Commodity Price Co-Movements: Back to Normal

By

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Abstract:

We present evidence overruling the claim that commodity prices over the recent ten years have been moving increasingly and permanently more in sync in the short term. True, correlations across physically unrelated commodities increased during the commodity boom-and-bust and the financial crisis. However, even during this period short-term commodity price changes were far from uniform in terms of covariances and distributions. Applying Principal Component Analysis (PCA) to weekly price changes for 14 different commodities during the period 2007-08, the first principal factor explains less than 50 per cent of total variation and more than five factors are required in order to explain more than 80 per cent. Since 2009 the covariance structure has evolved so that the first principal factor explains far less. After 2012, no single factor explains more than 25 per cent and seven factors are needed in order to explain more than 80 per cent. This is quite similar to the results from the PCA for the period 1990-2006, suggesting that the covariance structure has reverted back to what was normal prior to 2007. The large growth in commodity futures trading and commodity investments – often referred to as commodity "financialization" - has not turned commodities into "one" asset. Prices of different commodities behave differently.

Key Words. Commodity prices; Financialization; Principal Component Analysis.

Introduction

Figure 1 visualizes the price history 1990-2015 for three major commodity classes, i.e. energy; metals and minerals, and grains as measured by the World Bank Commodity Indices[2]. After having fluctuated around a flat trend during the 1990s, energy as well as metal and mineral prices started a long period of growth in 2001-02, peaking and collapsing in July and March 2008, respectively. Some three years later than energy, in 2006, grain prices started to climb. However, the price growth for grains was more modest compared to that of energy. Like energy and metals and minerals, grain prices peaked and collapsed in 2008 immediately ahead of the financial crisis. Energy and metal prices continued falling until early 2009 when another upward trend started, reaching a new peak in the spring of 2011. Again, grains lagged somewhat behind, starting an upward trend in the summer of 2010, peaking two years later.

Thus, these quite different commody classes all experienced a boom starting between 2003 and 2006 and a common "bust" in 2008 before prices again increased strongly from early 2009 (energy; metals and minerals) and from the summer of 2010 (grains). Based on a casual

[2]World Bank commodity indices, rebased at 100 in January 1990 Energy = Coal, crude oil, natural gas. Metals and minerals = Aluminium, copper, iron ore, lead, nickel, tin, zinc. Grains = Barley, corn, rice, wheat. For details, see http://www.worldbank.org/en/research/commodity-markets

inspection of the graphs, one may easily feel tempted to draw the conclusion that there is something fundamentally new driving commodity prices after the turn of the century. It may seem as if commodities with very different fundamentals both in production and consumption during the mid-2000s started to behave as "one" commodity.

The development revitalized the 25 years old debate on non-rational, herding behavior in the commodity markets, i.e. the excess co-movement hesis (ECH) put forward by Pindyck and Rotemberg who concluded that prices of unrelated commodities were moving too much in sync even after controlling for macroeconomic factors (inflation, industrial production, interest rates, exchange rates). (Pindyck and Rotemberg 1990). Non-rational herd behavior rather than economic fundamentals was said to be driving commodity prices.

