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focussing on the food price spike in 2007/08"

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Acronyms and Abbreviations

ADF Test	Augmented Dickey Fuller Test
bn	Billion
CBOT	Chicago Board of Trade
CE	Cointegrating Equation
CFTC	Commodities Futures Trading Commission
CTA	Commodity Trading Advisors
DDGs	Dried Distiller's Grains
df	Degrees of freedom
EG(2) estimation	Engle and Granger's two-step estimation
FAO	Food and Agricultural Organisation of the United Nations
ha	Hectares
IEA	International Energy Agency
IFPRI	International Food and Policy Research Institute
i.i.d.	Independent identically distributed
IMF	International Monetary Found
kt	Kilotonnes, thousand tonnes
LDCs	Less developed countries
LR	Likelihood ratio
max	Maximum
m	Million
m ha	Million hectares
mt	Megatons, million tonnes
NYMEX	New York Mercantile Exchange
OECD	Organisation for Economic Cooperation and Development
prob.	Probability
t	Tonnes
t/ha	Tonnes per hectare
UNCTAD	United Nations Conference on Trade and Development
USD	United States dollar
USDA	United States Department of Agriculture
VAR	Vector Autoregression
VEC	Vector Error Correction
WTI	West Texas Intermediate

1. Introduction

Between 2006 and mid-2008, many food commodity prices increased tremendously: Within two years time, wheat and corn prices doubled in nominal terms, and the rice price even tripled. The price hike affected people around the world in numerous ways and had disastrous impacts on the poor, especially the urban poor in developing countries. It therefore attracted broad social and political interest and media coverage, competing for attention only with the price spike in crude oil that reached peak levels at about the same time.

A great deal of literature has been written about the likely nature and causes of the food price hike.¹ The factors pushing food commodity prices are numerous and complex and have been intensely debated – especially until the second half of 2008, when food commodity and oil prices plunged. Two of the most controversially discussed potential factors are biofuels production and speculation in financial markets. Since the production of biofuels has been increasing remarkably throughout the last few years creating an additional source of demand for food commodities, many authors identified the growing substitution of fossil fuels by means of agrofuels to be the main reason for the extraordinary increase in food prices. Other authors denied that biofuels production would impact food prices at all. The case of speculation is similar: some have suspected speculation in agricultural markets to boost food prices, while other authors argued that speculation could only increase price volatility, but not price levels.

However, most studies used descriptive methods to analyse food price inflation. There are very few econometric studies investigating food and oil price behaviour during the recent crisis. The aim of this study is to help better understand food price development and the multiple links among different commodity prices by providing some insights into the dynamics at play among the price series of four major traded food commodities and crude oil during the recent price crisis. Since speculation is suspected to play an important role in price development, possibly contrary to market fundamentals, a purely data-based approach was chosen.

Another aspect in which this study differs from others dealing with similar subjects is that it focuses only on the time of the commodity price spike using highly frequent data (daily spot market prices).

¹ For a commented review on the literature analysing potential factors pushing food prices, see P.C. Abbott, C. Hurt and W.E. Tyner, *What's driving food prices? Farm Foundation Issue Report*, July 2008, Farm Foundation, 2008, retrieved 20 March 2009, www.farmfoundation.org/news/articlefiles/404-FINAL%20WDFP%20REPORT%207-21-08.pdf, pp. 52-77, and P.C. Abbott, C. Hurt and W.E. Tyner, *What's driving food prices? March 2009 Update*, *Farm Foundation Issue Report*, AgEcon Search, 2009, retrieved 22 July 2010, <http://purl.umn.edu/48495>, pp. 37-44.

This approach is particularly interesting for the case of crude oil and food prices, where there are multiple causal linkages at work. There is no doubt that crude oil price development has an influence on food price development due to the use of crude oil in food production, and the difference between these prices can easily be imagined to revert to an equilibrium value in the long run. It therefore would not be such a big surprise to find evidence for cointegration among crude oil and food commodities prices in the long run using low-frequency data. Still, food commodities are subject to crop cycles and take time to grow, and a change in input costs should not be immediately felt in the price of the final products. Extensive co-movements in daily prices can not be explained along the traditional lines of input, transportation and distribution costs.

The question of interest is therefore: If the price of one commodity rises even as extreme as crude oil did in 2007/08, can the long-run equilibrium among this and the other commodities still be retained? And if that is the case, what are the causal linkages reinforcing it? This question has been investigated in this study using Johansen's approach to cointegration.

Some earlier studies which have analysed the mutual influence of food prices on each other and/ or the influence of the crude oil price or some energy price index on food prices using multivariate cointegration analysis shall be mentioned: In and Inder² investigated the relationships between eight different vegetable oil prices using data from 1976 to 1990 and found four cointegrating vectors among the eight variables and the variables to be grouped according to their different end uses. Liu³ examined the behaviour of hog, corn and soybean meal futures price series from 1985 to 2001 and found one cointegrating vector among the three series, Yu, Bessler and Fuller⁴ that of four edible oils prices and the price of crude oil from 1999 to 2006 and also found one cointegrating relationship among the five price series. Campiche *et al.*⁵ analysed the covariability of the prices of crude oil, corn, sorghum, sugar, soybeans, soybean oil and palm oil during 2003-2007 and also during the two subperiods 2003-2005 and 2006-2007. They found no cointegrating relation in 2003-2005, but evidence for cointegration among the price series of crude oil, corn and soybeans in the latter time frame.

² F. In and B. Inder, 'Long-run Relationships between World Vegetable Oil Prices', *Australian Journal of Agricultural and Resources Economics*, vol. 41, no. 4, 1997, pp. 455-70, retrieved 23 July 2009, Wiley Online Library.

³ Q. Liu, 'Price relations among Hog, Corn, and Soybean Meal Futures', *The Journal of Futures Markets*, vol. 25, no. 5, 2005, pp. 491-514, retrieved 15 September 2010, Wiley Online Library.

⁴ T.-H.E. Yu, D.A. Bessler and S. Fuller, *Cointegration and Causality Analysis of World Vegetable Oil and Crude Oil Prices*, Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Long Beach, California July 23-26, AgEcon Search, 2006, retrieved 27 May 2009, <http://purl.umn.edu/21439>.

⁵ J.L. Campiche et al., *Examining the Evolving Correspondence between Petroleum Prices and Agricultural Commodity Prices*, Paper Presented at the American Agricultural Economics Association Annual Meeting, Portland, OR, July 29-August 1, 2007, AgEcon Search, 2007, retrieved 17 March 2009, <http://purl.umn.edu/9881>.

A very interesting and recent contribution was made by Baek and Koo⁶, adding econometric findings to the debate on the factors behind the food price spike: They used multivariate cointegration analysis to analyse the relationship among a food price index, a commodity price index, an energy price index and a real effective exchange rate index using monthly data from 1989 to 2008. Dividing the data into two subperiods, one covering January 1989 to October 1998 and the other November 2001 to January 2008, they found no evidence for cointegration in the earlier period. In the latter period, there is evidence for two cointegrating relationships, and the hypotheses of weak exogeneity of the energy price and the exchange rate index could not be rejected.

The remainder of this thesis is structured as follows: Chapter 2 provides a theoretical background in food price development: basic facts about trade in food commodities and food commodity prices are presented, the price spike in 2007/08 is described and potential factors behind it are discussed. In chapter 3, some facts concerning trade in crude oil and the oil price are given and the question, how a price spike in crude oil impacts food prices is investigated in more detail. Chapter 4 presents the data and chapter 5 the methodology used in this study. The empirical results are given in chapter 6. The last chapter contains a brief summary and the conclusion of this study.

⁶ J. Baek and W. W. Koo, 'Analyzing Factors Affecting U.S. Food Price Inflation', *Canadian Journal of Agricultural Economics*, vol. 58, no. 3, 2010, pp. 303–320, retrieved 15 September 2010, Wiley Online Library.

2. Food commodity prices and price development

2.1 Some basic facts about food commodity prices

A great variety of agricultural products is traded in cash and futures markets, among those grains, oilseeds, cotton, livestock, beverages and biofuels. The most widely traded food commodities include wheat, corn, sugar, soybeans and coffee.

Tables 2.1 and 2.2 provide an idea of the main commodities' and commodity groups' quantities produced and consumed in OECD countries and non-OECD countries as well as world total figures. Corn is by far the most important component in the coarse grains group, which also includes oats, barley and sorghum; soybeans are a major component in the oilseeds (soybean oil) as well as the protein meals (soybean meal) group.

Table 2.1 Production and Consumption: Different Commodities

	Wheat		Coarse Grains		Rice		Oilseeds		Protein Meals		Vegetable Oils	
	Prod	Cons	Prod	Cons	Prod	Cons	Prod	Cons	Prod	Cons	Prod	Cons
World	655,9	639,1	1103,7	1088,1	454,6	451,8	387,1	396,5	231,3	226,1	131,9	133,0
OECD	267,9	210,3	579,7	551,0	22,6	24,4	137,1	129,0	79,4	81,2	30,4	42,7
Non-OECD	387,9	428,8	524,0	537,2	432,0	427,4	250,0	267,5	151,9	116,9	101,5	90,3

Figures represent an average of 07/08- 09/10 (estimate) data, data is in mt.

Source: OECD/ FAO Outlook 2010.

Table 2.2 Production and Consumption: Sugar

	Sugar	
	Prod	Cons
World	161113	160310
OECD	37425	43488
Non-OECD	123688	116822

Figures represent an average of 07/08- 09/10 (estimate) data, data is in kt raw sugar equivalent.

Source: OECD/ FAO Outlook 2010.

Commodities are traded to highly varying degrees relative to their total production and consumption. Table 2.3 shows quantities of the commodities mentioned above traded on world markets, and the amounts imported and exported by OECD-countries, developing countries and

least developed countries respectively. According to these figures, 19% of global wheat production is exported, but only 11% of coarse grains production. Rice is even more thinly traded with only 7% of the global production being exported. On the other side of the scale are vegetable oils, of which 43% of total production are exported. More than 62% of vegetable oil exports are made up by palm oil, which however, makes up less than one third of global vegetable oil production, in which soybean oil and rapeseed oil also have large shares. Of sugar and protein meals production about 30% are exported.⁷

Table 2.3 Import and Export: Different Commodities

	Wheat		Coarse Grains		Rice		Oilseeds	
	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
World Trade	121 483		118 329		31 325		92 647	
OECD	25 874	78 881	56 908	77 994	5 150	3 589	34 625	45 909
Developing	97 233	15 778	81 184	28 652	26 130	26 603	65 840	36 828
LDCs	12 224	117	2 430	2 750	6 557	2 419	290	179

	Protein Meals		Vegetable Oils		Sugar	
	Imports	Exports	Imports	Exports	Imports	Exports
World Trade	66 297		56 447		48 712	
OECD	41 252	11 526	16 787	4 635	12 431	6 933
Developing	27 517	57 382	39 583	48 238	33 053	45 423
LDCs	409	200	3 928	191	4 834	1 844

Figures represent an average of 07/08- 09/10 (estimate) data, data is in kt.

Source: OECD/ FAO Outlook 2010.

While this study deals with spot prices, trade in commodity futures is of growing importance and attracts increasing numbers of non-commercial traders. Though initially intending physical delivery of a commodity (or cash settlement for some contracts) at contract maturity, the bulk of commodity futures nowadays is liquidated before delivery.⁸

Prices on world markets are classically seen to be formed by market fundamentals of supply and demand, the potential influence of other factors like speculative activity is debated. Speculation for example is often praised for providing liquidity for commercial traders intending to hedge risks and

⁷ According to own calculations using data provided by OECD and FAO, *OECD-FAO Agricultural Outlook 2010-2019. Highlights*, OECD Publishing, 2010, retrieved 21 July 2010, <http://www.agri-outlook.org/dataoecd/13/13/45438527.pdf> and PSD online, <http://www.fas.usda.gov/psdonline/psdDataPublications.aspx>.

⁸ J. Womach, *Agriculture: A Glossary of Terms, Programs, and Laws, 2005 Edition*, UNT Digital Library, 2005, retrieved 9 August 2010, <http://digital.library.unt.edu/ark:/67531/metacrs7246/>, p.122.

helping in price discovery, but at least the latter function has been questioned, expressing concerns that speculation might rather drive prices away from their market fundamentals. Interestingly, prices in cash and futures markets during the last years did often not converge for a number of food commodities. Factors of actual or potential influence on food price development are discussed in Chapter 2.3.

High volatility is a characteristic of world agricultural commodity prices.⁹ Quantities can only slowly adjust to price signals because of the natural time lag between production decisions and output, therefore prices are sensitive to short run shocks. Price volatility is also connected to the thinness of markets: Prices in thin markets, that is markets with a low share of global production being traded, like the rice market, will react more strongly to supply or demand shocks.

Finally, it is important to distinguish between international commodity prices and local (retail) food prices, especially when thinking about the impacts of the 2007/08 commodity price boom. Domestic prices for importing countries depend on the exchange rate, transportation and insurance costs, border policies and the domestic food supply chain, including wages and storage costs. According to the 2008 Outlook, farm gate prices of agricultural commodities on average account for 25-35% of the retail price in many developed countries - or much less for higher processed goods¹⁰. Since in developing countries food is consumed in a less processed form, increases in commodity prices have a greater impact on food prices there. Looking at the 2007/08 price spike, it is worth noting that although commodity prices have fallen remarkably after summer 2008, food prices stayed at high levels in many countries.¹¹

⁹ OECD and FAO, *OECD-FAO Agricultural Outlook 2008-2017. Highlights*, FAO, 2008, retrieved 17 March 2009, <http://www.fao.org/es/esc/common/ecg/550/en/AgOut2017E.pdf>, p.38.

¹⁰ *ibid* p 34.

¹¹ OECD and FAO, *OECD-FAO Agricultural Outlook 2009-2018. Highlights*, OECD Publishing, 2009, retrieved 25 August 2009, <http://www.agri-outlook.org/dataoecd/2/31/43040036.pdf>, p. 11.

2.2 The price spike in 2007/08

FAO defines a price spike as following:

“A price spike is a pronounced sharp increase in price above the trend value. For practical purposes, a price spike can be identified as an annual percentage change that is more than two standard deviations of the price in the five years preceding the year that the percentage change is calculated from.”¹²

The sharp increase in food commodity prices in 2007 and 2008 clearly falls in this category. From 2007 to summer 2008, rice prices tripled, wheat prices more than doubled and corn prices doubled.¹³ Costs of cereal imports of 82 low-income countries doubled between 2006 and June 2008, according to the Wall Street Journal¹⁴, food price inflation spread around the globe, leading to food insecurity and violent protests in some countries.¹⁵

The rise in food commodity prices however started earlier; but prices did not rise dramatically in the beginning. After a period of slowly declining prices from around 1996 to 2001, prices of many food commodities started an upward trend in 2002. In the beginning, however, this was only a very modest increase and most prices (with the exception of e.g. sugar) were rather stable from the late 90es to 2004. In 2005, cereal prices started to follow a sustained upward trend (see Figure 2.1). This was followed by an increase in oils prices in 2006. It is worth noting that both the gross cereal group (although not every single commodity within the group) and the oilseeds group had experienced a record crop year in 2004/05, just before prices started to rise, and also had extraordinary good yields in 2005/06.¹⁶

¹² FAO, *The State of Agricultural Commodity Markets 2009. High Food Prices and the Food Crisis – Experiences and Lessons Learned*, FAO, 2009, retrieved 22 July 2010, <ftp://ftp.fao.org/docrep/fao/012/i0854e/i0854e.pdf>, p.12.

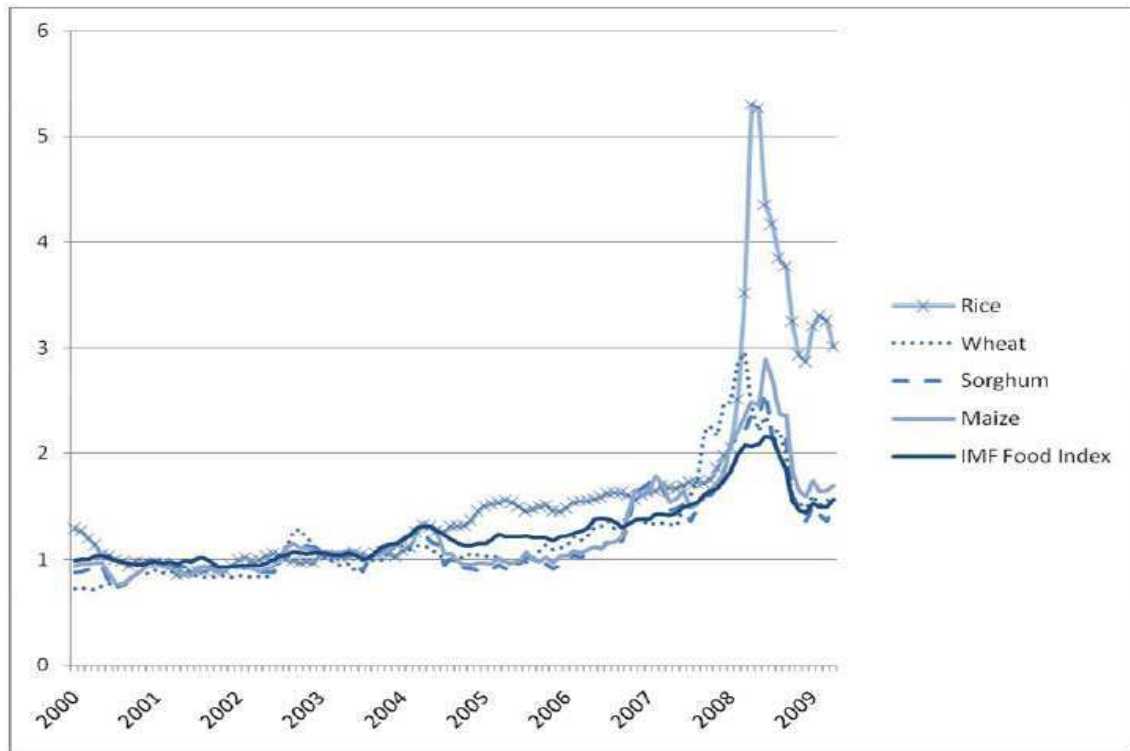
¹³ A. F. McCalla, 'World food prices: Causes and Consequences', *Canadian Journal of Agricultural Economics*, vol. 57, no. 1, 2009, pp. 23–34, retrieved 9 June 2009, Wiley Online Library, p.23.

¹⁴ Wall Street Journal, 10 June 2008, cited in McCalla, op.cit., p.23.

¹⁵ FAO, op.cit., p.9.

¹⁶ D. Mitchell, 'A Note on Rising Food Prices', *Policy research Working Paper* no. WPS 4682, The World Bank, 2008, retrieved 15 May 2009, http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2008/07/28/000020439_20080728103002/Rendered/PDF/WP4682.pdf, pp.2f.

Figure 2.1 Movements of International Agricultural Commodity Prices and the IMF Food Index



Normalised to equal 1.0 in 2002.

