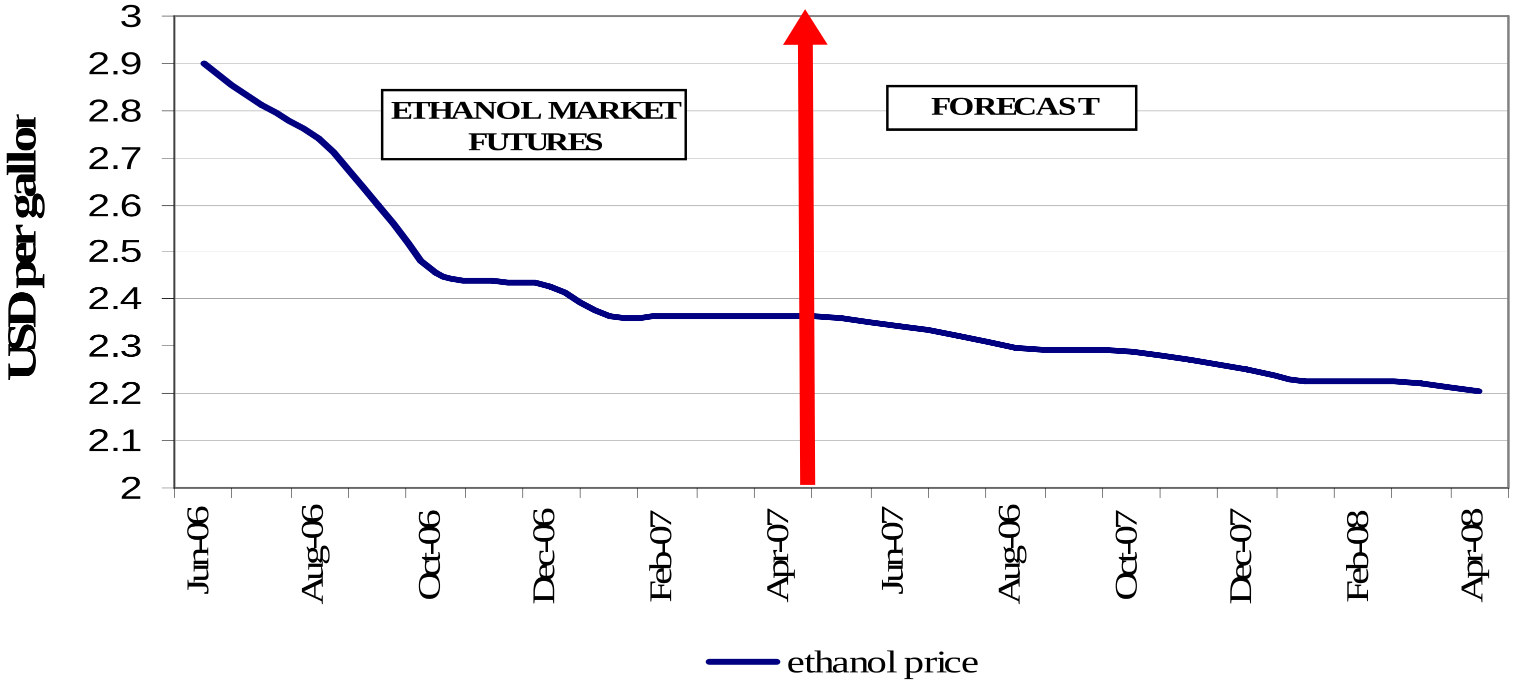
The futures of the world price of ethanol have a decreasing trend, which if sustained can increase the competitiveness for this biofuel

Figure 3. Futures and forecasts for ethanol world price



Source: Futures from Ethanol Market; Forecasts calculated from the data of futures of Ethanol Market.

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Biodiesel

•Fuels derived from renewable biological resources which are converted into methyl esters for use in diesel engines are known as biodiesel fuels.

•Animal fats and virgin and recycled vegetable oils derived from crops such as soybeans, canola, corn and sunflowers can be used in the production of biodiesel fuel.

•Vegetable oil was used as a diesel fuel as early as 1900, when Rudolf Diesel demonstrated that a diesel engine could run on peanut oil.

Biodiesel worldwide

•In Europe, increasing environmental concerns, expensive overproduction in European agriculture and changes in government policies have resulted in expanded testing and usage of biodiesel.