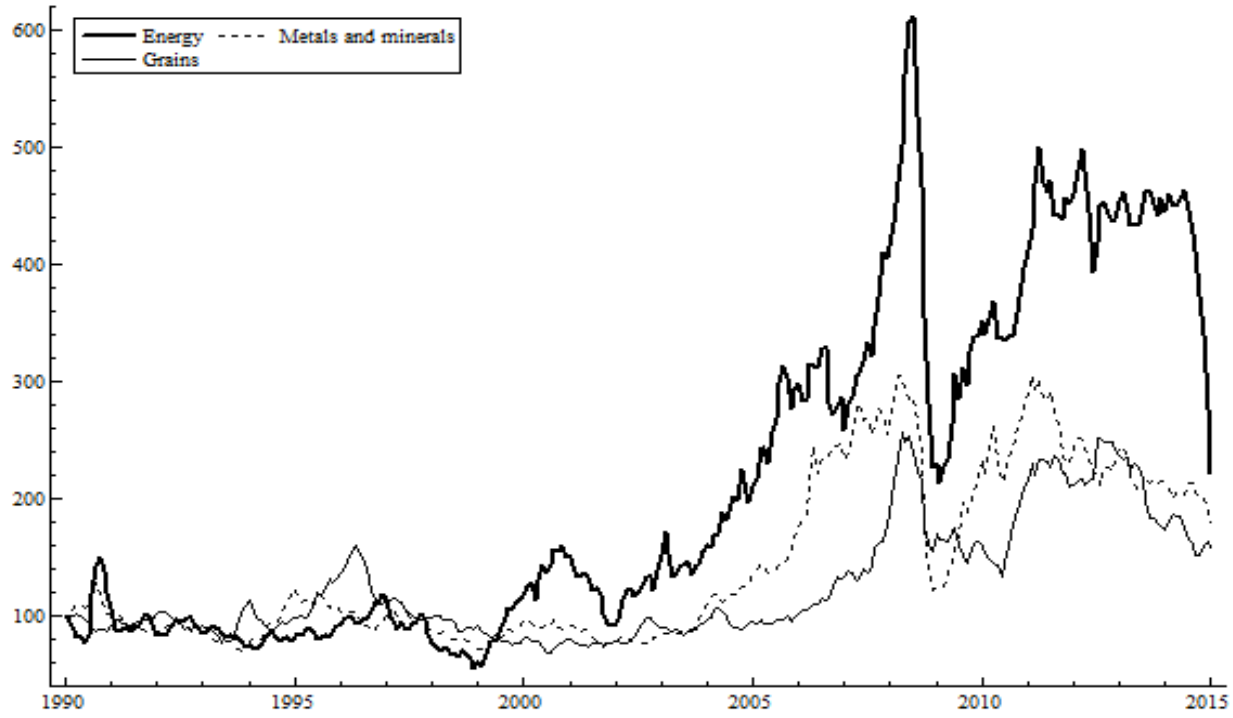


Figure 1. World Bank Indices: Energy; Metals and Minerals, and Grains, 1990-2015, monthly observations, rebased January 1990 = 100

The ECH was challenged in a number of articles published in the 1990s and early 2000s. Applying various methods on different data sets, the ECH was questioned – or at least downplayed – in studies by Palaskas and Varangis (1991), Deb, Trivedi, and Varangis (1996); and Ai, Chatrath, and Song (2006). Based on concordance measures, i.e. to what extent cycles are synchronized, McDermott, Cashin and Scott went as far as concluding that the excess comovement of unrelated commodities was a myth. (McDermott, Cashin, and Scott 1999).

At a time when the ECH seemed to have been put to rest, the dramatic commodity price movements during and after the commodity boom-and-bust 2007-08 generated a heated debate

on the possible effects from the growth in commodity futures investments among index trackers, hedge funds and various other commodity traders. A number of studies concluded in the same vein as Pindyck and Rotemberg that physically different commodities had become increasingly inter-correlated due to herding behavior. Rather than being driven by fundamentals in supply and demand, commodity prices were said to be driven by whatever factors are driving financial markets. Commodities were said to have become become "financialized".

A much cited study in the financialization literature is the one by Tang and Xiong, first published in 2010, subsequently revised in 2012. They found that concurrent with the rapid growth in index investment in commodity markets, futures prices of different commodities in the US had become increasingly correlated with each other and, in particular, with the oil price. Furthermore, they found this trend to be more pronounced for commodities included in two popular commodity indices, i.e. the GSCI and the DJ-UBS. Based on these findings, Tang and Xiong concluded that a financialization process of commodities markets was instrumental in the synchronized price boom-and-bust of a broad set of physically unrelated commodities. (Tang and Xiong (2010), (2012)). Similar conclusions have been presented by e.g. Du, Yu, and Hayes (2011), Dwyer, Gardner, and Williams (2011), Sieczka and Hołyst (2009), Silvennoinen and Thorp (2013), Bicchetti and Maystre (2012), Gilbert (2009), Delatte and Lopez (2012)).