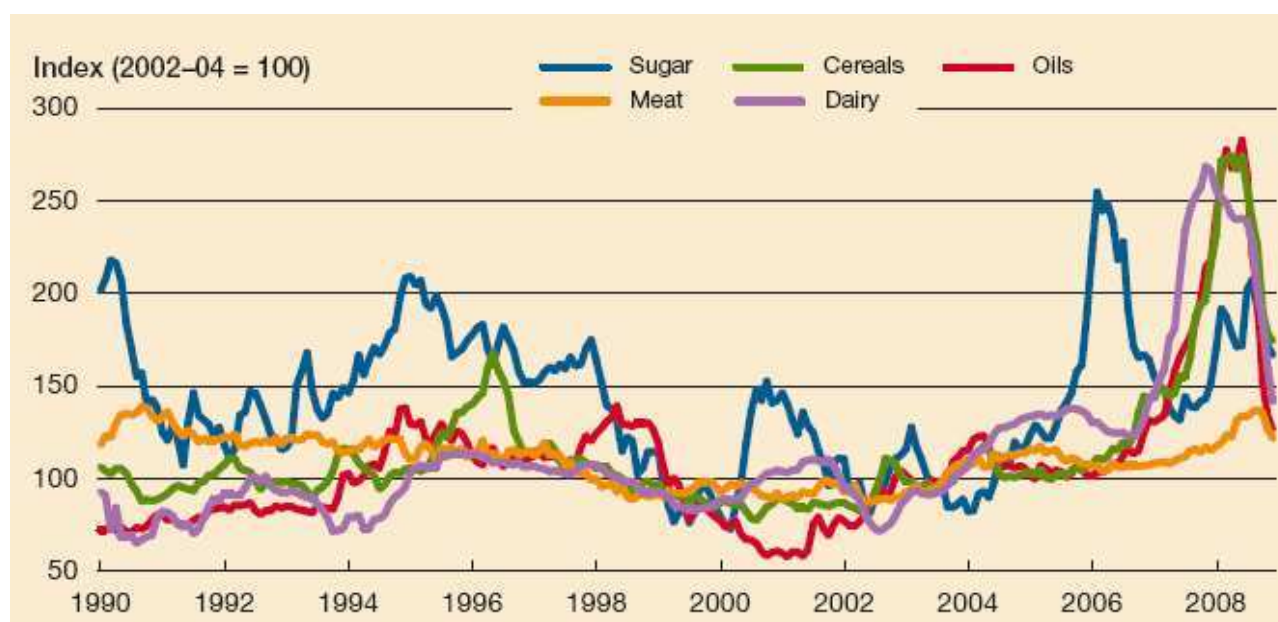
Source: P.C. Abbott and A.B. de Battisti, *Recent Global Food Price Shocks: Causes, Consequences and Lessons for African Governments and Donors*, International agricultural trade research consortium, 2009, retrieved 22 July 2010, <http://iatrc.software.umn.edu/activities/symposia/2009Seattle/seattle-Abbott.pdf>, p.6.

Sugar prices, however, followed a different path: being somewhat “ahead of time”, they peaked already in 2006 and were back to lower levels when cereals and oils prices started to explode. In 2007, they started to rise again, but did not reach 2006 levels (see Figure 2.2)

It is also remarkable that during the price spike in 2007/08 so many different and unrelated food commodities were affected. Nearly all food commodity prices increased at least nominally. The quantitative impact, however, varies greatly across commodities: prices of tropical fruit or shrimp increased by less than half their former level, cocoa or coffee prices experienced minor increases. In short, prices of basic foods rose much more than tropical products did (see Figure 2.3).¹⁷

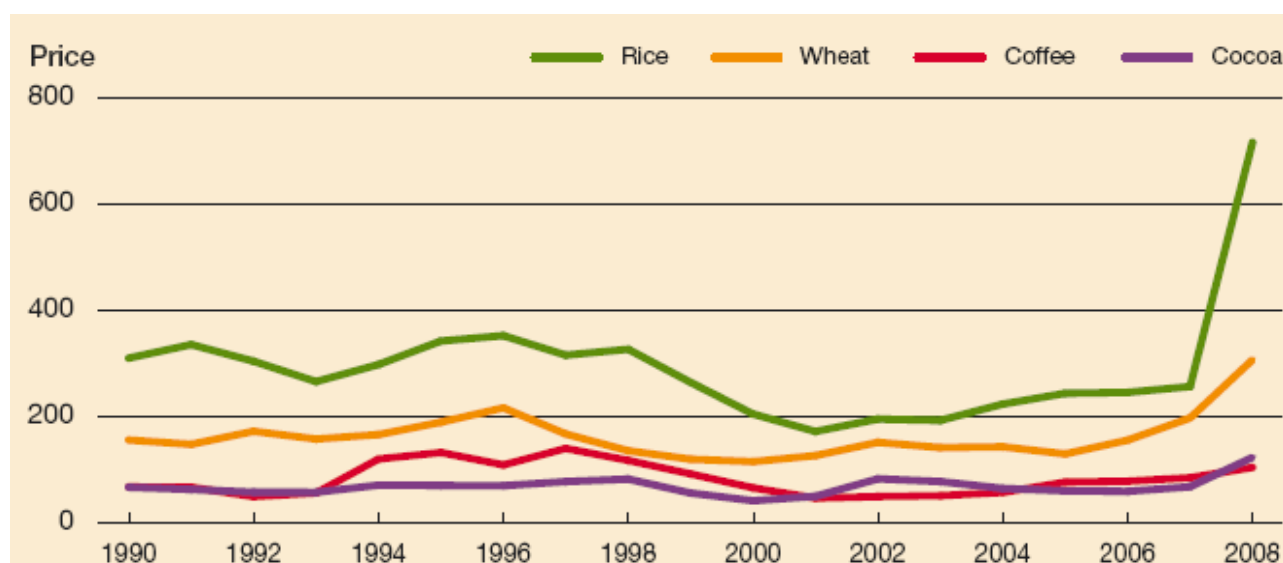
¹⁷ *ibid*, pp.2f, FAO, *op.cit.*, p.10.

Figure 2.2 Evolution of Monthly FAO Price Indices for Basic Food Commodity Groups



Source: FAO, op.cit., p.10.

Figure 2.3 Evolution of Prices for Tropical Export Crops



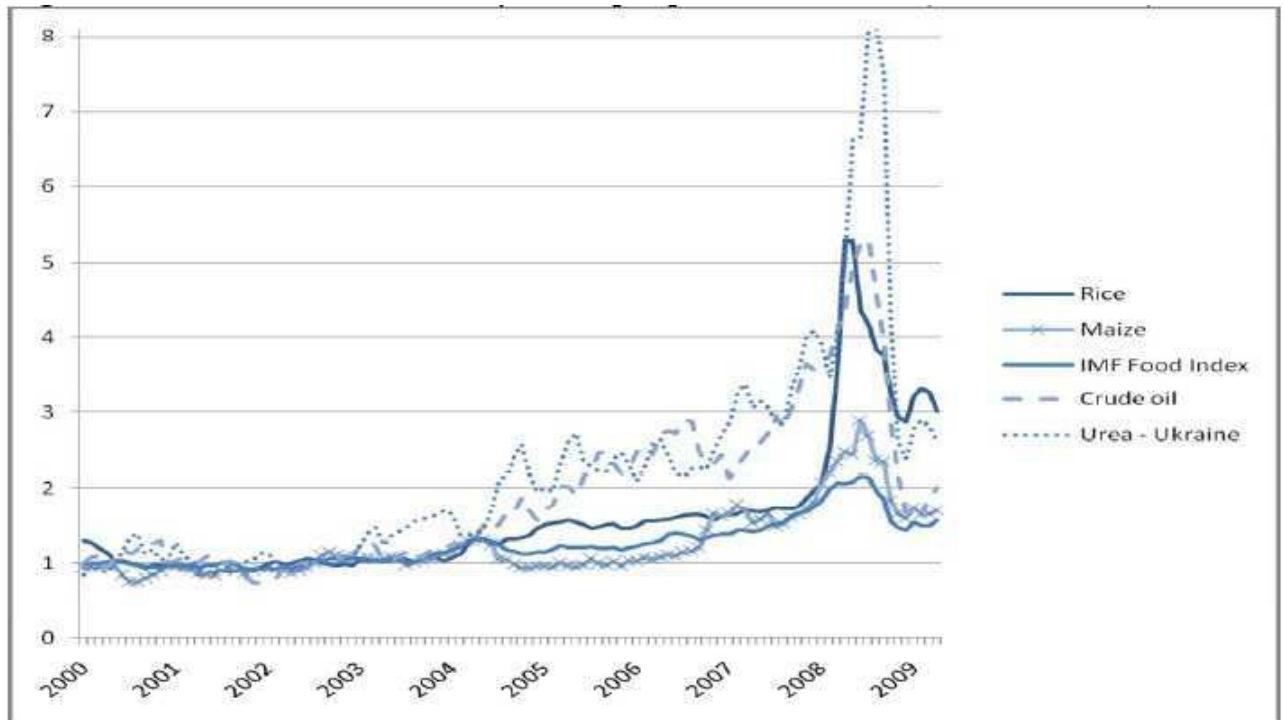
Rice and wheat prices in US-Dollar/tonne, cocoa and coffee prices in US-cents/pound.

Source: FAO, op.cit., p.10.

The rise in food commodities, as remarkable as it was, is somehow put into perspective by the general rise in commodity prices during that period. This is especially the case when compared to

the rising price of oil and some oil products, but also to some metal prices the movement of food prices looks less surprising (see Figure 2.4 for a comparison of the IMF food index, the rice price and the corn price to the price of crude oil and urea.)

Figure 2.4 Movements of International Commodity Prices



Normalised to equal 1.0 in 2002.

Source: Abbott and de Battisti, op.cit., p.7.

As an increase in food prices, however, can have disastrous effects on vulnerable groups, food price inflation is of great political concern – all the more so since the prices of basic foods were the ones to rise most significantly in 2007/08.

There was a substantial price spike to be noted in a number of partly related, partly unrelated food commodities in 2007-08 which needs explanation and merits closer investigation. Potential factors which influence food prices will be discussed in the following.

2.3 Factors influencing food prices

In the course of and shortly after the food price hike, a great deal of literature on the question of the reasons behind it has been written. While it is tempting to single out a few factors and claim them to be the sole culprits, the most probable answer is a complex interplay of many factors, some transitory, others permanent in nature, some on the supply, others on the demand side.

But as complex as the topic is, there is a remarkable consensus among the major studies concerning the set of factors influencing food prices. Attributing fractions of price changes to the different factors is a very difficult and arguable task that cannot be treated here, but the factors most frequently quoted in the literature shall be listed and briefly discussed in the following.

2.3.1 Weather-related production shortfalls

Weather conditions are the single most important factor causing supply shocks, and are clearly not a new phenomenon. Throughout human history, harvest shortfalls due to unfavourable weather conditions have driven up food prices which have come down again after successful and sufficient imports or following good harvests. Weather – related production shortfalls can thus be seen as a temporary factor influencing food prices, unless they are interpreted as a result of climate change and long-term changing weather conditions.

Unfavourable weather conditions, especially the consecutive droughts in Australia, are listed in all extensive studies as a relevant factor for the 2007/08 food price hike, only their relative importance is assessed differently and they are most often seen as aggravating an already difficult situation. In the period studied, the wheat and corn yields were most severely affected. The OECD- FAO World Agricultural Outlook calls weather shocks “responsible for much of the supply shortages on commodity crop markets”¹⁸ and goes on to explain that in 2007 Australian and Canadian yields, both countries being major food exporters, fell by 20% compared to 2005, which was already a dry year with a poor yield in Australia¹⁹. Furthermore, according to the World Agricultural Outlook the yields per hectare “were at or below trend in many countries“, but there was also a yield increase

¹⁸ OECD-FAO, *Outlook 2008-2017*, p.27.

¹⁹ *ibid*, p.40.

(e.g. in Brazil) against the background of poor harvests in 2005.²⁰

Mitchell paints the picture a bit differently, stating that droughts in Australia and poor harvests in the EU and Ukraine did reduce grain exports by roughly 9 million tons in 2005 and 19m tons in 2006, but claims that these shortfalls were “more than offset“ by good yields in other countries. Globally, he stresses, that total grain production declined by 1.3 % in 2006 but increased by 4.7% in 2007. Still, for wheat there was a real and significant shortfall, with a decline by 4.5% in 2006 and an increase of 2% in 2007.²¹ Mitchell emphasizes that weather-related production shortfalls would not have contributed much to a price increase if it were not for increased demand, land use changes and stock declines.²²

To give the reader a better idea of the figures, a table including figures on area, yield and production in different regions of the world is shown in Table 2.4.

Also Abbott, Hurt and Tyner²³ speak of the “exaggerated importance of drought in Australia“, explaining that weather-related shocks were not dramatic and “under normal circumstances“ would hardly impact prices, but that minor shocks had a large impact on prices due to the low stock-to-use ratio and other factors.²⁴

²⁰ *ibid*, p.40.

²¹ Mitchell, *op.cit.*, p.13f.

²² *ibid*, p.14.

²³ Abbott, Hurt and Tyner, *What's Driving Food Prices?*, p.8.

²⁴ *ibid*, p.48.

Table 2.4 Supply of wheat and corn

	2005 level	2007 level	Change 2005 to 2007	
			absolute	per cent
Prices, USD/t (Nominal)				
Wheat	168	319	150	89
Maize	106	181	75	71
Area harvested, m ha				
World	525	531	6	1
OECD	177	177	0	0
Australia and Canada	36	35	-1	-2
European Union	62	57	-6	-9
United States	55	61	5	10
Non-member economies	348	354	6	2
Brazil	16	16	0	-2
China	52	52	0	1
India	52	56	4	8
Indonesia	4	3	0	-2
South Africa	4	4	-1	-13
Yield, t/ha				
World	3,1	3,1	0,1	2
OECD	4,5	4,5	0,1	1
Australia and Canada	2,5	2	-0,5	-21
European Union	4,4	4,5	0,1	2
United States	6,5	6,7	0,3	4
Non-member economies	2,4	2,4	0,1	3
Brazil	2,7	3,5	0,8	31
China	4,7	4,9	0,2	4
India	1,9	1,9	0	0
Indonesia	3,6	3,6	0,1	1
South Africa	3,3	2,6	-0,7	-22
Production, mt				
World	1615	1661	46	3
OECD	792	801	9	1
Australia and Canada	90	70	-20	-22
European Union	277	256	-21	-8
United States	356	407	51	14
Non-member economies	823	860	37	5
Brazil	43	56	12	29
China	245	257	11	5
India	102	110	8	8
Indonesia	13	12	0	-1
South Africa	14	10	-5	-32

Source: OECD-FAO, *Agricultural Outlook 2008-2017*, p.39.

2.3.2 A rising oil price

The price of crude oil as well as other energy prices influence food prices in a number of ways. The decisive role that the high oil price played in the food price crisis is beyond question and always emphasized in the literature.

Because of the major importance of the oil price for food price development, this link will be examined more closely in Chapter 3.

2.3.3 Additional demand for food created by biofuels production

Biofuels production, both the production of bioethanol and of biodiesel, has grown remarkably in recent years and has created a major new source of demand for food commodities used as feedstock. Because of the close link of the development of this industrial sector to changes in the supply and price of crude oil, the impact of biofuels on food commodity prices will also be discussed in Chapter 3.

2.3.4 Speculation

The influence of speculative activity on the level of commodity prices is probably the most uncertain and the most intensely debated factor. It therefore merits some closer investigation.

Undoubtedly, the number of actors as well as trading volumes in commodity markets have increased sharply over the last few years, with investment funds and hedge funds being major new market participants, altering not only trading volumes but also typical trading patterns:

From February 2005 to February 2008, monthly trading volumes in wheat futures increased by 125%²⁵, total open interest increased from 0.22 million contracts to 0.45 million contracts and the share of non- commercial traders in opening interest in long positions rose from 28% to 42%. For

²⁵ OECD-FAO, Outlook 2008-2017, p.37. According to Mitchell, op.cit., p.15, from 2002 to 2006, wheat futures contracts traded on CBOT had even quadrupled!

corn, trading volumes had increased by 85%, but open interest rose from 0.66 million to 1.45 million contracts with the non-commercials' share in it rising from 17% to 43%. According to the Outlook, soybean trade followed a similar pattern, and only sugar among the food commodities investigated in this study does not provide evidence for the simultaneous increase of contract volumes and rising influence of non-commercial traders on total open interest, with monthly trading volumes even tripling, while the latter's share remained about a third.

The following table summarizes information on corn, wheat, soybean and sugar futures, clearly showing the peak in total open interest in 2008 coinciding with a peak in the share of non-commercial traders in corn and soybean futures markets in this year:

Table 2.5. Futures market activity: total volume of open interest contracts and distribution over commercial and non-commercial traders

Futures	Corn	Wheat	Soybean	Sugar Futures
Total open interest				
2005	657 417	222 752	272 127	400 084
2008	1 452 992	449 237	596 447	979 085
2009	812 240	305 491	322 897	660 712
% Commercial				
2005	61.6	55.4	59.5	43.8
2008	45.6	48.6	42.9	55.5
2009	50.0	48.0	47.0	50.5
% Non-commercial				
2005	16.9	28.0	19.9	34.8
2008	43.2	42.3	46	33.7
2009	36.2	42.8	39.9	37.4
% index traders –long				
2008	20.2	36.2	23.9	31.1
2009	21.7	40.6	24.9	24.0

Data from Chicago Board of trade and New York Board of Trade.

Source: OECD-FAO, Outlook 2009-2018, p.49.

The surge of new monies into the commodity futures markets has to be seen in the context of decreased equity market values due to the financial crisis: investors rearranged their portfolios, shifting money into real assets which were still profitable- like certain commodities²⁶. Besides, the tremendously increasing trading volumes of hedge funds and index funds fuelled non-traditional investment.

Speculators, and more generally non-commercial traders, traditionally are not seen to initiate price

²⁶ OECD-FAO, Outlook 2009-2018, p.48.

changes, instead, price changes are taken to be the result of changes in fundamental factors. But once prices are changing, new actors enter the markets trying to make profits out of their expectations concerning future price movements, speculating on continuing (or reversing) trends and thereby prolonging or enforcing them (or vice versa).²⁷

There is broad agreement among the various studies that price volatility does increase with the magnitude of speculative activity, not least because of the increased trading volumes, but also because many speculators and investors follow a rather simple investment strategy of extrapolating trends, regardless of underlying fundamentals, causing markets to “overshoot“.

What has been debated is whether non-commercial market participants can drive not only price volatility, but also price levels, and whether they can and do initiate price movements.

The mainstream view that speculation does not influence price levels, was often raised in response to the great number of articles written in 2008 searching for reasons behind the floating food prices and claiming (excess) speculation to be (at least part of) the answer. Price-driving influences are negated by Abbott and de Battisti²⁸, who insist that one doesn't have to “resort to mysterious speculation linkages“ to be able to explain price changes. Mitchell²⁹ points out that the most outstanding increase in wheat futures contracts happened between 2002 and 2006, clearly before the rise in wheat prices, but concedes that the rate of adjustment to a new equilibrium following a change in fundamental factors may be altered by speculative activity. Similarly, though more modestly, the 2008 edition of the OECD-FAO Agricultural Outlook predicts that the (short term) upward pressure on derivative market prices will be temporary because of adjustments in market procedures and participants' behaviour³⁰, but admits that the long-run aggregate effect of activities of non-traditional market participants in futures commodity markets on derivative market price levels as well as on the corresponding cash prices is very uncertain since investment funds are very large and move rapidly in and out of commodity markets. Permanently increased price volatility is still seen as the most probable result.³¹

In their 2009 edition of the Agricultural Outlook, the OECD-FAO team tackled the issue of whether there was excess speculation during the time of the food price hike, with “excess speculation“ referring to a market situation in which the “contract volume held by speculators exceeded the amount necessary to meet hedging needs of commercial traders“³². They use data from CFTC's

²⁷ S. Tangermann, 'Nahrungspreise schwanken künftig noch viel stärker', *Die Welt*, 30 May 2008.

²⁸ Abbott and de Battisti, op.cit., p.10f.

²⁹ ibid, p.15.

³⁰ OECD-FAO, Outlook 2008-2017, p. 44.

³¹ ibid., p.44.

³² OECD-FAO, Outlook 2009-2018, p.49.