•In the United States, depleting oil reserves and a desire to reduce current distillate imports are the main drivers for increased biodiesel usage and research.

•In Canada, environmental concerns are the main drivers for increased biodiesel usage and research.

•Europe, the United States, and Canada have conducted extensive tests of biodiesel in trucks, cars, locomotives, buses, tractors and small boats. Many tests have concluded that the best overall results are obtained with a blend of 20 percent biodiesel and 80 percent conventional diesel.

•The price of feedstock used in the production of biodiesel relative to petroleum prices is a key determinant in the feasibility of biodiesel.

•For biodiesel to be considered as a blend stock for petroleum diesel, it must be priced similar to that of a petroleum diesel blend component in order to be attractive.

Main benefits of biofuels

- Increased demand for domestic agricultural products

- Increased demand for **renewable** fuels from feedstocks that are considered waste, such as cooking oil and trap grease

- Biodegradability and improved air quality, particularly lower sulphur emissions than from fossil fuels

- **Less greenhouse gases emissions than fossil fuels**

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The first step to perform the co-integration test is to check that the series are non-stationary and have the same order of integration

Table 4. Augmented Dickey-Fuller unit root test applied to world reference oil prices 1998-2006

Variable	Augmented Dickey-Fuller test statistic	Level of significance	Test critical values	Result
Brent	0.165807	1%	-3.433400	Nonstationary
		5%	-2.862773	
		10%	-2.567473	
D (Brent)	-44.04239	1%	-3.433401	Stationary I (1)
		5%	-2.862774	
		10%	-2.567473	
WTI	-0.022693	1%	-3.433400	Nonstationary
		5%	-2.862773	
		10%	-2.567473	
D (WTI)	-47.14200	1%	-3.433400	Stationary I (1)
		5%	-2.862773	
		10%	-2.567473	

Source of data: US Government Energy Information Administration.

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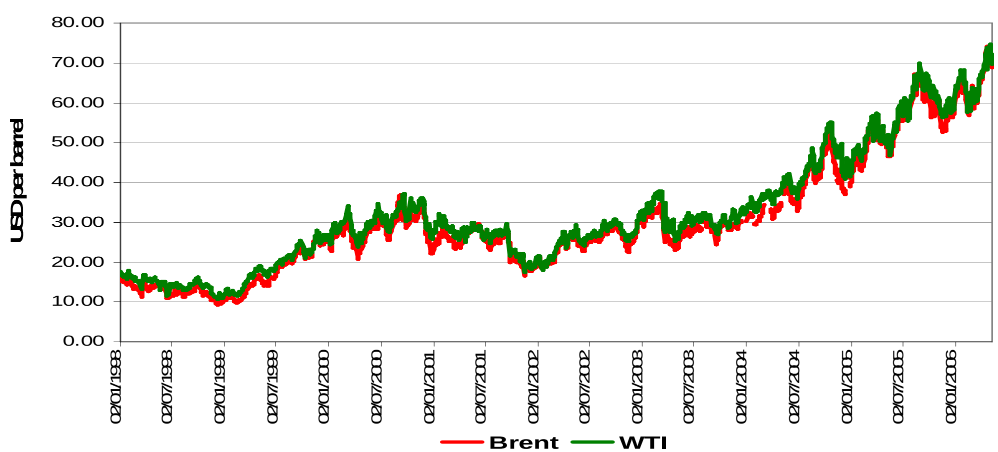
The co-integration test shows if exists a long-term equilibrium relationship between a group of variables. In this case the test shows co-integration between the world reference prices of oil.

Table 5. Johansen co-integration test applied to world reference oil prices 1998-2006

Variables	Hypothesized No. of Cointegrating Equations	Trace statistic	5% critical value	1% critical value	Result
WTI & Brent	None	66.03040	15.41	20.04	1 Cointegrating equation at both 1% and 5% levels
	At most 1	0.066230	3.76	6.65	

Source of data: US Government Energy Information Administration.

Figure 4. Wold reference oil prices 1998-2006



Source of data: US Government Energy Information Administration.