On the other side, a number of studies have raised critical questions to the claim that commodity index trackers and other invstors in commodity futures have had such an influence on prices (see e.g. several studies by Irwin and Sanders. (Sanders and Irwin (2015), Irwin and Sanders (2012), Irwin and Sanders (2011), Sanders and Irwin (2011a), Sanders and Irwin (2011b), Sanders and Irwin (2011c) and Irwin and Sanders (2009)). Fattouh et al question the view that there is a link between increased speculation in oil futures and the price of physical oil (Fattouh, Kilian, and Mahadeva 2012). Capelle-Blancard and Coulibaly find no causality between index-based positions and commodity futures prices (Capelle-Blancard and Coulibaly 2011). Demirer et al and Steen and Gjølberg find little support for "herd behaviour" in the commodity markets (Demirer, Lee, and Lien 2013, Steen and Gjolberg 2013), and Ai et al reject the the excess-co-movement hypothesis (Ai, Chatrath, and Song 2006) while Brooks and Prokopczuk conclude that it is inappropriate to treat commodities as a single asset class, They find high correlations for pairs of commodities from the same sub-class (e.g. corn and wheat), but almost zero across sub-classes (Brooks and Prokopczuk 2013).

Outside academia, the assumed commodity financialization has triggered calls for stricter regulations. NGOs, and market skeptics worldwide called for restrictions on investments in commodity futures in general and investments in products tracking commodity indices in particular. Numerous reports, pamphlets and newspaper articles on what was called "excessive speculation" and its alleged consequences for food supply and the poor were published under headlines like "*Farming Money. How European banks and private finance profit from food speculation and land grabs*" (Friends of the Earth Europe, 2012)[3]. "*Investing not betting*" (Finance Watch, 2012)[4]; "*Feeding the financial hype. How excessive financial investments impact agricultural derivatives market*" (Vander Stichele and Van Tilburg 2011); *"Speculators*

[3] http://www.foeeurope.org/farming-money-Jan2012

[4] Available pdf for download on: http://www.finance-watch.org/our-work/publications/475

deny the rights of the hungry" (Kaboub, *Financial Times* October 25, 2010)[5]. Dominican Republic President Leonel Fernández Reyna in his keynote address to a high-level expert meeting on food price volatility organized by the FAO in Rome in July 2012 is voicing the opinion of many when stating that *"Financial speculation is exacerbating market fluctuations and this exacerbation is generating uncertainty. This uncontrolled, unregulated exacerbation is provoking a dramatic impact on countries that are net food importers. We are not talking about an abstract concept here. We are talking about something that is having a devastating, dramatic and brutal impact on the lives of people."* [6]

Just after the commodity price peak in 2008, US senators Lieberman (D), Collins (R), and Cantwell (D) proposed a "Commodity Speculation Reform Act" based on their prediction that *"Speculators are overwhelming our commodity markets and leading to substantial increases in food and energy prices for years to come"* (Lieberman, Collins, and Cantwell 2008). The call for stricter regulations on financial investments in commodities was also loud and clear in Europe. Nicolas Sarkozy, then France's president, made an international agreement on commodity market regulation one of his main objectives for Paris's G-20 presidency in 2010. The EU internal market commissioner Michael Barnier announced that he planned to use the review of *the Markets in Financial Instruments Directive* (MiFID) and *the Market Abuse Directive* (MAD) to tackle what he and other EU officials considered "*dangerous price volatility*" in the commodity markets (Financial Times, September 20, 2010) . On both sides of the Atlantic, one proposed regulatory instrument was that of introducing position limits in the futures markets in order to reduce what was considered "excessive speculation". The European Securities and Markets Authority invested considerable resources into the MidFID II regulatory document originally scheduled to be in place early 2014, later postponed to be effective as from January 2018. The new rules for the first time establish mandatory position limits and position reporting across the EU. In the US, the Commodity Futures Trading commission (CFTC) in 2011 approved rules that would impose position limits on 28 physical commodity futures, including the major agricultural, energy and metal contracts. However, the rules were vacated by court order in the Fall of 2012. The court ruling questioned whether the rules were necessary to dimish or prevent excessive speculation. The rules, re-proposed in November 2013, are still being debated. The CFTC's Energy and Environmental Markets Advisory Committee (EEMAC) has just recently (February 2016) presented a report that concludes that *"the position limits rule as proposed is unnecessary, could harm liquidity and would create numerous practical challenges*".[7]