Commitment of Traders report and Working's T-statistic as a measure of excess speculation. The results show that, according to this indicator, excess speculation was lower between 2006 and 2009 than between 1998 and 2002.³³

In contrast, IFPRI publications strongly defend the view that the increase in food prices in 2007/08 cannot be fully explained by market fundamentals, but irrational expectations affected price levels as well as volatility.³⁴

In the UNCTAD- discussion paper “Speculative influences on commodity future prices 2006-2008”, Gilbert addresses the concern that large investors like CTAs might create the very trends they follow accordingly, which, amplified by herd behaviour, can lead to speculative bubbles.³⁵

In a well-functioning market, if such behaviour due to lack of information leads to prices not reflecting market fundamentals, this should be quickly adjusted by informed traders, who will take opposite positions and push the prices back towards their fundamental values.

Now Gilbert argues that in practice, this self-correction may be hindered by the fact that well-informed market participants may have too short time horizons to follow this sound strategy. He associates CTAs with extrapolative expectation formation and trend-following behaviour, and hedge funds with well-informed active investors whose managers might suffer from performance targets or reporting periods too short to bet on prices returning to market fundamentals, even if they knew them. In the extreme case, this may coerce hedge funds managers to follow (and amplify) a trend further even if they know it is contrary to fundamentals. The interplay of these factors, according to Gilbert, can generate explosive behaviour.

He goes on to “test“ for speculative bubbles in a number of commodity prices (prices of crude oil, wheat, soybeans, corn and three metals) with an econometric procedure developed by Phillips, Wu and Yu and Phillips and Wu in 2009³⁶. According to Gilbert, there is evidence for a speculative bubble in the soybeans market, but non for corn and wheat³⁷. The results for the oil market are not so clear³⁸, but he still takes account of index-based investment being “responsible for a significant

³³ *ibid.*, p.50.

³⁴ J. von Braun and M. TORERO, 'Implementing Physical and Virtual Food Reserves to Protect the Poor and Prevent Market Failure', *IFPRI Policy Brief*, no. 10, 2009, retrieved 23 July 2010, IFPRI, and IFPRI, 'High Food Prices: The What, Who, and How of Proposed Policy Actions', *IFPRI Policy Brief*, May 2008, retrieved 20 March 2009, IFPRI.

³⁵ C.L. Gilbert, 'Speculative Influences on Commodity Futures Prices 2006-2008', *UNCTAD Discussion Paper*, No. 197, 2010, retrieved 22 July 2010, UNCTAD, p. 3.

³⁶ In the papers P.C.B. Phillips, Y. Wu and J. Yu, *Explosive behavior in the 1990s Nasdaq: When did exuberance escalate asset values?* Cowles Foundation for Research in Economics, Yale University, and P.C.B. Phillips and J. Yu, *Limit theory for dating the origination and collapse of mildly explosive periods in time series data*. Cowles Foundation for Research in Economics, Yale University, cf. Gilbert, *op.cit.* pp. 4ff.

³⁷ Gilbert, *op.cit.*, pp.8ff.

³⁸ *ibid.*, pp.12ff.

and bubble-like increase of energy and non-ferrous metals prices³⁹, with a price impact on energy and metals price of about 3-10% in 2006-2007 but 20-25% in the first half of 2008. The impact of index-based investment on grains prices according to Gilbert is about half that on oil.⁴⁰

2.3.5 Economic Growth

In the decade before the crisis, many countries had enjoyed good economic growth including higher per capita income and greater purchasing power, among those developing as well as developed countries. Especially in developing countries, economic growth often went hand in hand with urbanization, changing diets (from staple food to more meat and dairy products, but also fruit and vegetables) and population growth.⁴¹

Economic growth leads to greater demand for agricultural products. This is intuitive for developing countries, but it is also true for developed countries where additional factors come into play:

Firstly, industrial demand for food commodities, e.g. for biofuels production, constitutes a major new demand factor, as described in Chapter 3.3.2.2. Still, as of 2008, food and feed demand accounted for the greatest share in demand growth for agricultural products.⁴²

Secondly, price elasticity of food demand is falling with rising incomes, since food expenditures then constitute only a minor share of the consumer's budgets and consumers usually care less about purchases that represent minor expenditures anyway. Even at remarkably higher prices, demand barely changes. Supply shocks will therefore have greater price impacts, since it will need much stronger price signals to make consumers reconsider their buying habits.⁴³

Thirdly, with urbanization and longer marketing changes, the actual commodity price component in the retail price consumers have to pay is declining, so e.g. a doubling in the commodity price will be felt by the consumer to a much smaller degree. This has the same effects as decreasing price elasticity.⁴⁴

Thus, via reduced demand elasticity, higher incomes are likely to increase world price volatility. This is a factor that will permanently influence food commodity markets.⁴⁵ Food price *levels* will

³⁹ *ibid.*, p.38.

⁴⁰ *ibid.*

⁴¹ OECD-FAO, Outlook 2008-2017, pp.11 and 46.

⁴² *ibid.*, p.11.

⁴³ *ibid.*, p.46.

⁴⁴ *ibid.*

⁴⁵ *ibid.*, p.44.

not permanently be increased by lower demand elasticity.

Since many market analysts in 2008 singled out China's and India's growing food demand and stressed their importance for the food crisis, this claim merits some closer investigation and shall therefore be investigated separately in the next section, although it is in fact an aspect of economic growth.

2.3.6 Changing diets in developing countries increasing demand

Some developing countries are experiencing population growth as well as rapid economic growth, leading to increasing food and feed demand, since diets with urbanization and greater purchasing power tend to shift from staple foods to more diversified diets including greater meat and dairy demands. This argument has often been brought forward as an explanatory factor for rising food prices, pointing most importantly to income and population growth in China and India.

Although it is true that economic growth generally leads to dietary transitions resulting in higher animal feed demand, and this has also been the case in China and India during the last decade, world market prices are only affected through the volumes being traded on world markets.

Studies investigating the trading volumes of China and India during the last decade conclude that these two countries did not significantly impact world grain prices, since they were self-sufficient in grains and even net food exporters during the time of the price hike. This is true only of small quantities, however, since they have been trading very little for years.⁴⁶ Also Chinese meat imports did not play a major role in the grain price surge, since meat imports have been rising in 2006-2008, but only modestly, and the total Chinese meat consumption that had been rising through 2005 even dropped, with levels in 2006, 2007 and 2008 remaining below meat consumption in 2005.⁴⁷

Goods that have indeed been affected by growing demand of developing countries are soybeans, which are used in Chinese poultry production and are imported in increasing amounts⁴⁸, and, more importantly, crude oil.⁴⁹ Rising oil imports can impact upon food prices indirectly since they push oil prices and thereby food prices in the way described in chapter 3. Increased demand for soybeans

⁴⁶ cf. Abbott and de Battisti, op.cit., p.10, Abbott, Hurt and Tyner, *What's Driving Food Prices?*, p.47, Mitchell, op.cit., p.14.

⁴⁷ Abbott, Hurt and Tyner, *What's Driving Food Prices?*, pp.14f. This is partly because of blue ear disease affecting domestic pork production.

⁴⁸ Abbott and de Battisti, op.cit., p. 10, Abbott, Hurt and Tyner, *What's Driving Food Prices?*, p.47, Mitchell, op.cit., p.14.

⁴⁹ Abbott, Hurt and Tyner, *What's Driving Food Prices?*, p.5.

and crude oil are primary factors driving these prices, and they are probably permanent in nature.

2.3.7 Devaluation of the U.S. dollar

Many scholars have argued that the observed price spikes of many commodities do not look so extreme when one moves away from considering their dollar values and takes their respective values in other currencies into account. Put another way, the devaluation of the U.S. dollar contributed much to the observed price hike.

Many world benchmark commodity prices, and particularly all of the prices used in this study, are priced in U.S. dollars, but commodities are purchased by holders of different currencies⁵⁰. There are two main relations by means of which a devaluation or depreciation of the dollar contributes to a rise in dollar-denominated prices: firstly, if the currency of an importer A strengthens relative to the U.S. dollar, commodities priced in dollar will become effectively cheaper for them (prices in their now stronger currency are falling), thus creating additional demand for the commodities. As demand increases, so do the dollar prices to move towards the new equilibrium.⁵¹

Secondly, if the currency of a major competitor, like the euro, strengthens relative to the U.S. dollar, dollar-priced commodities will become relatively cheaper compared to alternative euro-priced commodities to importer A, even if they should hold dollars or a currency that did not strengthen relative to the dollar, so their demand for dollar-priced commodities will increase and that for euro-priced commodities (or commodities in any other currency that appreciated relative to the dollar) will decrease, again creating additional demand for dollar-priced commodities and thus pushing dollar prices upwards.⁵²

Until July 2007, the dollar depreciated mainly against the euro, but after that also against other important currencies. After July 2008, the dollar appreciated again against the euro and several other currencies, simultaneous with falling commodity prices.⁵³

Mitchell uses the real trade-weighted exchange rate for US bulk agricultural products provided by USDA and cites studies that have shown that dollar depreciation increases dollar-valued commodity prices with an elasticity between 0.5 and 1. He concludes that, since the real trade-weighted

⁵⁰ *ibid.* p.6.

⁵¹ OECD-FAO, *Outlook 2008-2017*, p.43, B.A. Babcock, 'Exchange Rates and Agricultural Commodity Prices', *Iowa Ag Review*, vol. 13, no. 4, 2007, retrieved 3 August 2010, CARD Iowa State University, p 11.

⁵² Babcock, *op.cit.*, p.11.

⁵³ Abbott, Hurt and Tyner, *What's driving food prices? March 2009 Update*, pp.15f.

exchange rate fell by 26% between January 2002 and June 2008, food prices would have increased by about 20% between January 2002 and June 2008 because of the decline of the dollar, with 20% being simply the mean of the elasticity range times 26%⁵⁴.

Other studies don't go as far as to estimate the quantitative impacts of the dollar devaluation on commodity prices, but stick to brief qualitative conclusions: The Outlook 2008 attests that a weak dollar leads to a rise in dollar-denominated prices, but points out that “prices of most commodities in most currencies“ in 2008 were more expensive than two years before⁵⁵. The IMF argues that macroeconomic factors including the devaluation of the dollar supported the price increase, but were not primary factors.⁵⁶ The Iowa Ag Review highlights that most of the devaluation of the dollar took place well before the sharp increase in commodity prices. This leaves two options, “Either there is a long lag in the response of U.S. prices to a change in the value of the dollar or recent commodity price increases are caused primarily by other factors.”⁵⁷

Abbott and de Battisti stress that while exchange rates directly alter price relationships, they must not be seen as real causes of high prices, but rather as symptoms of underlying economic trends.⁵⁸

2.3.8 Falling stocks-to-use ratios in the years preceding the crisis

The stocks-to-use ratio is a measure calculated for the end of a crop marketing year, indicating the percentage of next year's estimated total demand for a certain commodity that can be satisfied by carryover stocks.⁵⁹

These stocks and stocks-to-use ratios had been high for many years, but declining since 1998/99, and had reached exceptionally low levels for many commodities in 2007/08 (see Figure 2.5). According to USDA's Production, Supply and Distribution (PSD) database, since 1973/74 corn stocks had not been as low as they were in 2007/08, soybean oil stocks had not been as low since 1976/77, and, with PSD data going back to 1960/61, the low level of wheat stocks in 2007/08 was even unprecedented.⁶⁰

⁵⁴ Mitchell, op.cit., p.15.

⁵⁵ OECD-FAO, *Outlook 2008-2017*, p. 44.

⁵⁶ McCalla, op.cit., pp.24f.

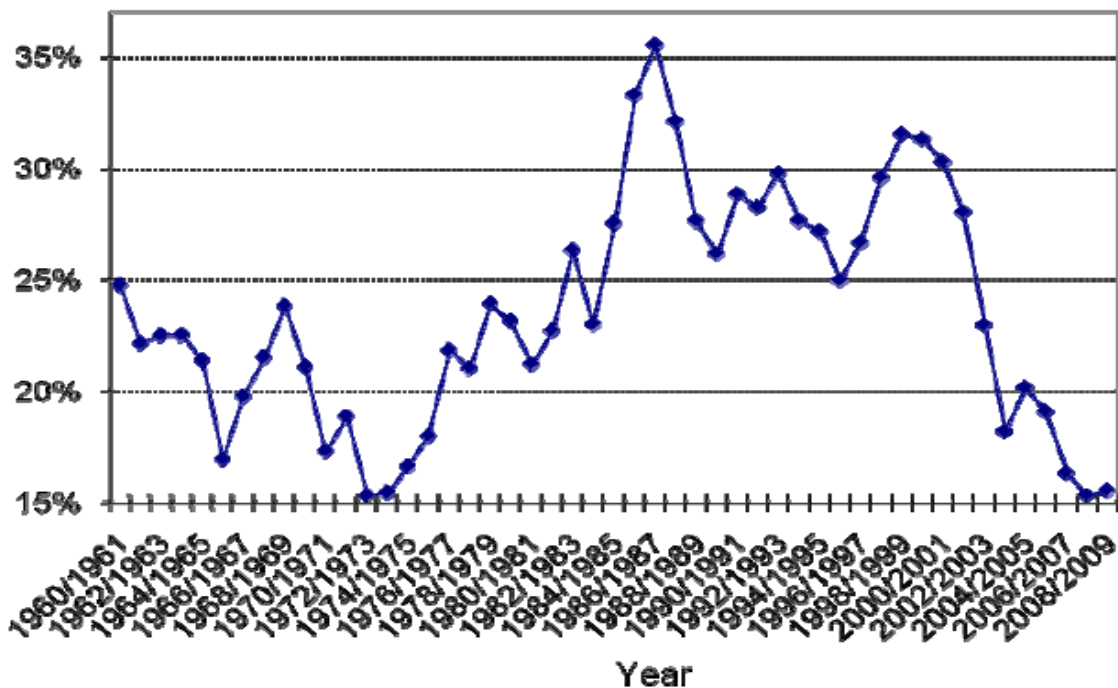
⁵⁷ Babcock, op.cit., p.11.

⁵⁸ Abbott and Battisti, op.cit., pp.11f.

⁵⁹ Womach, op.cit., p.246.

⁶⁰ PSD online, cited in Abbott, Hurt and Tyner, *What's driving food prices?*, p.11.

Figure 2.5. Stocks-to-Use Ratio for Total Grains in the World 1960-2009



Source: Abbott, Hurt and Tyner, *What's Driving Food Prices?*, p.13.

This decline in stocks is partly a result of changing agricultural policies: since yield variability could be reduced by means of new technical facilities and growing world trade facilitated sourcing commodities from other areas of the world in case there should still be a crop shortfall, holding buffer stocks did not seem that important any more.⁶¹

Still, buffer stocks help to absorb shocks on the both supply and demand side and help keep confidence in markets. When stocks are very tight, even before there is an actual shortage, market participants will anticipate it and drive up prices. A relatively small decrease in stocks, when associated with an actual shortage, can heavily impact upon prices.⁶²

Compared to historic relations in the development of stocks and prices, however, Abbott, Hurt and Tyner argue that the tight stocks alone “fail to explain” record commodity prices in 2008: they laid the foundation, but other factors contributed largely.⁶³

This view is supported by the fact that the turn in price development for many food commodities occurred in summer 2008, when USDA's World Agricultural Supply and Demand Estimates still

⁶¹ Abbott, Hurt and Tyner, *What's Driving Food Prices?*, p.10.

⁶² *ibid.*, p.11.

⁶³ *ibid.*, p.10.

forecasted that in the 2008/09 marketing year, stocks would become even tighter for corn and only increase slightly for wheat and soybeans.⁶⁴

2.3.9 Lack of investment in agriculture

During the last decade, world demand for agricultural products has grown faster than the supply of them. A lack of investment in agricultural research is seen as a major cause of this.

In developed countries, there is an extensive list of recent technological advances in agriculture, including genetic engineering, improved fertilizers and pesticides, and farm equipment. However, the rise in agricultural productivity has slowed down since 2000 in most developed and large developing or transition economies compared to the decade before – an indicator that technical progress and/or the diffusion and application of new technologies has slowed down.⁶⁵ This is understandable against the background of agricultural surpluses in the 1980s and 1990s.

In developing countries, agricultural productivity development varied by commodity.⁶⁶ Here, the lack of capital and credit accessibility is often a hindrance to investment in agriculture. This is a medium-run factor, since, even if investment in agricultural research are increased today, it will take several years until this will actually lead to yield increases. World productivity increases could be obtained relatively quickly by policy changes to permit more widespread adoption of existing technologies⁶⁷, but that of course is extremely unlikely.

2.3.10 Border measures by many countries aggravated the situation

Once markets were obviously tight and many food commodity prices very high and still rising, a number of countries adopted isolationist policies to increase supply to their domestic markets and protect their consumers from even higher prices; Mitchell names Argentina, India, Kazakhstan, Pakistan, Ukraine, Russia and Vietnam⁶⁸. These policies have limited supply to world markets and, according to many authors, contributed to the price increase. But the impact of such policies by a

⁶⁴ Abbott, Hurt and Tyner, *What's driving food prices? March 2009 Update*, p.6.

⁶⁵ OECD-FAO, *Outlook 2008-2017*, p.59.

⁶⁶ *ibid.*

⁶⁷ Abbott, Hurt and Tyner, *What's Driving Food Prices?*, p.48.

⁶⁸ Mitchell, *op.cit.*, p.13.

few countries critically depends on the thinness of the market, and the commodity most effected by export restrictions was rice (which is only traded by few countries), which is not considered in this study. Wheat prices were effected to a lesser extent.⁶⁹

2.4 Price spillover effects among food commodities

Moves in commodity prices tend to follow a common pattern. This is largely due to macroeconomic factors, such as exchange rate changes, impacting upon different commodities at the same time. But there are also price spillover effects running directly from one commodity to another, without common shocks.

For food commodities, one such effect is the possibility of substituting one commodity for another one that became too expensive. In high income countries, consumer food demand is largely inelastic to price changes, as described above, but food commodities are substituted in large quantities in animal feed depending on their price. For example, in pig breeding when using a complete protein-vitamin-mineral supplement, corn can be replaced with wheat on a one-to-one basis⁷⁰. Substitution may also occur in industrial use of food commodities, e.g. biofuels production from different feedstocks. If a commodity A which became more expensive is replaced with commodity B, additional demand for the latter will also drive up the price of B.

Secondly, allocation of agricultural land has a role in transmitting price increases: as prices of one commodity are projected to rise, farmers allocate more land to the estimated more profitable crop at the expense of other crops. As supply of the latter decreases, prices rise to balance the market.⁷¹

But even for unrelated commodities, that is commodities that traditionally exhibit cross-price elasticities close to zero, there still appears to be remarkable co-movement of prices after accounting for common macroeconomic shocks. This topic was first brought up by Pindyck and Rotemberg⁷² and became known as the excess co-movement hypothesis. Pindyck and Rotemberg

⁶⁹ For the whole paragraph, see Mitchell, op.cit., p.13, Abbott, Hurt and Tyner, *What's Driving Food Prices?*, p.5, OECD-FAO, *Outlook 2008-2017*, p.53, Abbott and Battisti, op.cit., p.10.

⁷⁰ R.O. Myer, J.H. Brendemuhl and R.D. Barnett, *Feeding Wheat to Swine*, AS25, University of Florida IFAS Extension, 2009, retrieved 10 August 2010, <http://edis.ifas.ufl.edu/pdffiles/AN/AN02700.pdf>, p3.

⁷¹ „There are links across markets that make all the agricultural prices move together, including land reallocations affecting supply, substitutions in use (e.g. feeding wheat), cost push on meat prices, and derived demand pulls on inputs from grain prices to fertilizer prices. But the timing of these interactions is not always instantaneous.“ Abbott, Hurt and Tyner, *What's driving food prices? March 2009 Update*, p.19.