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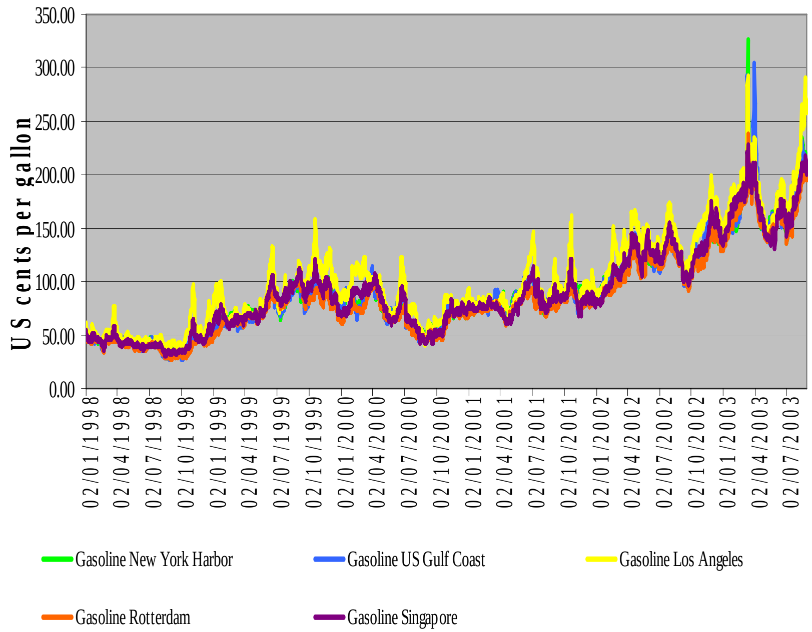
The world reference prices of gasoline are also co-integrated

Table 7. Johansen co-integration test applied to world reference gasoline prices 1998-2006

Variables	Hypothesized No. of Cointegrating Equations	Trace statistic	5% critical value	1% critical value	Result
Gasoline US Gulf Coast & Gasoline Los Angeles	None	76.76157	15.41	20.04	1 Cointegrating equation at both 1% and 5% levels
	At most 1	1.390508	3.76	6.65	
Gasoline US Gulf Coast & Gasoline New York Harbor	None	122.3255	15.41	20.04	1 Cointegrating equation at both 1% and 5% levels
	At most 1	1.257158	3.76	6.65	
Gasoline US Gulf Coast & Gasoline Rotterdam	None	100.0838	15.41	20.04	1 Cointegrating equation at both 1% and 5% levels
	At most 1	0.398127	3.76	6.65	
Gasoline US Gulf Coast & Gasoline Singapore	None	92.33057	15.41	20.04	1 Cointegrating equation at both 1% and 5% levels
	At most 1	0.686139	3.76	6.65	
Gasoline Los Angeles & Gasoline New York Harbor	None	68.77374	15.41	20.04	1 Cointegrating equation at both 1% and 5% levels
	At most 1	1.151152	3.76	6.65	
Gasoline Los Angeles & Gasoline Rotterdam	None	60.16596	15.41	20.04	1 Cointegrating equation at both 1% and 5% levels
	At most 1	0.352950	3.76	6.65	
Gasoline Los Angeles & Gasoline Singapore	None	57.09422	15.41	20.04	1 Cointegrating equation at both 1% and 5% levels
	At most 1	0.541438	3.76	6.65	
Gasoline New York Harbor & Gasoline Rotterdam	None	79.88586	15.41	20.04	1 Cointegrating equation at both 1% and 5% levels
	At most 1	0.304438	3.76	6.65	
Gasoline New York Harbor & Gasoline Singapore	None	79.74979	15.41	20.04	1 Cointegrating equation at both 1% and 5% levels
	At most 1	0.514382	3.76	6.65	
Gasoline Rotterdam & Gasoline Singapore	None	69.34980	15.41	20.04	1 Cointegrating equation at both 1% and 5% levels
	At most 1	0.397718	3.76	6.65	

Source of data: US Government Energy Information Administration.

Figure 5. World reference gasoline prices 1998-2006



Source of data: US Government Energy Information Administration.