It comes as no surprise that a number of people and businesses involved in commodity trading are skeptic to – or against - the proposed new regulations. Many investors and commodity exchanges dispute the conclusion that speculation is a main driver of volatility in the commodity markets. One opponent to the new regime is quoted ("a cure for a disease that does not exist"). The present article can be read as a contribution to the debate on the need for new regulations such as the introduction of position limits in order to reduce excessive speculation and harmful

[5] http://www.ft.com/cms/s/0/ed78484c-dfcb-11df-bed9-00144feabdc0.html#axzz4A8RsgvDW
[6] http://www.unmultimedia.org/radio/english/2012/07/fao-holds-expert-meeting-on-food-price-volatility/

[7] http://www.marketsreformwiki.com/mktreformwiki/index.php/Position_Limits_Regulation_-_Report_-_EEMAC%E2%80%99s_2015_Review_and_Consideration_of_the_CFTC_%E2%80%99s_Proposed_Rule_on_Position_Limits,_February_2016

price volatility by presenting new empirical evidence on commodity price volatility and comovements, including data for the years after the boom-and-bust. Our point of departure is simple. We believe that if one shall introduce a number of potentially costly regulations, this should be based on strong evidence suggesting that markets really are unusually volatile compared to what was the situation before index trackers and futures trading boomed. There is no doubt that commodity prices became very volatile during the time just before and through the financial crises, and that comovements across commodities and between commodities and financial assets increased through this period. Now, some eight years after the debate on excessive speculation took off, there is a large body of empirical evidence which can enable us to conclude whether high risk and high covariances have become a persistent feature of the commodity markets. Specifically, we analyze whether there has been a structural and permanent change in commodity price volatility and comomevents since the mid 2000s.

The paper is organized as follows. In the next section we outline how data for the analysis has been extracted, and our methodological approach. We then present some stylized facts on commodity price changes, volatility, distributions and correlations before we report the results from a series of Principal Component Analyses (PCAs) that describe the evolution of the commodity market covariance structure. We sum up our main findings and draw our conclusion in the final section.

Data and methodological issues

We analyze weekly price movements for 14 major commodities January 1990 – March 2015 in four broad commodity classes; agricultural, softs, metals, and energy (see the appendix for commodity descriptions and data sources). Like several other studies on commodity price co-movements we use continuous futures prices which involves some statistical issues related to the splicing of subsequent contracts. The "roll" often generates a jump or a discontinuity in the series. At times, these jumps may be large. This is specifically the case for commodities with seasonal production or consumption patterns. The first contract of the new marketing season may be priced quite differently from the contract terminating the carry and trade of last year's production. If different commodity contracts are rolled within the same month, the price jumps may in general generate noise when calculating correlations. If the jumps tend to be in the same direction across different commodities, this may generate artificially high correlations that may last for as long as the jumps are within the sample used for calculating the correlations. To avoid spurious correlations, one should take out the roll effect in the series, which may be done in different ways. In this study, price adjustments are made using a calendar weighted method. The price gap between consecutive contracts is smoothed by following a weighted-average process. The continuous contract gradually shifts from representing 100% front and 0% back weighting, to 0% front and 100% back weighting, over a period of 5 days. This price adjustment corresponds to a mechanical roll strategy wherein the trader rolls 20% of the position every day, for 4 days before the roll date.[8]

[8] The adjusted time series were extracted from the Quandl database, using the "Stevens Continuous Futures" series See https://www.quandl.com/data/SCF/documentation/about

Another statistical issue is related to observation frequency. Many studies on commodity price co-movements are presenting results based on monthly (and even quarterly) observations. Such low observation frequencies smooth out short term variations and makes it difficult to distinguish between common trends driven by common fundamentals and short term price movements driven by more or less erratic investors. We argue that in order to reach conclusions on herd behavior and financialization, one should use higher frequencies than monthly and quarterly observations. In the present study, we analyze weekly prices and price changes. In that way, herd behavior is more easily revealed in the way that herding should imply lead-lag effects from e.g. oil to physically unrelated commodities.