⁷² R.S. Pindyck and J.J. Rotemberg, 'The excess co-movement of commodity prices', *The Economic Journal*, Vol. 100, No. 403, 1990, pp. 1173-1189, retrieved 25 August 2009, JSTOR.

found excess co-movement among the unrelated commodities wheat, cotton, copper, gold, crude oil, lumber, and cocoa. They presented the following possible explanations: co-movements might be a result of liquidity constraints of financial markets participants. A price decrease of one commodity might “impoverish” investors that are long in multiple commodity markets at once and thus lead to a subsequent price decrease in other commodity markets.⁷³ Another explanation provided by Pindyck and Rotemberg is that co-movements are results of traders betting on rising or falling prices in all commodities “for no plausible economic reason” (herding behaviour).⁷⁴ They highlight the relevance of this explanation by asserting that such co-movements are not seen as economically implausible, but, quite the contrary, taken for granted by many market participants:

“Indeed, our finding would be of little surprise to brokers, traders, and others who deal regularly in the futures and cash markets, many of whom have the common belief that commodity prices tend to move together. Analyses of futures and commodity markets issued by brokerage firms, or that appear on the financial pages of newspapers and magazines, refer to copper or oil or coffee prices rising because commodity prices in general are rising, as though increases in those prices are caused by or have the same causes as increases in wheat, cotton, and gold prices.”⁷⁵

Pindyck and Rotemberg's findings have since been debated and similar studies have tested for excess co-movement in prices, returns and volatility using different commodities, datasets and methods, some confirming, others contradicting the existence of excess co-movements⁷⁶. What can be said at least is that the hypothesis of excess co-movements in commodity prices due to market psychology could not be ultimately rejected.

To mention two contributions: A world bank study in 1991 offers an alternative explanation of excess co-movement: in their view, a reason for excess co-movement might be that traders cannot quickly distinguish macroeconomic shocks from commodity-specific supply shocks. When a number of commodities are contemporaneously affected by a common supply shock, traders may

⁷³ *ibid.*, p.1186.

⁷⁴ *ibid.*, p.1173.

⁷⁵ *ibid.*

⁷⁶ E.g. C. Ai, A. Chatrath and F. Song, 'On the comovement of commodity prices', *American Journal of Agricultural Economics*, vol. 88, no. 3, 2006, pp. 574–588, 2006, retrieved 25 August 2009, Wiley Online Library, contradict the existence of excess co-movement, F. Lescaroux, 'On the excess co-movement of commodity prices – A note about the role of fundamental factors in short-run dynamics', *Energy Policy*, vol. 37, no. 10, 2009, pp. 3906-3913, retrieved 25 August 2009, ScienceDirect finds mixed results, Y. Le Pen and B. Sévi, 'Revisiting the Excess Co-movements of Commodity Prices in a Data-Rich Environment', Memo Université de Nantes (2010), retrieved 15 September 2010, http://congres.afse.fr/docs/2010/418821excess_comovement_commodities_150410.pdf, find evidence for excess comovement in returns. See also the World Bank and IMF contributions cited in the following.

mistake it for a macroeconomic shock and change their positions in commodities unaffected by the supply shock.⁷⁷ The IMF in its Economic Outlook 2008 mentions still another theory that argues that investors who lack knowledge about specific commodities may invest in a commodity index, thus contributing to co-movement.⁷⁸

More interestingly, the IMF supports the view that financial investment is a driver of excess co-movement with a study examining commodity price returns from 1997 to 2008 for a group A of heavily traded commodities and a second group B of less traded commodities. Commodities in group A show a higher co-movement than those in group B. Furthermore, since investment in commodity markets has grown most strongly since 2003, they divided their sample in two subsamples from 1997-2002 and 2003-2008. Co-movement has increased from the former to the latter period, and increased more in group A than in group B.⁷⁹

Figures 2.6 and 2.7 illustrate the co-movements in food commodity and general commodity prices during the period of interest- clearly, these figures do not provide information about the explanatory power of possible common macroeconomic shocks. Interesting about the movements in agricultural food crop prices (Figure 2.6) is the common price spike in wheat, corn, soybeans and rice in 2007/08, with the latter commodity having the most outstanding price increase. While there are numerous links between the price of corn and that of wheat, the situation is different for these commodities on one and rice on the other side: rice is barely used as a substitute for any of the other food crops, neither in food nor in animal feed use, and there is no relevant biofuel industry using rice as a feedstock. Also, there is less land use change between areas being used for rice plantation and those used for plantation of other crops. It would therefore be understandable if rice followed a pattern more different from those of the other crops. The fear of a general food price inflation (whether economically plausible or not) very likely had it's share in convincing governments of rice exporting countries to adopt isolationist policies, that increased the rice price (see Chapter 2.3.10). Figure 2.7 shows the rise in energy prices that happened at the same time and affected food prices (confer Chapter 3). The co-movements of the Commodity Agricultural Raw Materials Index (including timber, cotton, wool, rubber and hides)⁸⁰, the more energy-dependent Commodity Food Price Index and Commodity Metals Price Index and the Commodity Fuel (energy) Index in these

⁷⁷ T.B. Palaskas and P.N. Varangis, 'Is There Excess Co-Movement of Primary Commodity Prices? A Co-integration Test', *Policy Research Working Paper*, no. WPS 758, 1991, retrieved 10 August 2010, The World Bank, p.34.

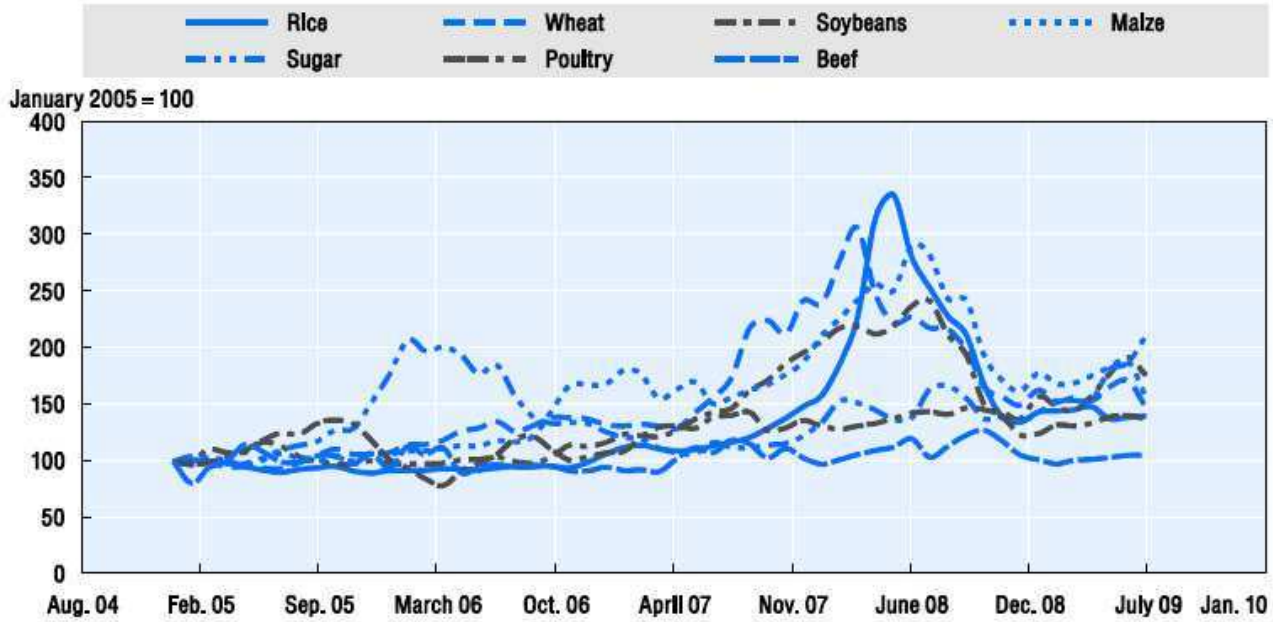
⁷⁸ IMF, Research Dept., *World Economic Outlook, October 2008: Financial Stress, Downturns, and Recoveries*, IMF, 2008, retrieved 25 August 2009, <http://www.imf.org/external/pubs/ft/weo/2008/02/pdf/text.pdf>, p.89.

⁷⁹ *ibid.*, p.92.

⁸⁰ IMF, *Indices of Primary Commodity Prices, 2000-2011*, IMF, retrieved 14 April 2011, <http://www.imf.org/external/np/res/commod/index.asp>.

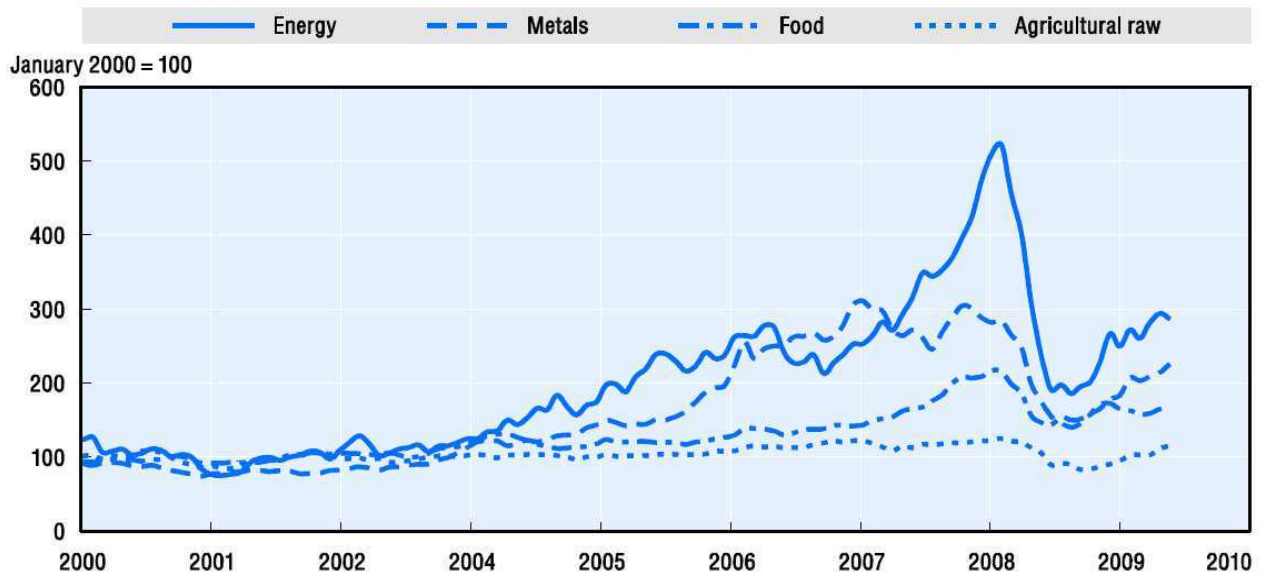
data that are not adjusted for common shocks are modest, but visible.

Figure 2.6 Co-movements of agricultural food crop prices



Source: OECD-FAO, Outlook 2010-2019, p.51.

Figure 2.7. Co-movements of commodity prices 2000-2010



Source: OECD-FAO, Outlook 2010-2019, p.50.

3. The price of oil

3.1 Some basic facts concerning oil trade and the oil price

Crude oil is the most widely traded and most liquid commodity. A variety of oil types and grades exist that vary mainly in gravity and sulphur content. Three blends however function as primary crude oil benchmarks, each representing a major drilling region: West Texas Intermediate (WTI), a light sweet crude oil traded on NYMEX for the North American region, Brent Blend for Europe and Dubai crude for the Persian Gulf; most of the other blends and grades trade on fixed price spreads above (or below) these pricing markers.

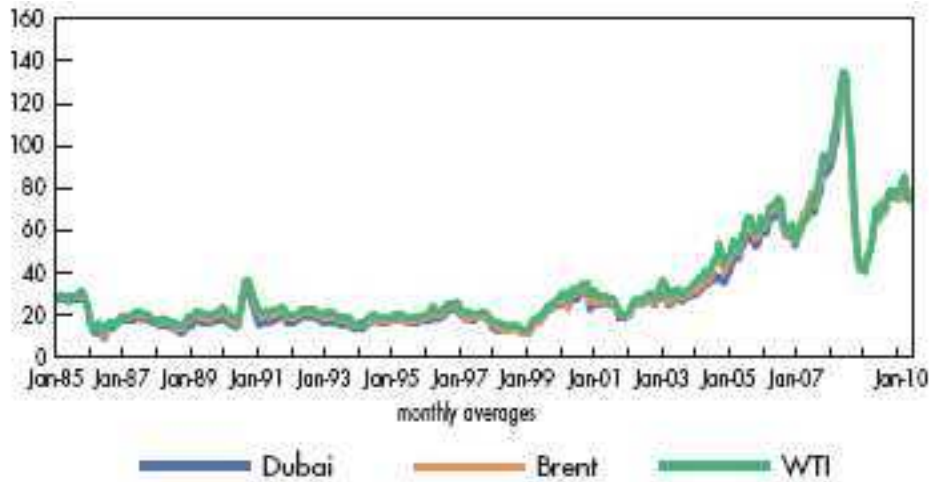
The main established stock exchanges that trade in oil are the New York Mercantile Exchange (NYMEX, trading, among others, Brent), ICE (Intercontinental Exchange) Futures in London (trading, among others, Brent) and Singapore International Monetary Exchange (SIMEX). NYMEX is the most liquid among these: in 2004, about 65% of world trade in oil futures took place at the NYMEX;⁸¹ at that time, commercial traders accounted for 10% of market agents.

The largest share of crude oil that is actually physically delivered is not traded on stock markets, but under contracts, often multi-year contracts. These contracts however are bound to market indicators like the price in the spot market or that in the futures markets. So most crude oil is bought and sold under contracts, over-the-counter, yet at prices closely bound to the spot price.

Figure 3.1 shows the spot market prices of WTI, Brent and Dubai Fateh from 1985 to 2010. Because of the difference in quality – Brent e.g. is slightly heavier and more sour than WTI – WTI trades at a higher price than Brent, and both higher than Dubai. This spread is fairly constant, but may also vary over time.

⁸¹ Mineralölwirtschaftsverband e.V., *Preisbildung am Rohölmarkt*, MWV, 2004, retrieved 1 September 2009, www.mwv.de/cms/upload/pdf/faq/preisbildung.pdf, p.37.

Figure 3.1 Key crude oil spot prices in US-Dollar/barrel



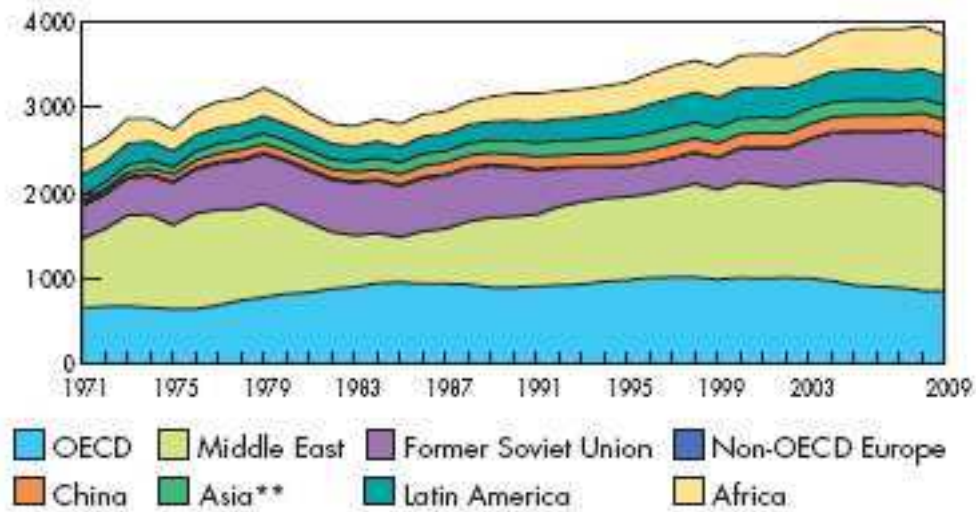
Source: IEA, *Key World Energy Statistics 2010*, IEA, 2010, retrieved 11 September 2010, http://www.iea.org/textbase/nppdf/free/2010/key_stats_2010.pdf, p.40.

The oil price is even more volatile than food commodity prices.⁸² It usually exhibits seasonality, with stronger prices in the northern hemisphere winter, since demand is greater during the heating period in the Northern Hemisphere. But these seasonal swings can combine with other influences and thus not be detectable. Like food commodity prices, the price of crude oil also depends on a number of factors on both the supply and the demand side, including total production and consumption, exchange rate changes and speculation.

Figures 3.2 and 3.3 show the development of world crude oil production and consumption since 1971.

⁸² IMF, Research Dept., *World Economic Outlook, April 2007: Spillovers and Cycles in the Global Economy*, IMF, 2006, retrieved 25 August 2009, <http://www.imf.org/external/pubs/ft/weo/2007/01/pdf/text.pdf>, p.36.

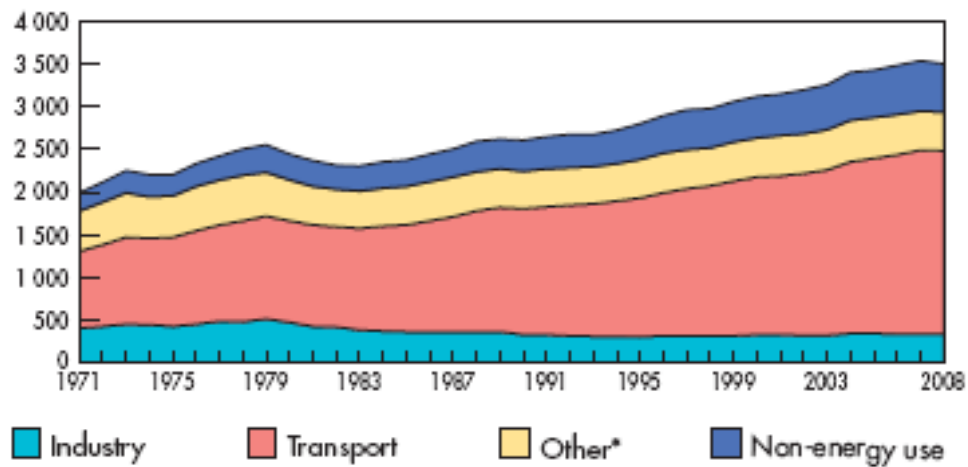
Figure 3.2 Crude Oil Production: Evolution from 1971 to 2009 by Region



Data in Mt. **Asia excludes China.

Source: IEA, op.cit., p.40.

Figure 3.3 World Total Oil Consumption: Evolution from 1971 to 2008 by Sector



Data in Million tonnes of oil equivalent. *Includes agriculture, commercial and public services, residential, and non-specified other.

Source: IEA, op.cit., p.33.

3.2 Spillover effects of a rise in the oil price

The link between the oil price and the general economy has been extensively studied in economics. Basic insights are taught in every introductory macroeconomic class and do not need to be repeated here. Therefore, it shall suffice to focus on the actual and potential impact of the oil price on the selected food commodities.

3.2.1 Effects on agricultural commodity prices

3.2.1.1 Input costs

The price of crude oil as well as other energy prices have strongly contributed to the rise in food commodity prices in 2007/08. The “conventional“ way the oil price influences agricultural commodity prices is via the pass-on of rising input costs of food production. Energy is increasingly used in many stages of the production process: production depends on fuel and fertilizers, food processing, transportation and storage (refrigeration) are energy-intensive. The link between the oil price and agricultural commodity prices has become much stronger with industrialised farming, more food processing and longer transports.⁸³ On the other hand, a rising oil price may have similar price effects in developing countries: as energy prices rise, inputs such as fertilizers may become prohibitively expensive for the poor. This results in reduced yields and rising prices.