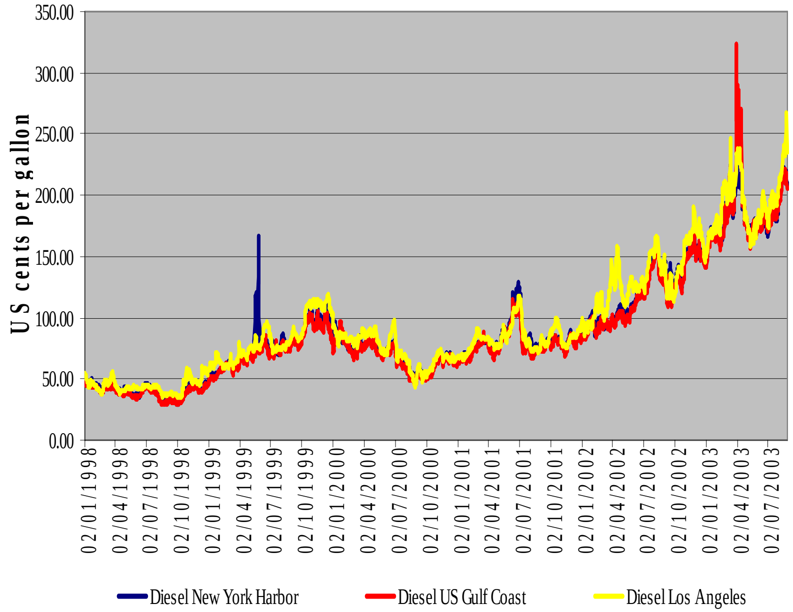
Similarly, the world prices of diesel are co-integrated

Table 9. Johansen co-integration test applied to world reference diesel prices 1998-2006

Variables	Hypothesized No. of Cointegrating Equations	Trace statistic	5% critical value	1% critical value	Result
Diesel US Gulf Coast & Diesel Los Angeles	None	47.27888	15.41	20.04	1 Cointegrating equation at both 1% and 5% levels
	At most 1	0.017796	3.76	6.65	
Diesel US Gulf Coast & Diesel New York Harbor	None	65.05565	15.41	20.04	1 Cointegrating equation at both 1% and 5% levels
	At most 1	0.044515	3.76	6.65	
Diesel Los Angeles & Diesel New York Harbor	None	52.87296	15.41	20.04	1 Cointegrating equation at both 1% and 5% levels
	At most 1	0.000331	3.76	6.65	

Source of data: US Government Energy Information Administration.

Figure 6. World reference diesel prices 1998-2006



Source of data: US Government Energy Information Administration.

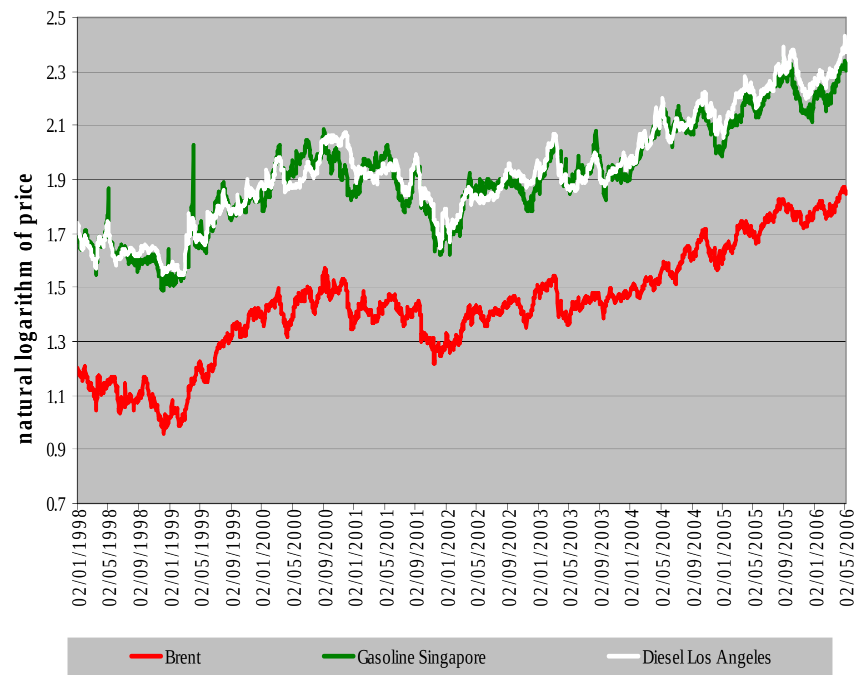
Also, the world reference prices of oil and its derivatives have long-run equilibrium relationship