Many studies on commodity prices draw conclusions based on trends in bi-variate and often unconditional correlations. One problem with this approach is related to the fact that a shock within the sample window that influences two or more commodities may generate high correlations long after the shock occurred, the so-called "ghost feature". ((Alexander 2009). The dramatic price changes across the entire commodity market during a few months 2007-08, regardless of what factors drove these changes, will inflate correlations for as long as these months are included in the sample. Conclusions regarding excessive co-movements and financialization of commodities based on correlations through and just after the food and financial crises may change once the ghost effect disappears. Some six years after the commodity boom-and-bust, we are on firmer ground as to decide whether there has been a permanent change in the commodity correlations.

Furthermore, in order to draw a more complete picture of the commodity co-movements bi-variate correlations should be supplemented with analyses that provide evidence on the covariance structure for the entire market. In the present study we apply *Principal Component Analysis* (PCA) in order to to reduce the dimensionality to a few uncorrelated dimensions and in that way reveal patterns in the data that may otherwise be hard to find. PCA extracts from the variance-covariance (or the correlation) matrix a number of independent linear combinations or factors, and identifies and ranks the linear combinations and their contribution to total variability. Each linear combination is a "principal component" and is identified by the strength of the covariance between its constituents. The principal components or factors (F) are extracted in decreasing order of importance so that the first factor accounts for as much of the variation as possible in the original data set, the second factor the maximum additional variation, and so on. Having extracted the factors, these components can be interpreted in terms of the original variables and thereby generate a better understanding of the totality of the variations in the observed data. Using the covariance matrix as input into the PCA, the results are influenced by the relative volatilites as well as the correlations of the price changes.

When analyzing a market with large variations and differences in variances across commodities, the co-variance matrix is the preferred basis for conducting the PCA. The results from the PCA contain information on relationships beyond that obtained from the bi-variate correlations by presenting a comprehensive and compact picture of the total covariance structure. By running PCAs for different periods, one may detect whether and to what extent changes have taken place in the covariance structure. In our PCAs, we have first analyzed four different sub-samples from the years between 1990 and 2015. The first sub-sample is January 1990- December 2006, the second is the boom-and-bust period, January 2007-December 2008, the third sub-sample covers the years right after the bust, January 2009-December 2011, while the fourth sub-sample covers the period January 2012 –March 2015, after the main dust from the boom-and-bust had settled. In

addition, we have run a large number of rolling PCAs in order to reveal gradual changes in the principal components and in that way obtain evidence as to whether commodities increasingly have been clustering on one (or a few) common factor(s)

Commodity prices 1990-2015: Basic statistics

Before presenting the results from our PCA analyses, we start out by outlining stylized facts as regards short term commodity price movements 1990-2015 in terms of means, standard deviations, higher moments and correlations. In order to find whether there has been a general drift towards "one" commodity market during these 25 years, we have split the sample in four sub-periods, the first covering the years up till 2006, the second the boom-and-bust, the third after two subsequent years, and the fourth the most recent period 2012-15.

Means and standard deviations

Table 1 reports the annualized means and standard deviations of weekly price changes (log returns) in the four sub-periods. Focusing on the claim that commodities have increasingly become more similar with one another and in particular with oil, the evidence provided by the means and standard deviations is mixed. Standard deviations for almost all the commodities increased considerably in 2007-09 compared to 1990-2006. Coffee is the only exception. Thus, as far as volatility is concerned, commodities clearly behaved more like one 2007-08. During the two subsequent sub-periods volatility decreased for all, although at a different pace. During the lates sub-period the volatility picture is more or less similar to that before 2007. The development is depicted in figure 2, showing the standard deviations for corn and crude oil through a 104 weeks rolling window 1990-2015.