There have been prominent oil price crises before, but few enough so that the price levels in 2008 can still be seen as exceptional circumstances. Noteworthy about the recent increase in the oil price is that a certain increase – though clearly not the 2008 peak levels – is seen by many scholars as a permanent, not temporary shift to a higher oil price level, and future increases are expected, resulting in higher average food prices in the middle and long run.⁸⁴ The OECD-FAO Agricultural Outlook 2009 projects the crude oil price in 2009-2018 on average to be 60% higher in real terms

⁸³ OECD-FAO, *Outlook 2009-2018*, p.10.

⁸⁴ OECD-FAO, *Outlook 2008-2017*, p.44.

than the average of the 10 years preceding the price spike.⁸⁵

3.2.1.2 Demand for biofuels

Input costs may be the conventional way the oil price impacts food prices, yet scholars⁸⁶ have argued that the strongest influence of oil on food prices was via creating incentives for increased production of biofuels.

During the last few years, both production and use of biofuels have increased strongly: fuel ethanol production tripled between 2000 and 2007, biodiesel production increased more than 11-fold from less than 1 billion to 11 billion litres.⁸⁷ And this ongoing increase in production continued throughout the period of observation: world ethanol production was about 66 billion litres in 2007, 77 bn litres in 2008 and 80 bn litres in 2009, the increase in world biodiesel production slowed down remarkably with about 12 billion litres in 2008, but then expanded to 19 billion litres in 2009.⁸⁸

From the early days of biofuels production to the recent past, Brazil has been the world's leading ethanol producer and exporter, producing fuel ethanol from sugar cane: Already in 2005-2007, more than half of its sugar cane crop was used for ethanol production, and this share continues to grow⁸⁹. Because of the rapid expansion of the bioethanol industry in the USA, where mainly corn is used as a feedstock, the United States are now the largest producer, while Brazil continues to be the leading ethanol exporter. Production growth in the US and Brazil account for most of the increase in world ethanol production, but more and more countries have started to produce ethanol from a variety of feedstocks or expanded their existing renewable energy programs.⁹⁰ In the EU, ethanol is mainly produced from wheat, sugar beet and coarse grains⁹¹, in Asian and African countries, also cassava

⁸⁵ OECD-FAO, *Outlook 2009-2018*, p.10.

⁸⁶ E.g. Trostle, *Global Agricultural Supply and Demand: Factors Contributing to the Recent Increase in Food Commodity Prices*, Outlook Report No. WRS-0801, USDA, 2008, retrieved 7 January 2009, <http://www.ers.usda.gov/Publications/WRS0801/WRS0801.pdf>, Abbott, Hurt and Tyner, *What's Driving Food Prices?*, p.6.

⁸⁷ OECD-FAO, *Outlook 2008-2017*, p 22

⁸⁸ All data are according to *OECD-FAO Agricultural Outlooks 2008-2017, 2009-2018 and 2010-2019* or are own calculations according to data provided in these editions of the Outlook.

⁸⁹ OECD-FAO, *Outlook 2008-2017*, p 19.

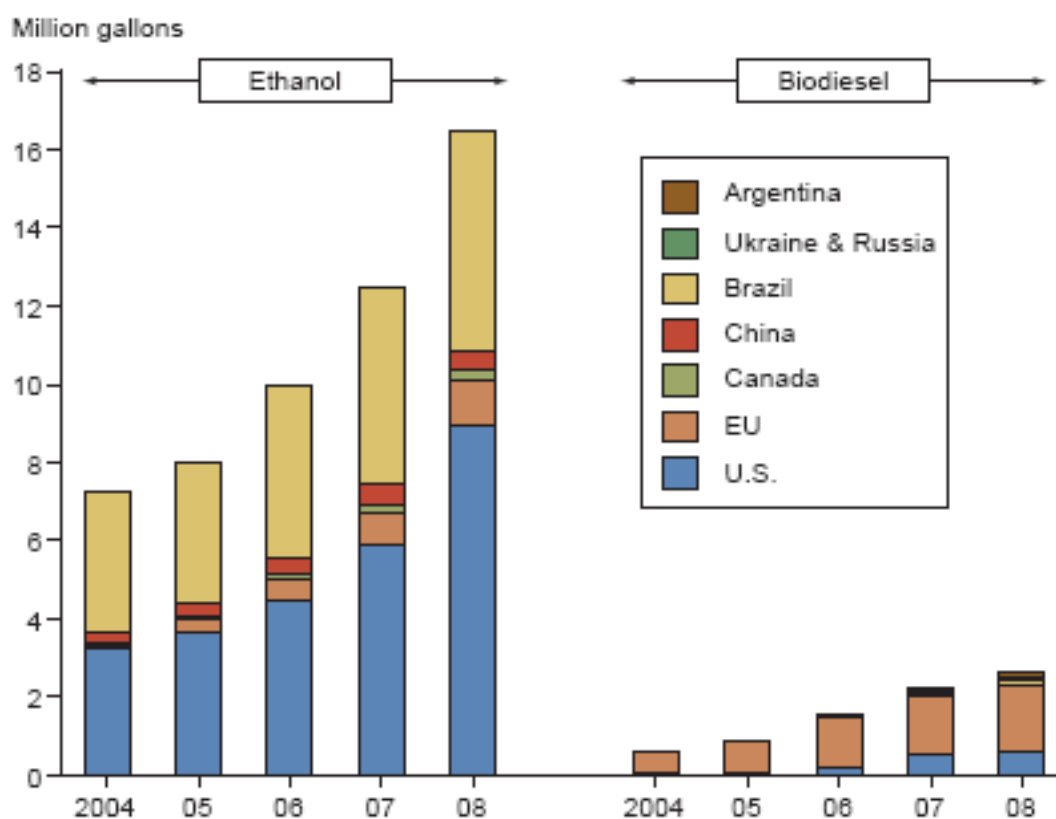
⁹⁰ OECD-FAO, *Outlook 2008-2017*, p.22.

⁹¹ OECD-FAO, *Outlook 2010-2019*, p.32.

and sorghum are used for ethanol production.

For biodiesel, the EU continues to be by far the leading producer, but many other countries have started biodiesel programs. The EU produces biodiesel mainly from rapeseed oil, in the US soybean oil is the main biodiesel feedstock. A variety of other oils like palm oil, sunflower oil and jatropha or fats are also used, but to a much lesser extent. While the US are successfully developing their biodiesel industry, production or expansion plans in many South East Asian or Sub-Saharan-African countries were heavily affected by or even abandoned because of the economic crisis, the downturn in crude oil prices and somewhat dampened euphoria about biofuels in the context of soaring food prices.⁹²

Figure 3.4 World's Largest Producers of Biofuels Expand Output



Source: R. Trostle, 'Fluctuating Food Commodity Prices. A Complex Issue With No Easy Answers', *Amber Waves*, vol. 6, no. 5, 2008, pp. 10-17, retrieved 23 July 2010, USDA.

⁹² OECD-FAO, *Outlook 2009-2018*, pp.21-23, OECD-FAO, *Outlook 2010-2019*, p.32.

To put biofuel production in the context of total demand: between 2005 and 2007, in the advent of the food price crisis, total demand for wheat and coarse grains, e.g. corn, increased by 80 Mt. Biofuels demand for these commodities increased by 47 Mt, thus more than half of that figure, the largest share of which was made up by US demand for biofuels, which rose by 41 Mt (figures are already adjusted for DDGs which are added to feed use). Other industrial use remained fairly unchanged in this period.⁹³ The situation of vegetable oil demand is similar: again, biodiesel production accounted for slightly more than half of the total demand increase between 2005 and 2007.⁹⁴

Biofuels production constituted the largest source of demand increase for these commodities. Still, it shall not be neglected that food and feed uses also accounted for almost half of the increase in grain and vegetable oil demand, and more than half of total demand increase for all agricultural products.⁹⁵

The increase in biofuels production has been driven by two factors: the high oil price and policies like mandates and subsidies. These policies in part are themselves a response to a high and rising oil price, but they may also be motivated by fundamental concerns to be less dependent on politically unstable petrol exporting countries or concerns about world oil reserves running out, and thus are not directly affected by short-run changes in the oil price. In any case, policy decisions take a long time and thus cannot adapt to short-run price changes. The relative importance of these two factors has varied over time. The development of the fuel ethanol industry has been initiated by the oil price crisis of the 1970s and has again been stimulated by the rising oil prices since 2004, but supportive policies have been critical for the development and viability of the young industry at least until 2006.

For the situation of the United States, Abbott, Hurt and Tyner conclude that the rising oil price has been an “especially important driver” of biofuels production increase from 2006 to 2008.⁹⁶ The corn price, however, followed the oil price increase. In 2008, when corn prices were very high and ethanol prices had not risen enough to offset them, ethanol plant construction plans made before were abandoned and existing capacity temporarily shut down, so that the Revised Fuels Standard became binding in late 2008.

⁹³ OECD-FAO, *Outlook 2008-2017*, p p 40.

⁹⁴ *ibid.*, p.44.

⁹⁵ OECD-FAO, *Outlook 2008-2017*, p 11.

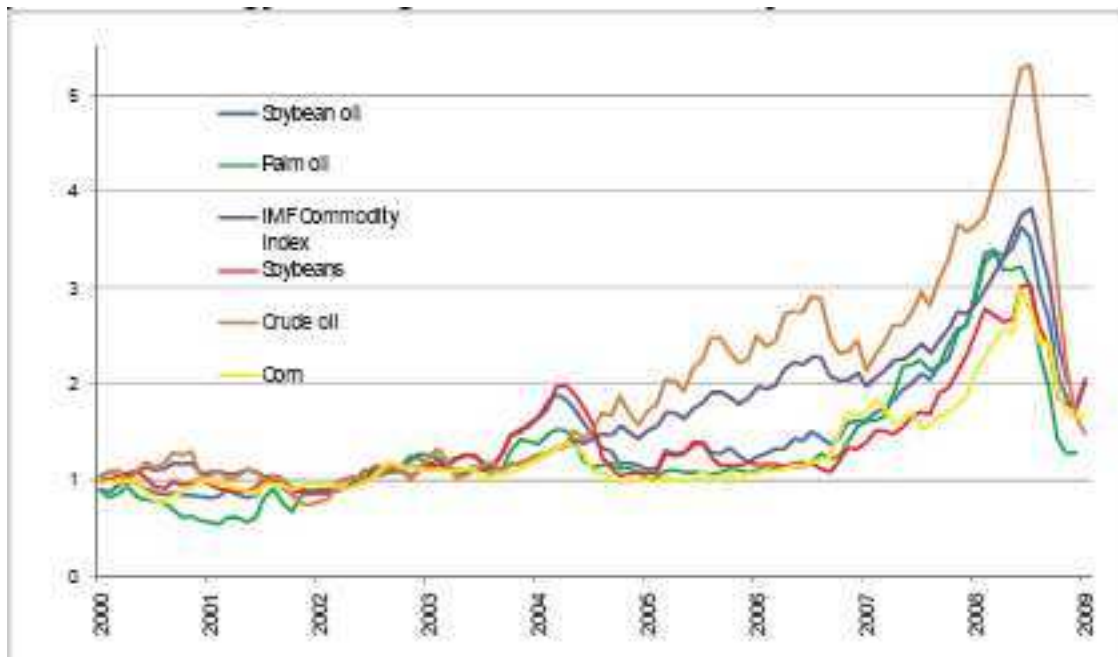
⁹⁶ Abbott, Hurt and Tyner, *What's driving food prices? March 2009 Update*, p.24.

For the case of biodiesel production in the EU, according to these authors, supportive policies remained the main driving force throughout the observation period since biodiesel is still less competitive with fossil fuels than bioethanol.

But this distinction between political support and a high crude oil price boosting biofuels production does not mean that policy changes were not connected to oil price changes: Firstly, they share a common set of causes: A high oil price is also a sign of an anticipated shortage, and the medium-term average of the oil price is generally assumed to rise steadily over the next few years because of limited crude oil reserves, that is, due to the same factors that boost policy support for ethanol production. Expectations on future oil price development drive both the actual oil price and support for biofuels production. Then, even if a high oil price would in fact not be the sign of an anticipated shortage, it will very likely be interpreted as such by policy makers, resulting in the same policy decisions. Finally, a rising oil price does raise policy support for renewable energy, although policies only adapt with a reasonable delay.

It is therefore justified to discuss increased biofuels production due to improved competitiveness of biofuels at higher crude oil prices and due to policy mandates both under the topic of a high crude oil price raising the demand for biofuels.

Figure 3.5: Energy and agricultural commodity price indices 2000-2009



Commodity prices and indices are normalized to equal 1.0, on average, for 2002.
Source: Abbott, Hurt and Tyner, *What's driving food prices? March 2009 Update*, p.24.

The current level of food commodity demand for biofuels production is a new phenomenon that will continue in the near future, more exactly, even expand according to mandatory blending, although targets are being revisited in some countries. While industrial demand for food commodities is generally rather inelastic, this is all the more true for food demand as biofuel feedstock, which is so strongly supported by policies. Markets therefore hardly adjust to price changes. Strong demand will likely continue for the next years and support food prices. In the long run, current biofuels may be replaced by new generations of biofuels or, in the very long run, made obsolete by alternative power plants.

3.2.1.3 Speculation

In Chapter 2.4 it was already mentioned that prices of unrelated commodities seemingly move together for speculative reasons or because of the magnitude of certain investment instruments like index funds. If this is true for unrelated commodities, speculative and/ or investment activity causing price spillover effects is all the more plausible and likely for economically closely related goods like crude oil and certain food commodities, where an impact of the price of the former on the latter can reasonably be expected by speculators and investors in financial markets.

3.2.1.4 Income effects

The dominant links between the oil price and food commodity prices cause food commodity prices to follow oil price movements in the same direction. But theoretically, there is also a link pushing prices in the opposite direction: when the price of crude oil rises, the individual's purchasing power is reduced. This should dampen the demand for food commodities and thus contribute to a fall in food commodity prices. However, the income elasticity of food demand is very low, and this is all the more true for individuals with high energy consumption (that is, richer individuals) and for staple foods like those investigated in this study. It is therefore reasonable to assume that income effects will barely influence food demand.

4. The data

In this study, price series of wheat, corn, sugar, soybeans and crude oil are analysed. Since one of the multiple links between the crude oil price and certain agricultural commodity prices is in the substitution of crude oil by biofuels, it shall be noted that all of the four food commodities are used for biofuel production (wheat, corn and sugar for ethanol, soybeans for biodiesel).

The study uses daily data running from March 8th, 2006 to August 27th, 2009 and provides 906 observations. This time span captures the time of the so-called food crisis, starting before the crisis broke out and ending about one year after many prices had come down again from their record highs. The use of daily data is certainly uncommon in econometrics since highly frequent data are hardly ever available for economic variables. Baffes⁹⁷ even argued that for agricultural commodities, only annual frequency was relevant since most agricultural commodities were subject to crop cycles and land allocation decisions are generally taken once a year. Yet, the interest of this study is especially in the dynamics that were at work during the short time of the food crisis. Prices, as discussed above, are influenced by a number of factors not related to production decisions that may well be reflected in daily data.

All of the prices are world benchmark prices for trading in the commodity considered: for sugar, the price of Raw Cane Sugar Nr. 11 traded at Chicago Board of Trade (CBOT) was taken, the corn price refers to Yellow Corn Nr. 2 traded at CBOT, the wheat price to Soft Red Winter Wheat Nr. 2 traded at CBOT, the soybean price to Yellow Soybeans Nr. 2 traded at CBOT, the oil price to Light Sweet Crude Oil (West Texas Intermediate) at New York Mercantile Exchange (NYMEX), both exchanges now being part of the CME group. All of the prices are free-on-board (FOB) or cost-insurance-freight (CIF) prices at various destinations. Prices are obtained from F.O.Licht database. Whenever a holiday was a non-trading day at either one of the stock exchanges, the last day's value was taken to replace the missing value, which is unproblematic since the data are closing values of each trading day and thus are a good proxy for the information available for traders trading in this specific commodity. The original pricing unit for wheat, corn and soybeans is US-cents/ bushel, with 1 bushel being equal to 56 pounds or 0,0254012 metric tons for corn and equal to 60 pounds or

⁹⁷ J. Baffes, 'Oil spills on other commodities', *Resources Policy*, vol. 32, no. 3, 2007, pp. 126–134, retrieved 9 June 2009, The World Bank eLibrary, p.128.

0,0272155 metric tons for wheat and soybeans, the price of raw cane sugar is measured in US-cents/pound and that of crude oil in USD/ barrel. For the sake of creating a graph of the nominal prices of the variables, the prices of the food commodities were converted to USD/t. The joint graph of the five nominal price series is presented in Figure 4.1. (The strengthening of the USD already discussed above will clearly be reflected in higher prices.)

Figure 4.1 The five nominal commodity price series

Data in USD/tonnes.