Table 10. Johansen co-integration test applied to world reference prices of oil and its derivatives 1998-2006

Variables	Hypothesized No. of Cointegrating Equations	Trace statistic	5% critical value	1% critical value	Result
Brent & Gasoline Singapore	None	40.47223	15.41	20.04	1 Cointegrating equation at both 1% and 5% levels
	At most 1	0.059641	3.76	6.65	
Brent & Diesel Los Angeles	None	56.42028	15.41	20.04	1 Cointegrating equation at both 1% and 5% levels
	At most 1	0.074905	3.76	6.65	
Gasoline Singapore & Diesel Los Angeles	None	46.57682	15.41	20.04	1 Cointegrating equation at both 1% and 5% levels
	At most 1	0.038628	3.76	6.65	

Source of data: US Government Energy Information Administration.

Figure 7. World reference prices of oil and its derivatives 1998-2006



Source of data: US Government Energy Information Administration.

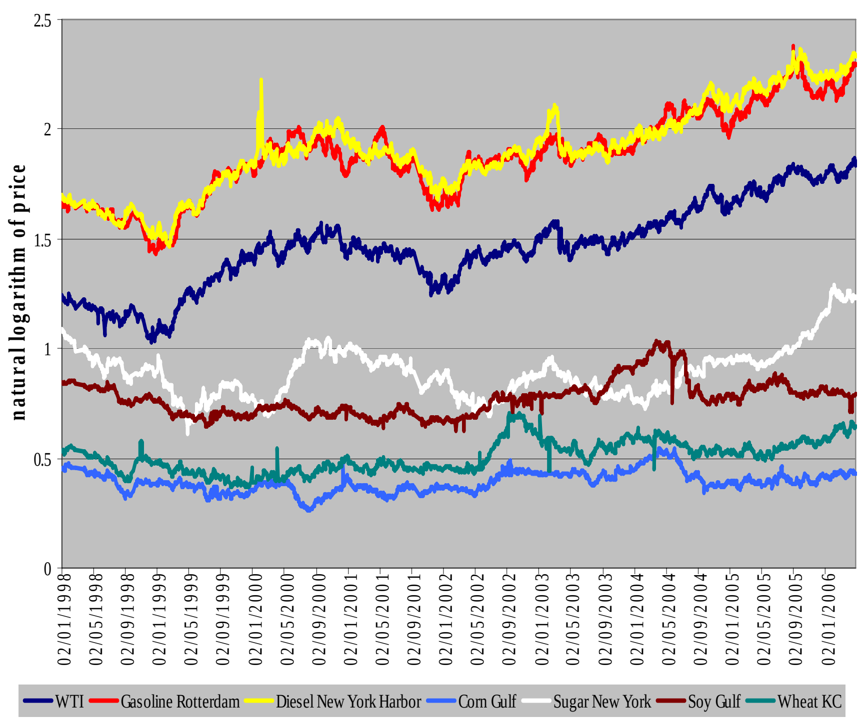
Considering prices for corn, soy, sugar and wheat, only sugar price showed a co-integration relation with one of the fuels' prices (gasoline Rotterdam)

Table 12. Johansen co-integration test applied to world reference prices of fuels and commodities 1998-2006

Variables	Hypothesized No. of Cointegrating Equations	Trace statistic	5% critical value	1% critical value	Result
WTI & Corn Gulf	None	8.985215	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.003262	3.76	6.65	
Diesel New York Harbor & Corn Gulf	None	9.095767	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.004547	3.76	6.65	
Gasoline Rotterdam & Corn Gulf	None	10.56776	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.164059	3.76	6.65	
WTI & Soy Gulf	None	5.007987	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.002450	3.76	6.65	
Diesel New York Harbor & Soy Gulf	None	4.762283	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.025321	3.76	6.65	
Gasoline Rotterdam & Soy Gulf	None	6.924655	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.722594	3.76	6.65	
WTI & Sugar NYC	None	14.89276	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.063529	3.76	6.65	
Diesel New York Harbor & Sugar NYC	None	14.32907	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.282803	3.76	6.65	
Gasoline Rotterdam & Sugar NYC	None	16.65071	15.41	20.04	1 Cointegrating Equation at the 5% level & No Cointegration at the 1% level
	At most 1	0.005056	3.76	6.65	
WTI & Wheat KC	None	8.562517	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.016165	3.76	6.65	
Diesel New York Harbor & Wheat KC	None	8.303194	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.008342	3.76	6.65	
Gasoline Rotterdam & Wheat KC	None	8.936437	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.030963	3.76	6.65	

Source of data: US Government Energy Information Administration and Reuters.