Table 1. Annualized means and standard deviations

		(01)1990-(52)2006		(01)2007-(52)2008		(01)2009-(52)2011		(01)2012-(03)2015	
Group	Commodity	Mean	St.dev.	Mean	St.dev.	Mean	St.dev.	Mean	St.dev.
Grains	Corn	0,03	0,23	0,03	0,44	0,14	0,35	-0,15	0,26
	Soybeans	0,01	0,22	0,16	0,35	0,07	0,26	-0,06	0,24
	Wheat	0,01	0,25	0,09	0,42	0,01	0,37	-0,06	0,28
Softs	Sugar	-0,01	0,33	-0,03	0,40	0,25	0,42	-0,19	0,25
	Coffee	0,03	0,40	-0,08	0,29	0,24	0,28	-0,14	0,34
	Cocoa	0,03	0,31	0,24	0,38	-0,06	0,32	0,07	0,25
	Cotton	-0,01	0,27	-0,10	0,31	0,21	0,42	-0,10	0,26
Metals	Copper	0,06	0,23	-0,40	0,43	0,33	0,33	-0,09	0,17
	Gold	0,03	0,14	0,16	0,26	0,20	0,19	-0,10	0,16
	Silver	0,05	0,25	-0,10	0,42	0,34	0,43	-0,19	0,26
	Palladium	0,05	0,31	-0,33	0,43	0,44	0,38	0,04	0,22
	Platinum	0,05	0,19	-0,12	0,34	0,16	0,24	-0,08	0,18
Energy	Crude oil	0,06	0,36	-0,24	0,49	0,32	0,40	-0,24	0,24
	Heating oil	0,05	0,22	-0,14	0,33	0,18	0,35	-0,10	0,26

Figure 2 visualizes price volatility as measured by the (annualized) standard deviation for weekly price changes corn and crude oil. Graphs for the other 12 commodities (not presented) paint a very similar picture. For both, price volatility remained relatively stable up till 2006. Crude being normally the more volatile. While the corn price volatility increased gradually from around 2005 from around 25 per cent to 43 per cent end of 2008, the increase did not by far match that of oil. After a downward trend around 2005, oil price volatility surged to some 60 per cent 2009-10. Although commodities in general became more volatile after 2005, there is no strong support for the hypothesis that commodities became more similar in terms of riskiness. Even during the boom-and-bust period, there are clear differences in standard deviations across commodities.