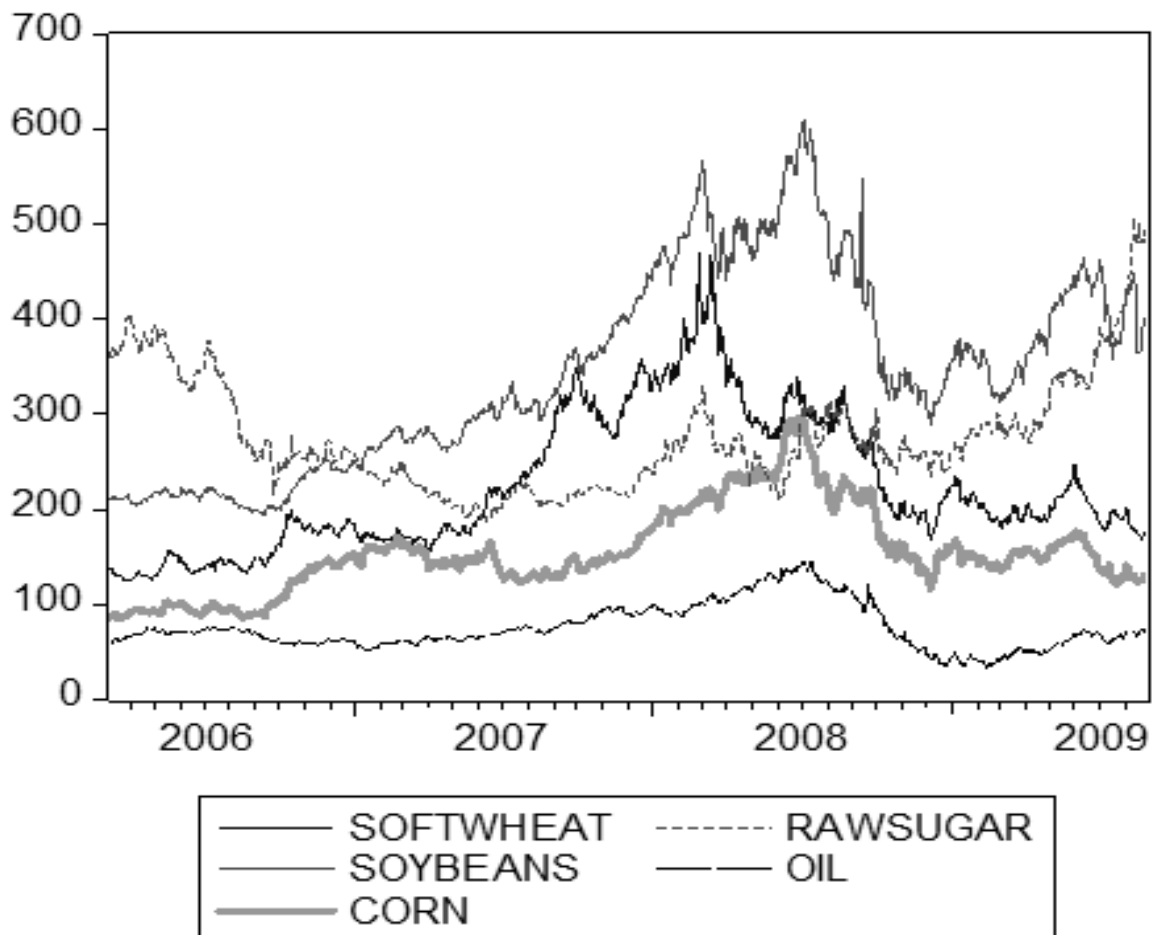
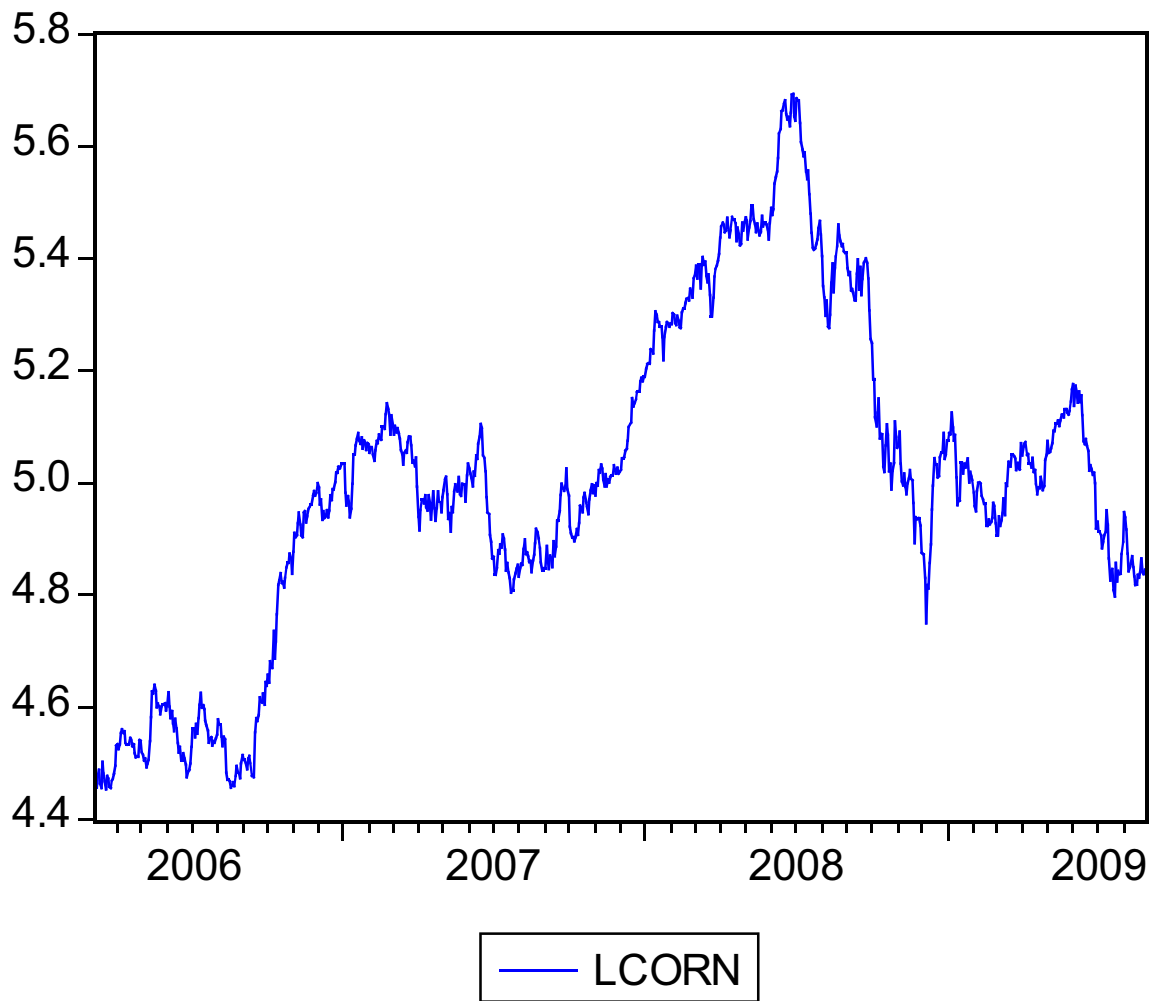


Table 4.1 presents a statistical summary of the five commodities; figures 4.2- 4.6 show the natural logarithms of the price series.

Table 4.1 Statistical summary of the data in logs

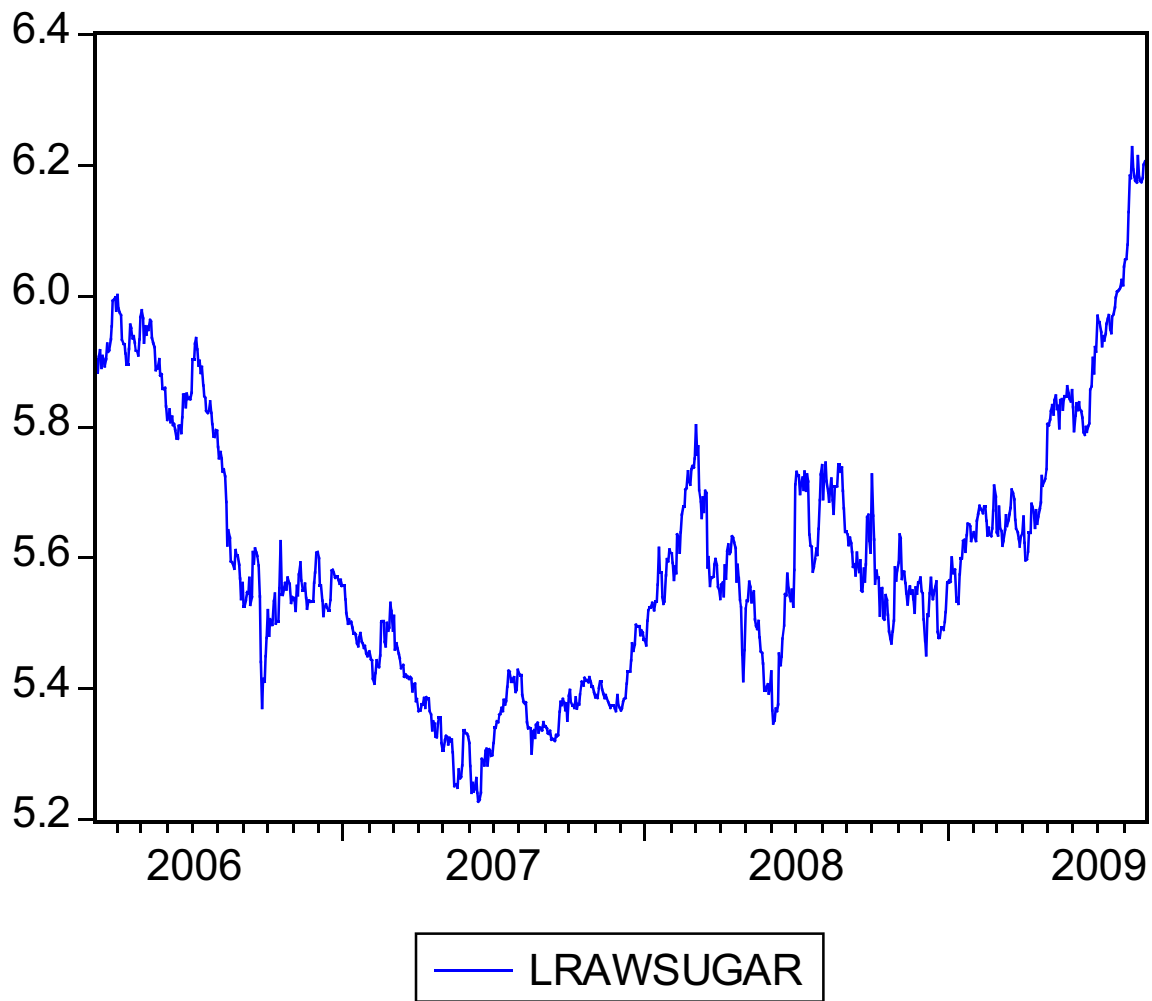
	lsoybeans	lsoftwheat	lrawsugar	loil	lcorn
Mean	5.801506	5.367972	5.598443	4.279671	5.003061
Median	5.808388	5.293140	5.565469	4.246064	5.000035
Maximum	6.412164	6.153412	6.227330	4.978732	5.694176
Minimum	5.266472	4.827007	5.227308	3.522530	4.453431
Std. Dev.	0.304207	0.309813	0.202509	0.305884	0.286092
Skewness	-0.059844	0.299476	0.632200	0.183261	0.050551
Kurtosis	1.906926	2.120459	2.937292	2.782409	2.716201
Jarque-Bera Probability	45.69530 0.000000	42.79292 0.000000	60.56637 0.000000	6.866135 0.032288	3.430091 0.179956
Sum	5261.966	4868.751	5077.788	3881.662	4537.776
Sum Sq. Dev.	83.84323	86.96170	37.15485	84.76971	74.15460
Observations	907	907	907	907	907

Figure 4.2 The Corn Price Series



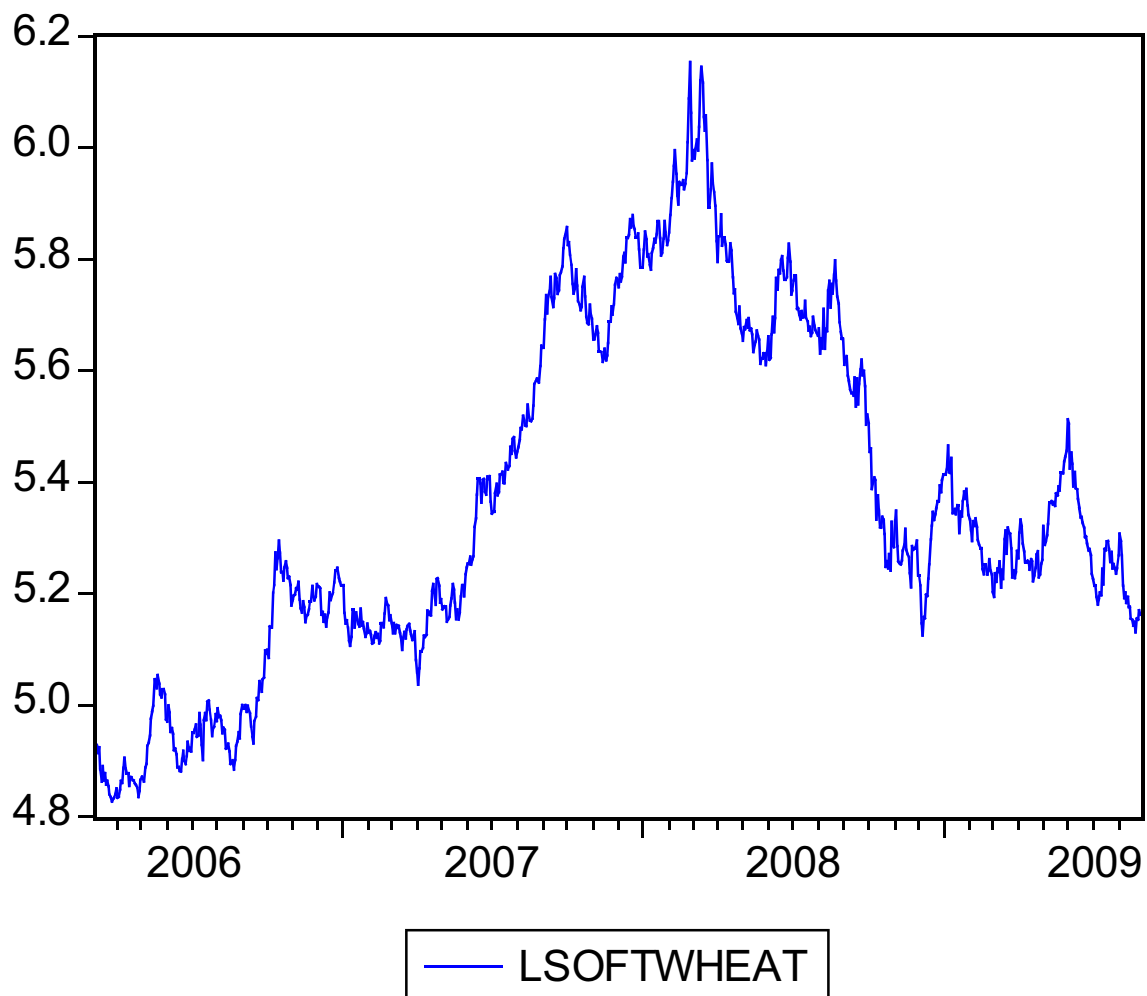
No. 2 Yellow Corn traded on CBOT. Data in logs.

Figure 4.3 The Raw Sugar Price Series



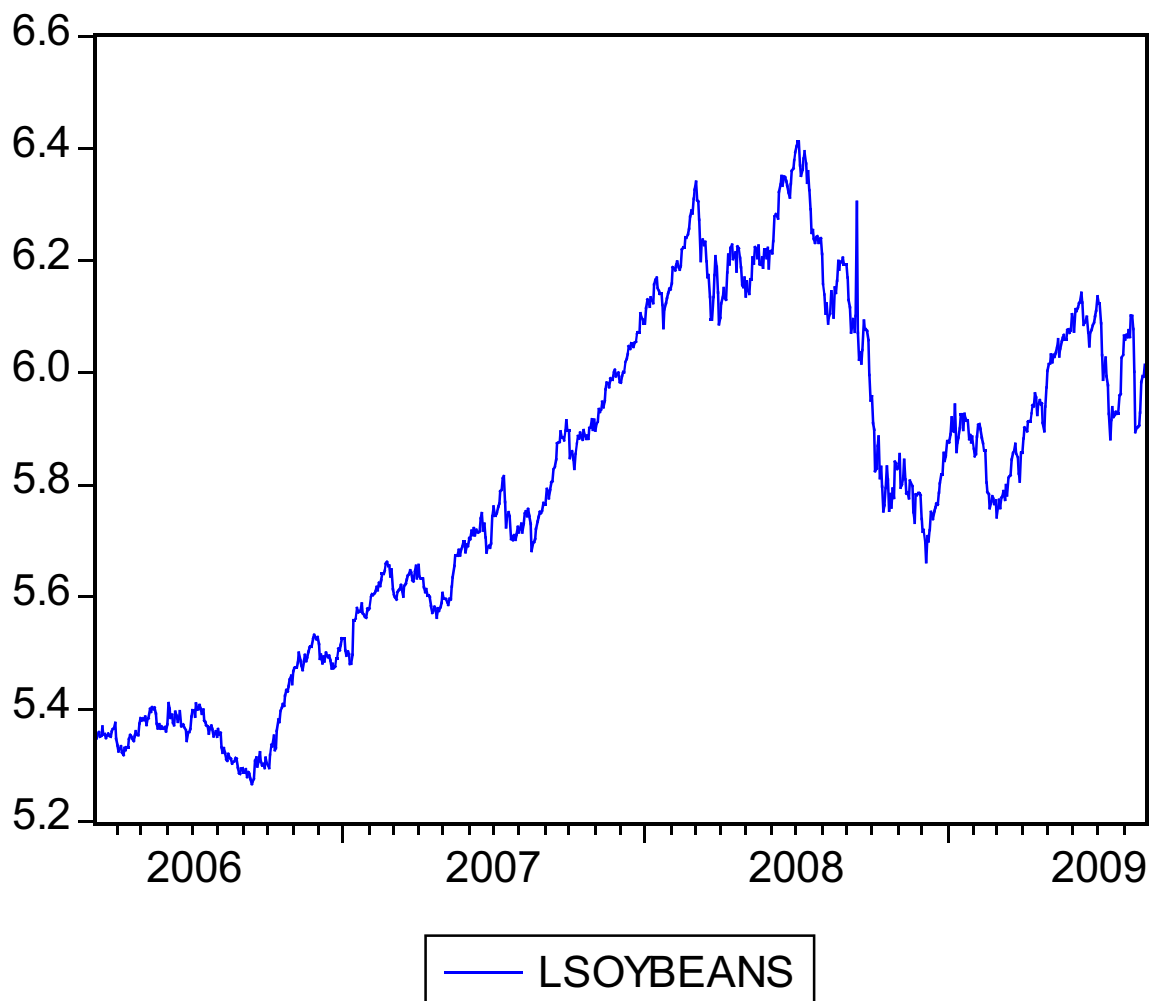
Raw Cane Sugar No. 11 traded at CBOT. Data in logs.

Figure 4.4 The Wheat Price Series



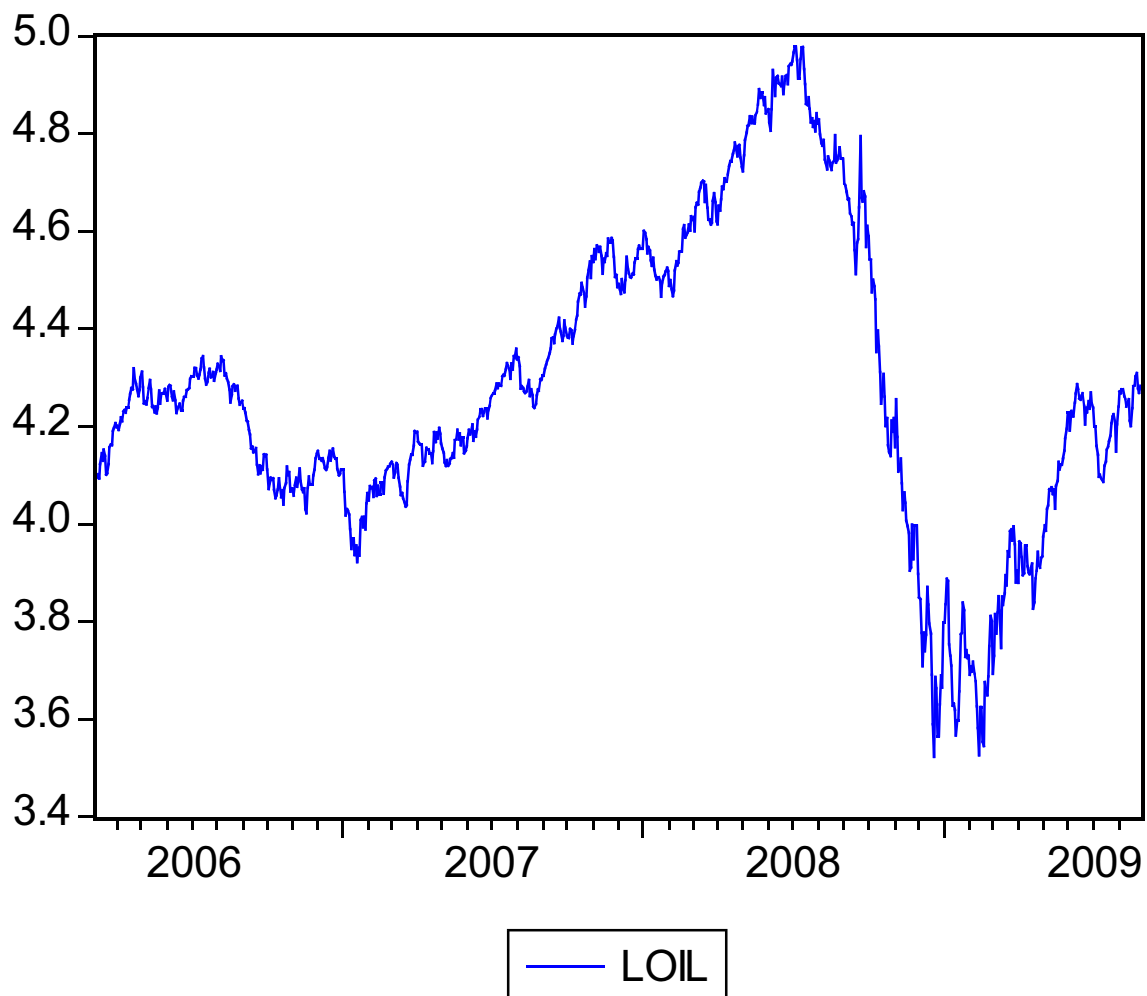
No. 2 Soft Red Winter Wheat traded at CBOT. Data in logs.