Figure 8. World prices of fuels and commodities 1998-2006



Source of data: US Government Energy Information Administration and Reuters.

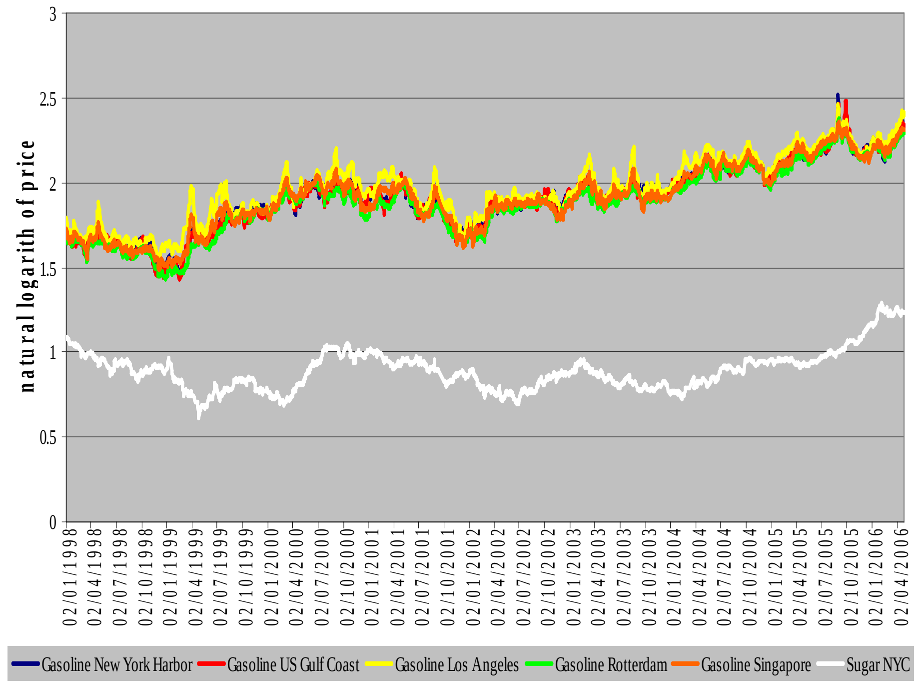
The world prices of gasoline and sugar seem to have developed a long-run equilibrium relationship

Table 13. Johansen co-integration test applied to world reference prices of fuels and sugar 1998-2006

Variables	Hypothesized No. of Cointegrating Equations	Trace statistic	5% critical value	1% critical value	Result
WTI & Sugar NYC	None	13.70548	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.037215	3.76	6.65	
Brent & Sugar NYC	None	13.67840	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.320186	3.76	6.65	
Gasoline New York Harbor & Sugar NYC	None	16.57788	15.41	20.04	1 Cointegrating Equation at the 5% level & No Cointegration at the 1% level
	At most 1	0.076082	3.76	6.65	
Gasoline US Gulf Coast & Sugar NYC	None	17.85352	15.41	20.04	1 Cointegrating Equation at the 5% level & No Cointegration at the 1% level
	At most 1	0.043659	3.76	6.65	
Gasoline Los Angeles & Sugar NYC	None	15.00254	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.553073	3.76	6.65	
Gasoline Rotterdam & Sugar NYC	None	16.65071	15.41	20.04	1 Cointegrating Equation at the 5% level & No Cointegration at the 1% level
	At most 1	0.005056	3.76	6.65	
Gasoline Singapore & Sugar NYC	None	13.51162	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.048591	3.76	6.65	
Diesel New York Harbor & Sugar NYC	None	13.30156	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.294931	3.76	6.65	
Diesel US Gulf Coast & Sugar NYC	None	14.03634	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.124048	3.76	6.65	
Diesel Los Angeles & Sugar NYC	None	12.75946	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.232882	3.76	6.65	

Source of data: US Government Energy Information Administration and Reuters.