Figure 4.5 The Soybeans Price Series



No. 2 Yellow Soybeans traded at CBOT. Data in logs.

Figure 4.6 The Oil Price Series



Light Sweet Crude Oil (WTI) traded at NYMEX. Data in logs.

5. Methodology

The dynamic interrelationship among the price series described above is investigated using multivariate time series analysis. A multivariate or multiple time series is a vector of time series, where the value of every variable involved is assumed to not only depend on past realisations of this very variable, but also on past realisations of the other variables. Accordingly and in contrast to regression analysis, in a vector autoregressive model (VAR) there is not a single dependent variable estimated using a number of explanatory variables, but all the variables are equally interdependent.

Following the notation of Lütkepohl⁹⁸, let y be a discrete stochastic process, in which the same data generating law prevails in all periods T . A realisation ad infinitum of this process is called its trajectory, the finite sequence of observations of this trajectory at the observed time points $t = 1, \dots, T$ is called a time series.

Let y also denote the (multivariate) time series, and $k = 1, \dots, K$ be the number of variables observed, then y_{kt} denotes the realisation of the k^{th} variable at time $t = 1, \dots, T$ and T is equal to the sample size.

A vector autoregressive process is a special case of a discrete stochastic process that can be written as

$$y_t = v + A_1 y_{t-1} + \dots + A_p y_{t-p} + u_t \quad (1)$$

where

$y_t = (y_{1t}, \dots, y_{Kt})'$ is the K - dimensional vector of the variables at time t ,

$v_t = (v_{1t}, \dots, v_{Kt})'$ is the K - dimensional vector of the constants (intercept),

p is the lag order of past values of y that y depends on,

$A_i, i = 1, \dots, p$ are $K \times K$ - matrices of the coefficients

and $u_t = (u_{1t}, \dots, u_{Kt})'$ are a sequence of i.i.d. random K -dimensional vectors with zero mean vector.

⁹⁸ H. Lütkepohl, *New Introduction to multiple time series analysis*, corr. 2. print, Berlin et al., Springer 2007.

5.1 Cointegration and Error Correction

The concept of stationarity is well-known. When dealing with univariate time series, nonstationary or integrated time series are simply transformed into stationary time series, e.g. by taking first differences of the integrated series, but in the multivariate case taking first differences of every integrated series separately might lead to a loss of information and thus to a misspecification of the vector autoregressive model.⁹⁹

The question of interest in the multivariate case is, whether the integrated series are cointegrated. Following, with minor modifications, the definition of cointegration for the case that all variables are integrated of the same order d used in Lütkepohl¹⁰⁰, the variables in a K -dimensional process y_t are called cointegrated of order (d, b) , $y_t \sim CI(d, b)$, if all components of y_t are $I(d)$ and there exists a linear combination $z_t := \beta' y_t$ with $\beta = (\beta_1, \dots, \beta_K)' \neq 0$ such that z_t is $I(d - b)$. The vector β is then called the cointegrating vector.

In economics, most of the integrated time series are $I(1)$ variables, in which case cointegration implies that there exists a linear combination of the integrated variables which is stationary. If there is no such stationary linear combination of the integrated variables, one can just take the first differences of the series separately, as in the univariate case and then estimate a VAR- model of the variables in first differences.

For cointegrated series, Granger¹⁰¹ and Engle and Granger¹⁰² have shown that a $CI(1, 1)$ cointegrated VAR(p) can be written as a vector error correction model (VECM). Vector error correction models had been used before in economics to describe the behaviour of two or more variables which are in some kind of equilibrium relation. This equilibrium constraint may not be satisfied at a certain point in time, but every period, a certain proportion of the last period's

⁹⁹ Precisely, this will be the case if and only if the series are cointegrated. A VAR- model using the non-differenced cointegrated data would also suffer from omitted important constraints. (cf. R.F. Engle and C.W.J. Granger, 'Co-Integration and Error Correction: Representation, Estimation, and Testing', *Econometrica*, vol. 55, no. 2, 1987, pp. 251-276, retrieved 28 July 2009, JSTOR, p. 259).

¹⁰⁰ cf. Lütkepohl, op.cit., p.245f.

¹⁰¹ C.W.J. Granger, *Co-Integrated Variables and Error-Correcting Models*, unpublished UCSD Discussion Paper, 1983, 83-13, cited in Engle and Granger, op.cit., p.255.

¹⁰² Engle and Granger, op.cit.

disequilibrium is being corrected. Additionally, the variables may depend on previous changes of all the included variables, so that a vector error correction model contains both a long-run equilibrium relationship and flexible short-run dynamics. Typical examples for (suspected) error correcting behaviour are different interest rates, household income and expenditures or prices of the same commodity in different markets.¹⁰³ The observed schemes of co-movement can be interpreted as the result of optimal behaviour under incomplete information or some kind of adjustment costs.¹⁰⁴ Granger¹⁰⁵ first pointed out the link between cointegration and vector error correction, but only Engle and Granger¹⁰⁶ fully formalized the approach and provided a suitable estimation and testing technique for the existence of a cointegrating relationship. Their proposal to estimate such systems in a two-step procedure became very popular and widely used in economics.

Still, it suffers from substantial shortcomings. Most notably, the use of this technique implies that only one cointegrating relationship can be found, while there may be multiple cointegrating equations in a multivariate time series. Secondly, while cointegrated variables are in fact interdependent, a single variable has to be selected as the left-hand side variable in the regression. There is no rule to help one decide which of the variables should be used, but in finite samples the results can critically differ depending on the choice of the “explained” variable. Thirdly, since it is a two step procedure, any estimation error in the first step (the generation of the residual series) is taken to the second step (the regression estimation).¹⁰⁷

¹⁰³ cf. Engle and Granger, op.cit., p. 251.

¹⁰⁴ *ibid.*, p. 254.

¹⁰⁵ C.W.J. Granger, 'Some Properties of Time Series Data and their Use in Econometric Model Specification', *Journal of Econometrics*, vol. 16, 1981, pp.121-130, retrieved 10 August 2010, The University of North Carolina at Chapel Hill.

¹⁰⁶ Engle and Granger, op.cit.

¹⁰⁷ D. Asteriou and S.G. Hall, *Applied Econometrics. A modern approach using EViews and Microfit*, Basingstoke (et al.), Palgrave Macmillan 2007, p.317.

5.2 The Johansen approach

Johansen¹⁰⁸ and Johansen and Juselius¹⁰⁹ developed a maximum likelihood procedure for estimating and testing a cointegrating relation that does not suffer from the above mentioned shortcomings of the EG(2)-estimation (most importantly, it can find multiple cointegrating vectors) and thus became the standard estimation technique for potentially cointegrated systems.

Building on Granger's and Engle and Granger's work on the representation of VAR(p)- processes in error correction form¹¹⁰, they worked with a VEC- model in the form of

$$\Delta y_t = \Pi y_{t-1} + \Gamma_1 \Delta y_{t-1} + \dots + \Gamma_{p-1} \Delta y_{t-p+1} + u_t \quad (2)$$

where

Δ ... differencing operator, $\Delta y_t = y_t - y_{t-1}$

Π ... a $K \times K$ matrix, containing information about the (long-run) equilibrium relations

Γ_i ... coefficient matrices of the short-run dynamics

u_t ... Gaussian white noise,

which is equivalent to (1), with

$$\Pi = -IK + A_1 + \dots + A_p$$

$$\Gamma_i = -(A_{i+1} + \dots + A_p), \quad i = 1, \dots, p-1$$

The information about the equilibrium relation is contained in the matrix Π , that corresponds to Engle's and Granger's error correction representation. The rank of the matrix Π , $\text{rk}(\Pi) = r$, $0 \leq r < K$, is equal to the number of linearly independent cointegrating vectors in the system; if the

¹⁰⁸ S. Johansen, 'Statistical Analysis of Cointegration Vectors', *Journal of Economic Dynamics and Control*, vol. 12, no. 2-3, June-September 1988, pp. 231-254.

¹⁰⁹ S. Johansen and K. Juselius, 'Maximum Likelihood Estimation and Inference on Cointegration -With Application to the Demand for Money', *Oxford Bulletin of Economics and Statistics*, vol. 52, no. 2, May 1990, pp. 169-210.

¹¹⁰ The notation used in the original paper by Engle and Granger is different, but the idea is the same.

matrix Π has a certain rank r , the K -dimensional VAR(p) process given in (1) is said to be cointegrated of rank r . In the $CI(1,1)$ case, Π must have reduced rank ($r < K$), and can therefore be written as the product of two matrices, $\Pi = \alpha\beta'$, with $(K \times r)$ -matrices α and β of full rank r . The matrix β contains the cointegrating vectors and can thus be called the cointegrating matrix, it fulfils $\beta'y_t \sim I(0)$, the matrix α contains information about the reactions of the variables to deviations from the equilibrium (“adjustment coefficients“). The decomposition of the matrix Π is clearly not unique, hence the cointegrating vectors cannot be uniquely identified. What can be identified is only the cointegration space spanned by β and the adjustment space spanned by α ¹¹¹, but it is possible to obtain a unique result by imposing restrictions on α and β (e.g. restrictions motivated by economic theory).¹¹²

There are basically 2 important cases:

1. $r = 0$: There is no cointegration at all. For further analysis, one can take first differences of each variable and then estimate a VAR in first differences.
2. $0 < r < K$: There are r linearly independent cointegrating relations of the form $\beta'y_t \sim I(0)$ contained in the columns of β .

The third possible case, $r = K$, would mean that all variables in y_t are stationary. Since, in practice, unit root tests are carried out before cointegration analysis is begun and only nonstationary variables are tested for cointegration, this test result should hardly be obtained.¹¹³

As evident from the above, testing for cointegration in the Johansen framework is equal to testing for the rank of Π .

Using Johansen's multivariate estimation method, under the normality assumption and taking the rank restriction for Π into account, the vector error correction model is estimated by maximum

¹¹¹ S. Johansen, 'Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models', *Econometrica*, vol. 59, no. 6, 1991, pp. 1551-1580, retrieved 28 July 2009, JSTOR, p.1553.

¹¹² For the whole paragraph, cf. Lütkepohl, op.cit., pp.248ff.

¹¹³ If, in practice, a Johansen cointegration test on $I(1)$ variables gives the result that $r = K$, this most probably indicates low power of the test due to a too small sample size, or it indicates a specification error. (cf. Quantitative Micro Software, LLC, *EViews 5 User's Guide*, 2004, p.728.)

likelihood. The log-likelihood function for the simple case without deterministic terms (as in (2)) is given by

$$\ln l = -\frac{KT}{2} \ln 2\pi - \frac{T}{2} \ln |\Sigma_u| - \frac{1}{2} \text{tr} \left[(\Delta Y - \alpha \beta' Y_{-1} - \Gamma \Delta X)' \Sigma_u^{-1} (\Delta Y - \alpha \beta' Y_{-1} - \Gamma \Delta X) \right] \quad (3)$$

with

T ... sample size

$$\Gamma := [\Gamma_1, \dots, \Gamma_{p-1}]$$

$$\Delta X := [\Delta X_0, \dots, \Delta X_{T-1}] \quad \text{with} \quad \Delta X_{t-1} := \begin{bmatrix} \Delta y_{t-1} \\ \vdots \\ \Delta y_{t-p+1} \end{bmatrix}.$$

The log-likelihood function is maximised for

$$\beta' = \tilde{\beta}' := [v_1, \dots, v_r]' S_{11}^{-\frac{1}{2}}$$

$$\alpha = \tilde{\alpha} := \Delta Y M Y_{-1}' \tilde{\beta} (\tilde{\beta}' Y_{-1} M Y_{-1}' \tilde{\beta})^{-1} = S_{01} \tilde{\beta} (\tilde{\beta}' S_{11} \tilde{\beta})^{-1},$$

$$\Gamma = \tilde{\Gamma} := (\Delta Y - \tilde{\alpha} \tilde{\beta}' Y_{-1}) \Delta X' (\Delta X \Delta X')^{-1},$$

$$\Sigma_u = \tilde{\Sigma}_u := (\Delta Y - \tilde{\alpha} \tilde{\beta}' Y_{-1} - \tilde{\Gamma} \Delta X) (\Delta Y - \tilde{\alpha} \tilde{\beta}' Y_{-1} - \tilde{\Gamma} \Delta X)' / T,$$

where

$$M := I_T - \Delta X' (\Delta X \Delta X')^{-1} \Delta X,$$

$$R_0 := \Delta Y M,$$

$$R_1 := Y_{-1} M,$$

$$S_{ij} := R_i R_j' / T, \quad i = 0, 1$$

$$\lambda_1 \geq \dots \geq \lambda_K \quad \dots \text{ eigenvalues of } S_{11}^{-1/2} S_{10} S_{00}^{-1} S_{01} S_{11}^{-1/2},$$

v_1, \dots, v_K ... corresponding eigenvectors.

The maximum is given by

$$\max \ln l = -\frac{KT}{2} \ln 2\pi - \frac{T}{2} \left[\ln |S_{00}| + \sum_{i=1}^r \ln(1 - \lambda_i) \right] - \frac{KT}{2}.^{114} \quad (4)$$

For testing a certain cointegration rank, say r_0 , against the alternative of a larger rank r_1 , the likelihood ratio test statistic and the asymptotic distributions have to be determined.

The LR-statistic is given by

$$\begin{aligned} \lambda_{LR}(r_0, r_1) &= 2 \left[\ln l(r_1) - \ln l(r_0) \right] \\ &= T \left[-\sum_{i=1}^{r_1} \ln(1 - \lambda_i) + \sum_{i=1}^{r_0} \ln(1 - \lambda_i) \right]. \\ &= -T \sum_{i=r_0+1}^{r_1} \ln(1 - \lambda_i), \end{aligned} \quad (5)$$

the asymptotic distributions of the LR-test statistics under the null hypothesis are functions of Wiener processes¹¹⁵ that depend on the specification of the VEC-model and on the dimension of the problem $(k - r)$ ¹¹⁶. Two pairs of hypothesis have become the most popular in the literature:

$$H_0 : \text{rk}(\Pi) = r_0 \quad \text{versus} \quad H_1 : r_0 < \text{rk}(\Pi) \leq K$$

which is also known as the trace test, and

$$H_0 : \text{rk}(\Pi) = r_0 \quad \text{versus} \quad H_1 : \text{rk}(\Pi) = r_0 + 1$$

which is known as the maximum eigenvalue test.

Since critical values for the LR-tests are tabulated¹¹⁷ and included in econometric software such as EViews, testing is convenient in spite of the non-standard distributions.

¹¹⁴ Formulas are taken from Lütkepohl, op.cit., pp.294f.

¹¹⁵ *ibid.*, pp.328ff.

¹¹⁶ Johansen, op.cit., p.1555.

¹¹⁷ Distributions for $(p-r) = 1, \dots, 5$ have been tabulated in S. Johansen and K. Juselius, 'Maximum Likelihood Estimation and Inference on Cointegration - With Application to the Demand for Money', *Oxford Bulletin of Economics and Statistics*, vol. 52, no. 2, May 1990, pp. 169-210.

Testing for the cointegration rank actually includes a sequence of tests, starting with the null hypothesis of no cointegrating relation ($r = 0$), and, if that can be rejected, moving on to the null hypothesis of 1 cointegrating relation and so on, until the null hypothesis cannot be rejected for the first time.

Estimates for α and β (and the Γ_i) are estimated simultaneously with the cointegration test.

There are different possibilities of including deterministic terms such as constants, a time trend or dummy variables in the VECM. Motivations for choosing one or the other specification shall be discussed in the following chapter.

6. Empirical Analysis

The series in logarithms are tested for unit roots using Augmented Dickey- Fuller (ADF) tests.

The results of the tests on the levels and on the first differences of the five series are summarised in the following table.

Table 6.1 ADF Tests

Variables	ADF test statistic in level	ADF test statistic in first differences
corn	-1.083441	-28.73815**
wheat	-0.980453	-30.70928**
sugar	-1.098849	-29.81083**
soybeans	-1.557095	-31.17284**
oil	-1.530191	-31.57972**

Critical values: at 1% level -3.968211, at 5% level -3.414782, at 10% level -3.129555.

** denotes rejection of the null hypothesis at the 5% level.

While the tests do not reject the null hypothesis of a unit root in levels, in first differences all of the series are integrated of order one (I(1)). Given that the series are integrated, the number of cointegrating relationships among the variables has to be estimated. Prior to carrying out the Johansen cointegration test, the lagged variable terms as well as potential exogenous variables and deterministic terms to be included in the test need to be determined. Since there are strong theoretical reasons for seasonal fluctuations due to the nature of the contracts as well as to the crop cycles, eleven monthly dummies are created to capture potential seasonality. Then, a VAR of the five variables is fitted. For choosing the lag order p of the VAR, information criteria for different lag orders are compared. The LR statistic would choose a lag order of $p = 13$ out of a maximum of 22 lags included in the test¹¹⁸, while the Schwarz and Hannan-Quinn criteria would choose a lag order

¹¹⁸ The maximum of 22 lags was set according to the structure of the data, since in this data set, due to weekends and holidays that are non-trading days at either CBOT or NYMEX or both, a month on average consists of 21,75

of $p = 1$. Since Akaike is not consistent under the prevailing conditions, it is only advisable to rely on Akaike in small samples or if the objective is forecasting¹¹⁹, both of which are not the case here.

The model selection process hence is started with estimating a VAR(1) including a constant and eleven monthly dummies and checking the model adequacy. The residuals of this estimate reveal highly significant residual autocorrelations at lags 5, 6, 12, 13, 17 and 22. The Jarque-Bera statistics are also very high, clearly rejecting the null hypothesis of normality of the residuals, but this is a characteristic of daily data that will not be resolved maintaining the high frequency; nevertheless, an improvement would be preferable. Since the sample size is big enough the inclusion of lags of higher orders is not problematic per se. Still, the inclusion of all the lags might lead to an oversized model. To reduce the model size while keeping the most “informative” lagged variables, a VAR(22), VAR(17), VAR(13) and VAR(6) model were estimated, and lag exclusion tests were conducted on these models. The VAR(13) passes the lag exclusion tests, since the lags of high orders are highly significant (although the lag of 4th, 8th and 9th order are not) with a chi-squared test statistic for the joint significance of a lag of 13th order of 54,1547 (corresponding to a p-value of 0.0006). The autocorrelations and Jarque-Bera statistics also improved, so a VAR(13) is chosen as the best model.

In spite of the theoretical support, very few of the monthly dummy variables exhibit significant t-statistics, so a model without dummy variables seems to be more accurate. This decision is supported by the information criteria.

Lastly, deterministic terms such as constants and trends to be included in the model need to be specified. These deterministic terms can appear either inside or outside the cointegrating relations, that is, either in the long-run or in the short-run dynamics of the model, or in both parts of the VECM.

observations.

¹¹⁹ Cf. Lütkepohl, op.cit., pp.150f.

The most general formulation of a VECM including all of these options (without dummy variables) is given by the following equation:

$$\Delta y_t = \alpha \begin{pmatrix} \beta \\ \mu_1 \\ \delta_1 \end{pmatrix} (Z_{t-1} \quad 1 \quad t) + \Gamma_1 \Delta y_{t-1} + \dots + \Gamma_{p-1} \Delta y_{t-p+1} + \mu_2 + \delta_2 t + u_t \quad (6)$$

with

μ_i ... constant

δ_i ... trend

Johansen¹²⁰ discussed five different cases of deterministic terms in a VECM, that are also included in EViews:

1. No deterministic terms in the cointegration equation nor in the VAR: $\delta_1 = \delta_2 = \mu_1 = \mu_2 = 0$

Under this restriction, one excludes the possibility of any deterministic terms, trends as well as intercepts, in the level data and in the cointegrating equation. This is a rather unrealistic assumption and hardly ever used in practice. A number of applied econometrics books¹²¹ only mention it for the sake of completeness but conclude that the choice of the appropriate model specification is basically a choice between options 2-4. Other authors recommend to only choose this most restricted model if it is known that all series have zero mean.¹²²

2. An intercept but no trend in the CE, neither intercept nor trend in the VAR: $\delta_1 = \delta_2 = \mu_2 = 0$

This specification should be used when none of the series exhibits a linear trend. The intercept is restricted to the long-run relationship.

3. Intercepts in the CE and in the VAR, no trends: $\delta_1 = \delta_2 = 0$

This model specification allows for linear trends in the level data. Theoretically, both the long-run

¹²⁰ S. Johansen, *Likelihood-based Inference in Cointegrated Vector Auto-regressive Models*, Oxford, Oxford University Press 1995.

¹²¹ E.g. Asteriou, op.cit., pp.323f.

¹²² E.g. Quantitative Micro Software, op.cit., p.725.

and the short-run dynamics of the model are allowed to drift around an intercept. Since the intercept appears in both parts of the model, the decomposition is not uniquely identified. Asteriou notes that the intercept in the CE is assumed to be “cancelled out by the intercept in the VAR”¹²³, so that solely the latter one remains, while EViews discloses that they “identify the part inside the error correction term by regressing the cointegrating relations on a constant”.

4. Intercepts in the CE and in the VAR, (linear) trend in the CE, no trend in the VAR: $\delta_2 = 0$

In this specification, a linear trend is not only allowed for in the data, but enters also the cointegrating equation. In contrast to model specification 3, this model best fits trending series when some of the series are believed to be trend-stationary, while model 3 should be used for trending series when all trends are stochastic. The trend-stationary variable inside the cointegrating equation captures potential exogenous growth like technological progress. Additionally, intercepts are allowed for in both parts of the model.

5. Intercepts and trends in both the CE and the VAR

This unrestricted model allows for quadratic trends in the data: Since it implies the possibility of ever-increasing rates of change and often produces implausible forecasts, it is hardly used in practice. As in model specification 3, the decomposition of the deterministic parts (this time intercept and trend) to the long- and short-run part of the model is not uniquely identified.

Identifying the best model specification for a given dataset is always an uncertain task – a reason for which Agung¹²⁴ suggests that specification 3 (which is also the EViews default-option) should always be used.

In our case, specifications numbers 1 and 5 can be screened out: neither zero means for all series nor quadratic trends can be supported by the data. From economic theory, option no. 4 is also implausible, since a deterministic trend in the cointegrating equation is not likely for price series; still, it could be the case since the dataset covers only a 3 ½ years time span.

From the graphs of the series, a linear trend in some of the series, especially soybeans and corn, seems very plausible; also the first differenced series do not have zero means, but are close to that.

¹²³ Asteriou, op.cit., p.323.

¹²⁴ I G.N. Agung, *Time series data analysis using EViews*, Singapore, Wiley 2009.

Therefore, a model with intercepts (but no trends) in both the CE and the VAR-part is taken as the most plausible model, but since this specification is uncertain, a model containing only one intercept inside the cointegrating equation shall be estimated later for comparison.

Now the Johansen cointegration test can finally be performed, using 12 lagged first differenced terms, no dummy variables and allowing for intercepts (but no trends) in both the CE and the VAR-part. The results are shown in the tables below:

Table 6.2 Trace Test

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.038945	71.85063	69.81889	0.0341
At most 1	0.024720	36.33773	47.85613	0.3795
At most 2	0.007919	13.96020	29.79707	0.8429
At most 3	0.006469	6.852567	15.49471	0.5949
At most 4	0.001175	1.050693	3.841466	0.3053

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

Table 6.3 Maximum Eigenvalue Test

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.038945	35.51290	33.87687	0.0316
At most 1	0.024720	22.37753	27.58434	0.2016
At most 2	0.007919	7.107633	21.13162	0.9496
At most 3	0.006469	5.801874	14.26460	0.6388
At most 4	0.001175	1.050693	3.841466	0.3053

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

Both the trace test and the maximum eigenvalue test reject the null hypothesis of no cointegrating equation at the 5% level, but fail to reject the null hypothesis of “At most one cointegrating equation”, so there is evidence for exactly one cointegrating relationship among the five variables.

Given there is only one cointegrating vector among them, it is possible that not all variables enter the cointegrating relation. Exclusion restriction tests on every single variable in the β -vector are conducted, results of the tests are presented in Table 6.4

Table 6.4 Exclusion Restrictions on β

$$H_0 : \beta_i = 0$$

wheat	LR= 13,07256	p= 0,000300
corn	LR= 12,39711	p= 0,000430
sugar	LR= 11,64596	p= 0,000643
soybean	LR= 11,57806	p= 0,000667
oil	LR= 3,128110	p= 0,076953

The null hypothesis of $\beta_i = 0$ can be rejected for all variables at the 5% level and for all except oil also at the 10% level. Thus, the situation is not as clear for oil as for the other variables, but it is still reasonable to maintain the hypothesis of oil entering the cointegrating relation.

Next, the variables are tested for long-run weak exogeneity. A weakly exogenous variable influences other variables in the system, but is itself not influenced by shocks in the other variables. It can thus be interpreted as a driving variable, that possibly drives other variables away from adjusting to the cointegrating equation. This seems particularly plausible for crude oil, that, as discussed before, impacts food commodities through a variety of ways, but is usually not seen to be driven by price developments in agricultural commodities. Testing for weak exogeneity can be done by testing zero restrictions on the coefficients in the vector α . Results of the tests are shown in the following table:

Table 6.5 Exclusion restrictions on α

$$H_0 : \alpha_i = 0$$

wheat	LR= 8,850556	p= 0,002930
corn	LR=0,071882	p= 0,788616
sugar	LR= 5,158708	p= 0,023130
soybeans	LR= 0,447782	p= 0,503390
oil	LR= 0,001783	p= 0,966322

The results are strikingly clear: with a very low LR-statistic of 0,001783, the null hypothesis of weak exogeneity cannot be rejected for crude oil, as expected, and is not rejected for corn and soybeans either. It can, however, be rejected for wheat and sugar. For the sake of completeness, a test on the joint binding restrictions is provided in Table 6.6. For the relevant case of $r=1$, the hypothesis $\alpha_2 = \alpha_4 = \alpha_5 = 0$ is clearly not rejected.

Table 6.6 Testing $\alpha_2 = \alpha_4 = \alpha_5 = 0$

Restrictions:

$$A(2,1)=0$$

$$A(4,1)=0$$

$$A(5,1)=0$$

Tests of cointegration restrictions:

Hypothesized No. of CE(s)	Restricted Log-likelihood	LR Statistic	Degrees of Freedom	Probability
1	11019.13	0.505549	3	0.917671
2	11030.37	0.400449	2	0.818547
3	11033.97	0.313373	1	0.575618
4	11037.03	NA	NA	NA

NA indicates restriction not binding.

This cointegrating vector under the restriction $\alpha_2 = \alpha_4 = \alpha_5 = 0$ is given by

$$\hat{\beta} = (-8,675802 \quad -6,351556 \quad -7,282108 \quad 11,91425 \quad 1,699299)$$

Since the cointegrating vector is not uniquely identified, one can impose arbitrary normalizations that identify the cointegrating relation. Normalised on softwheat, the restricted cointegration coefficients (with standard errors in parentheses below the coefficients) are given by

$$\hat{\beta} = (1 \quad 0,732079 \quad 0,839368 \quad -1,373215 \quad -0,195881)$$

$$(0) \quad (0,18159) \quad (0,13051) \quad (0,16561) \quad (0,08171)$$

Adjustment to this long-run equilibrium takes place according to the adjustment coefficients given in the (restricted) α -vector (with standard errors in parentheses below the coefficients)

$$\hat{\alpha} = (-0,027317 \quad 0 \quad -0,021550 \quad 0 \quad 0)$$

$$(0,00563) \quad (0) \quad (-0,021550) \quad (0) \quad (0)$$

The VECM is estimated with the identified equilibrium relation and restrictions and the model specifications discussed above. Diagnostic tests indicate that there are only minor autocorrelations left. The residuals are not white noise, but this is a characteristic of high-frequency data, which cannot be overcome by alternative model specifications. Comparison to alternative models shows that neither a change in the lag order nor in the choice of the deterministic term would improve the non-normality of the residuals. Therefore the model specification is accepted.

The cointegrating equation, expressed in terms of softwheat, is given by

$$lsoftwheat_t = 4,924526 - 0,732079 * lcorn_t - 0,839368 * lrawsugar_t + 1,373215 * lsoybeans_t$$

$$+ 0,195881 * loil_t + u_t,$$

where u_t is the equilibrium error. Since all variables are in logarithms, the coefficients can be interpreted as elasticities. The coefficient of the oil price has a positive sign. This is in accordance with the theoretical considerations, that an increase in the price of crude oil increases food prices for

various reasons. The interpretation of the other coefficients is less intuitive, but according to the cointegrating equation, there are strong negative relationships between the prices of corn and sugar on the one hand and that of wheat on the other and a strong positive relation between the price of soybeans and that of wheat. All variables in the equation are statistically significant at the 5% level (see Table 6.7 for test statistics).

Table 6.7 Significance of the Cointegrating Coefficients

	LSOFTWHEAT	LCORN	LRAWSUGAR	LSOYBEANS	LOIL
Coefficient	1.000000	0.732079	0.839368	-1.373215	-0.195881
Standard error	(0.00000)	(0.18159)	(0.13051)	(0.16561)	(0.08171)
t-statistic		4,03000	6,43000	-8,29000	-2,40000

The coefficients of the error-correction term are negative and significant (see Table 6.8 for the t-statistics). The negative signs ensure that adjustment to the equilibrium takes place, the coefficients indicate the speed of adjustment: every day, 2,73% of the disequilibrium are being adjusted by a change in the price of wheat, and 2,16% by the adjustment of the price of raw sugar. This means that it takes 37 days for wheat and 47 days for raw sugar to adjust to the long-run equilibrium.

Table 6.8 Significance of the Error-Correction Term

	LSOFTWHEAT	LCORN	LRAWSUGAR	LSOYBEANS	LOIL
Coefficient	-0.027317	0.000000	-0.021550	0.000000	0.000000
Standard error	(0.00563)	(0.00000)	(0.00614)	(0.00000)	(0.00000)
t-statistic	[-4.85611]	[NA]	[-3.50858]	[NA]	[NA]

Information about the short-run dynamics in the system are included in the coefficient matrices of the lagged variables. Since the model is fairly large due to the inclusion of 13 lags (12 lagged first differenced terms) and 5 variables, detailed estimates are omitted here.

Noteworthy about the coefficients of the lagged first differenced terms is that they provide evidence on short-run linkages among the variables that could not be found in the long run: for example, corn has been found to be weakly exogenous in the long run; in the short run, however, it is significantly influenced by a number of lagged first differenced terms of the other variables, e.g. the 4th, 5th and 6th lag of oil. Similar results are found for soybeans and oil.

To evaluate the joint effects, Granger causality tests including twelve lags are calculated for the five

variables: the hypotheses that the growth rate of the wheat price is not Granger-caused by the lagged growth rates of the corn price and of the soybeans price could be rejected, the hypotheses that it is not Granger-caused by the growth rate of the raw sugar price or by that of the oil price could not be rejected. For corn, only the hypothesis that the growth rate of crude oil does not Granger-cause the growth rate of corn could be rejected, for raw sugar, only that of soybeans not Granger-causing it was rejected. For soybeans, none of the exclusion hypotheses could be rejected and not even that of the joint exclusion of the other four variables. For crude oil, only the hypothesis of the growth rate of soybeans not Granger-causing the growth rate of oil could be rejected.

Hence, there is empirical evidence for short-run Granger causality running from corn and soybeans to wheat, from oil to corn, from soybeans to raw sugar and from soybeans to oil. Test results are shown in the Table below.

Table 6.9 Granger Causality Tests

VEC Granger Causality/Block Exogeneity Wald Tests

Date: 09/28/10 Time: 17:41

Sample: 3/08/2006 8/27/2009

Included observations: 894

Dependent variable: D(LSOFTWHEAT)

Excluded	Chi-sq	df	Prob.
D(LCORN)	50.79982	12	0.0000
D(LRAWSUGAR)	6.011660	12	0.9155
D(LSOYBEANS)	27.36008	12	0.0069
D(LOIL)	14.86788	12	0.2487
All	85.36607	48	0.0007

Dependent variable: D(LCORN)

Excluded	Chi-sq	df	Prob.
D(LSOFTWHEAT)	14.36290	12	0.2781
D(LRAWSUGAR)	15.43993	12	0.2183
D(LSOYBEANS)	18.28358	12	0.1073
D(LOIL)	24.66740	12	0.0165
All	79.50771	48	0.0029

Dependent variable: D(LRAWSUGAR)

Excluded	Chi-sq	df	Prob.
D(LSOFTWHEAT)	17.61861	12	0.1278
D(LCORN)	13.35255	12	0.3439
D(LSOYBEANS)	29.39763	12	0.0034
D(LOIL)	15.43217	12	0.2186
All	77.23254	48	0.0047

Dependent variable: D(LSOYBEANS)

Excluded	Chi-sq	df	Prob.
D(LSOFTWHEAT)	14.46864	12	0.2718
D(LCORN)	8.965256	12	0.7059
D(LRAWSUGAR)	14.95399	12	0.2440
D(LOIL)	14.52595	12	0.2684
All	57.77657	48	0.1577

Dependent variable: D(LOIL)

Excluded	Chi-sq	df	Prob.
D(LSOFTWHEAT)	8.764581	12	0.7229
D(LCORN)	7.981006	12	0.7866
D(LRAWSUGAR)	10.24592	12	0.5944
D(LSOYBEANS)	26.77978	12	0.0083
All	66.95148	48	0.0366

To check the robustness of the results, the cointegration test was repeated restricting the intercept to the cointegrating equation and, alternatively, allowing for a linear trend in the cointegrating equation. In every case, there is evidence for one cointegrating equation. The quantitative results barely differ from those using (just) an unrestricted intercept.

7. Conclusion

In 2007/08, prices of many commodities increased dramatically. While the prices of crude oil and many metals experienced even stronger increases, food prices were the ones to attract the greatest worldwide public attention because of the direct and devastating impact of a pronounced rise in food prices on the poor.

A great deal of literature has been written on the likely factors driving food prices in general and factors particularly relevant in the recent situation. This study did not attempt to identify the factors behind the food price spike, let alone to attribute quantitative shares to them, but the aim was to provide better insight into the dynamic interrelationships between a number of food prices on the one hand and between the crude oil price and these representative food prices on the other hand to help understand how prices impact each other in the short run as well as in the long run.

If in fact commodities are close substitutes of each other, as corn and wheat in feeding purposes or as bioethanol for gasoline, their price series are likely to show substantial co-movements and will hardly diverge greatly in the long run. Econometrically speaking, one would expect to find cointegration among their price series. Of course, all the commodities considered are utilized for a large variety of end uses, and are only substitutes for one another in one or some of these end uses. Crude oil is clearly not a substitute for food commodities apart from their special use in bioethanol and biodiesel production, thus the substitutability is limited and, in this case, mainly unidirectional. The magnitude of co-movement still increases with the possibility of substitution, and the absence of a cointegrating relation would strongly speak against the perception that biofuels are effectively employed as a substitute for crude oil (this, however, does not necessarily need to be found in daily data).

Since cointegration among food commodities or between food commodity prices and the oil price has been found in a number of studies using long observation periods and low frequency data, this study concentrates on the time of the price spike in food and oil prices and investigates if an equilibrium relation among these prices can still be found even under exceptional circumstances like those of the price spike plus a short time span before and after it.

Johansen's cointegrating procedure has been used to test for cointegration among the price series

and find a potential equilibrium relation.

The main empirical findings are that there exists a long-run equilibrium relation among the daily spot prices of wheat, corn, soybeans, sugar and crude oil between March 2006 and August 2009, and that there is evidence for exactly one cointegrating vector among these variables. Although all five variables enter the cointegrating equation, not all are responding to deviations from the equilibrium in the same way: crude oil, corn and soybeans were found to be weakly exogenous, meaning that they act as price leaders, supplying new information to the system while their markets do hardly or not at all respond to perturbations in the long-run equilibrium. This was expected for the price of crude oil, that impacts food prices but is usually not thought to be influenced by changes in food prices. For corn and soybeans, this result is more surprising. One explanation for corn may be that corn functioned as a price leader among food commodities in the food price hike with a pronounced price increase in late 2006, which motivated farmers to increase corn acreage and reduce wheat and soybeans acreage, leading to reduced wheat supply and rising wheat prices.¹²⁵ As the main food commodity used for biofuels production in the US, it may also be influenced by investment or speculation in financial markets ahead in time of other food prices and to a greater extent. Adjustment to the long-run equilibrium is accordingly achieved by wheat which takes 37 days to correct deviations from the equilibrium and sugar which takes 47 days to correct deviations, so that adjustment is achieved after 47 days.

In the short run, there is evidence for additional linkages among the variables. The price of corn, weakly exogenous in the long run, was found to be Granger-caused by the price of crude oil. The wheat price in the short-run is Granger-caused by the corn and the soybeans price. Interestingly, there is also evidence for short-run Granger causality from the soybeans price on the one of crude oil. The price of soybeans, however, was not found to be Granger-caused by any of the other variables.

These insights into the long-run relationship among the five selected commodities and the dynamic adjustment to changes in this price system are interesting for considerations concerning the stabilisation of food prices. If a policy aims at preventing future major price spikes in a bundle of food prices or all food prices, it is not necessary to tackle all commodities separately. An effective management of some prices would stabilize the whole system. Among the five commodities in our

¹²⁵ Baek and Koo, op.cit., p.304.

sample, it would be advisable to concentrate efforts on stabilising the prices of crude oil, corn and soybeans. Efforts to loosen the link between crude oil and food commodities might also be of help.

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Abstract

In 2007/08, prices of many commodities increased dramatically. This study attempts to provide better insight into the dynamics between different food prices and the oil price during this period. It analyses the interrelationships between the price series of wheat, corn, sugar, soybeans and crude oil using daily data running from March 8th, 2006 to August 27th, 2009. Johansen's cointegrating procedure is used to test for cointegration among the price series and find a potential equilibrium relation. The main empirical findings are that there exists a long-run equilibrium relation among these spot prices, and that there is evidence for exactly one cointegrating vector among these variables.

Abstract

In den Jahren 2007/08 sind die Preise vieler Rohstoffe dramatisch gestiegen. Ziel dieser Studie ist es, besseren Einblick in die Dynamik zwischen verschiedenen Nahrungsmittelpreisen und dem Ölpreis während dieser Zeitspanne zu gewähren. Sie analysiert die wechselseitigen Beziehungen zwischen den Preisen von Weizen, Mais, Zucker, Sojabohnen und Rohöl unter Verwendung täglicher Daten von 8. März 2006 bis 27. August 2009. Um auf Kointegration zwischen den Preisreihen zu testen und eine potentielle Gleichgewichtsbeziehung zu finden wird Johansens Testverfahren verwendet. Das wichtigste empirische Resultat ist, dass eine langfristige Gleichgewichtsbeziehung zwischen diesen Spotpreisen existiert, und dass es Evidenz für genau einen kointegrierenden Vektor zwischen diesen Variablen gibt.

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