Figure 9. World prices of gasoline and sugar 1998-2006



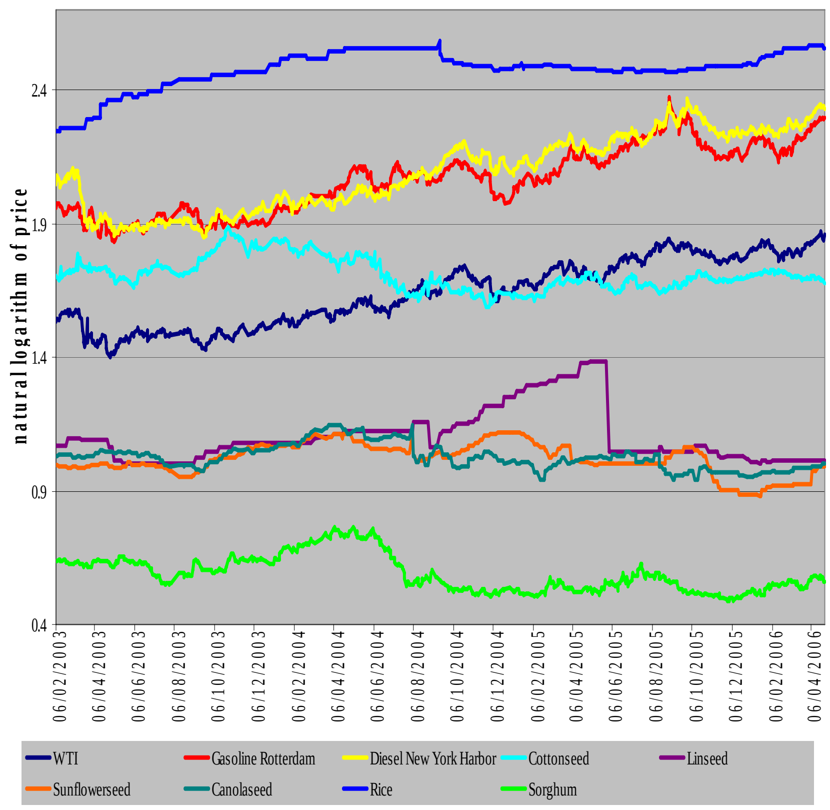
Source of data: US Government Energy Information Administration and Reuters.

The world prices of several oilseeds, rice and sorghum did not present a co-integration relationship with the world prices of fuels

Table 15. Johansen co-integration test applied to world reference prices of fuels and commodities 2003-2006

Variables	Hypothesized No. of Cointegrating Equations	Trace statistic	5% critical value	1% critical value	Result
WTI & Cottonseed	None	5.099105	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.041466	3.76	6.65	
Gasoline Rotterdam & Cottonseed	None	5.389460	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.484644	3.76	6.65	
Diesel New York Harbor & Cottonseed	None	5.350853	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.082686	3.76	6.65	
WTI & Lineseed	None	3.909786	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.055074	3.76	6.65	
Gasoline Rotterdam & Lineseed	None	4.495680	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.608551	3.76	6.65	
Diesel New York Harbor & Lineseed	None	3.901936	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.135897	3.76	6.65	
WTI & Sunflowerseed	None	3.059235	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.030094	3.76	6.65	
Gasoline Rotterdam & Sunflowerseed	None	3.876873	15.41	20.04	No Cointegration at both 5% and 1% levels
	At most 1	0.281671	3.76	6.65	
Diesel New York Harbor	None	3.692690	15.41	20.04	No Cointegration at both 5% and

Figure 10. World prices of fuels and commodities 2003-2006



Source of data: US Government Energy Information Administration and Reuters.

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The world prices of oil and its derivatives have reached historical records during the last years

- If the prices of oil and its derivatives continue increasing, the incentives to search for alternative sources of energy will increase, too

- Biofuels appear as an alternative to substitute at least partially in the short run fossil fuels

- If the demand for biofuels increases, the potential economies of scale of production could favour the reduction of its cost and price through research and technological innovation (lowering price factor of biofuels)

- Also, if the demand for biofuels increases, the demand for those agricultural inputs used to produce them will increase

- The demand pressure for agricultural commodities used as inputs to produce biofuels will tend to increase the price of such commodities (increasing price factor of biofuels)

- If a higher proportion of commodities is diverted to produce biofuels, the prices of such commodities will tend to track the prices of fuels, i.e. the case of sugar

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