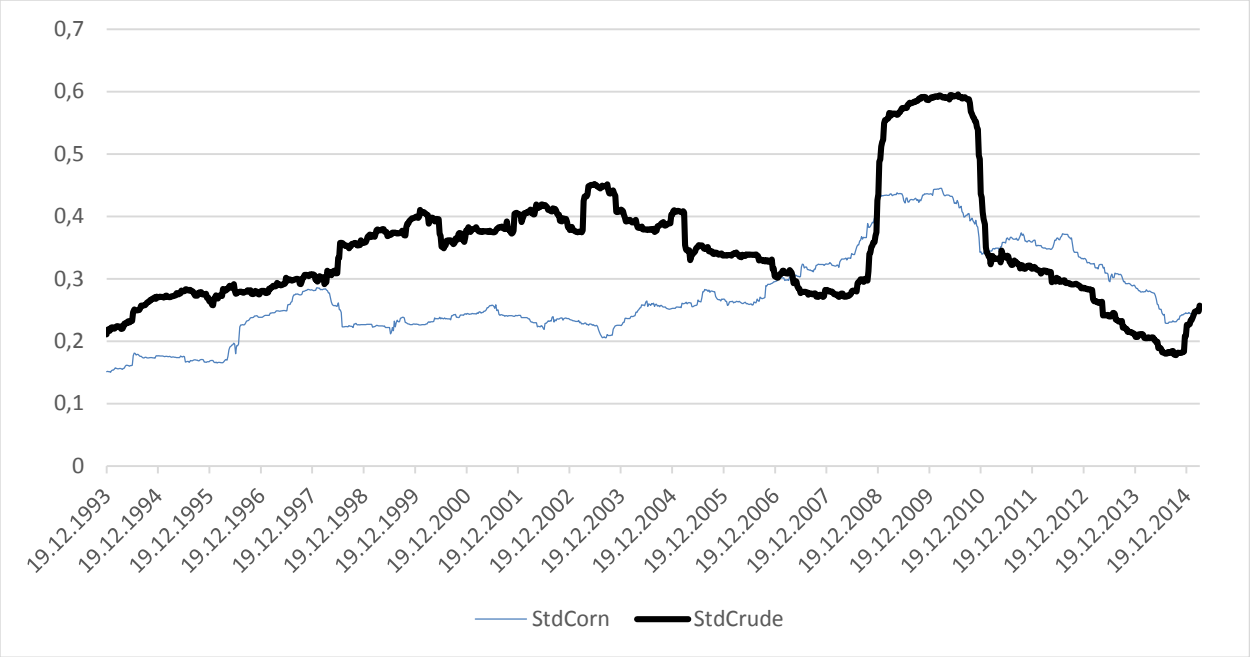


Figure 2. Standard deviations (annualized) 104 weeks rolling, crude oil and corn

Higher moments

Table 2 exhibits skewness and (excess) kurtosis for the same commodities and sub-periods as above. Again, we focus on the claim that commodities grew increasingly more similar in terms of short-term price changes due to "financialization" and excessive speculation. In terms of skewness, all but one (sugar) come out as negatively skewed 2007-09. This is also the case for the period 2009-11, now with wheat as the one exception. In the most recent period, the skew commodities became more similar in the way that between 2007 and 2011, the typical distribution was one with a negative skewness for most commodities.

As regards kurtosis, there have been differences across commodities in all periods, including 2007-08 when crude oil and to some extent copper stand out as different from the other commodities.

Table 2. Skewness and excess kurtosis, weekly commodity returns 1990-2015

		(01)1990-(52)2006		(01)2007-(52)2008		(01)2009-(52)2011		(01)2012-(03)2015	
Group	Commodity	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
Grains	Corn	0,18	1,95	-0,44	1,02	-0,30	0,14	-0,28	1,88
	Soybeans	-0,27	2,66	-1,03	1,31	-0,48	1,29	-0,73	1,69
	Wheat	0,18	1,61	-0,31	0,74	0,12	0,19	0,54	1,43
Softs	Sugar	-0,40	2,82	0,41	1,37	-0,35	0,21	0,88	1,47
	Coffee	0,87	6,11	-0,68	1,61	-0,19	0,20	0,49	1,39
	Cocoa	0,36	1,96	-1,07	2,99	-0,18	-0,70	0,42	0,71
	Cotton	-0,75	9,43	-0,42	1,54	-1,09	5,45	-0,37	0,53
Metals	Copper	-0,22	0,96	-1,47	3,83	-0,23	1,33	0,08	0,14
	Gold	0,14	3,99	-0,38	1,12	-0,44	1,33	-0,38	0,53
	Silver	-0,45	3,11	-1,06	1,85	-1,94	9,05	0,13	1,83
	Palladium	0,17	4,51	-0,69	1,44	-0,59	0,72	-0,12	-0,09
	Platinum	-0,05	2,40	-0,95	1,17	-0,70	1,87	0,39	0,20
Energy	Crude oil	-0,74	4,64	-1,88	5,82	0,34	2,85	-0,92	2,61
	Heating oil	-0,29	4,58	-1,02	2,21	-0,37	0,77	-1,12	5,88

Part of the financialization debate has been related to erratic market behavior. In efficient markets, prices react to relevant new information. Inefficient markets driven by non-rational investors react to irrelevant news, e.g. news that "everyone" says that the price has to go up (or down). Assuming that relevant major price driving news arrive stochastically and that what is relevant price driving news differ across commodities, dramatic price changes should occur in no particular time pattern. If commodity prices, on the other hand, have become increasingly driven by irrational herders during the last decade, one would expect to see much more frequent dramatic price changes occurring simultaneously. Defining a weekly price change of more than 10 per cent as a dramatic event, figure 3 displays the distribution over time for such events for four physically and otherwise unrelated commodities (corn, coffee, copper, crude oil). A visual inspection of the graphs tells us that, for one, dramatic price changes have occurred throughout the period being analyzed. There were several dramatic weeks for all the four commodities during the late 1990s. All four markets also experienced dramatic weeks in 2008 when prices fell by 10 to 30%. Beyond this, it is hard to see any specific pattern in the occurrence of extremes across the four commodities over the last decade compared to earlier experience.

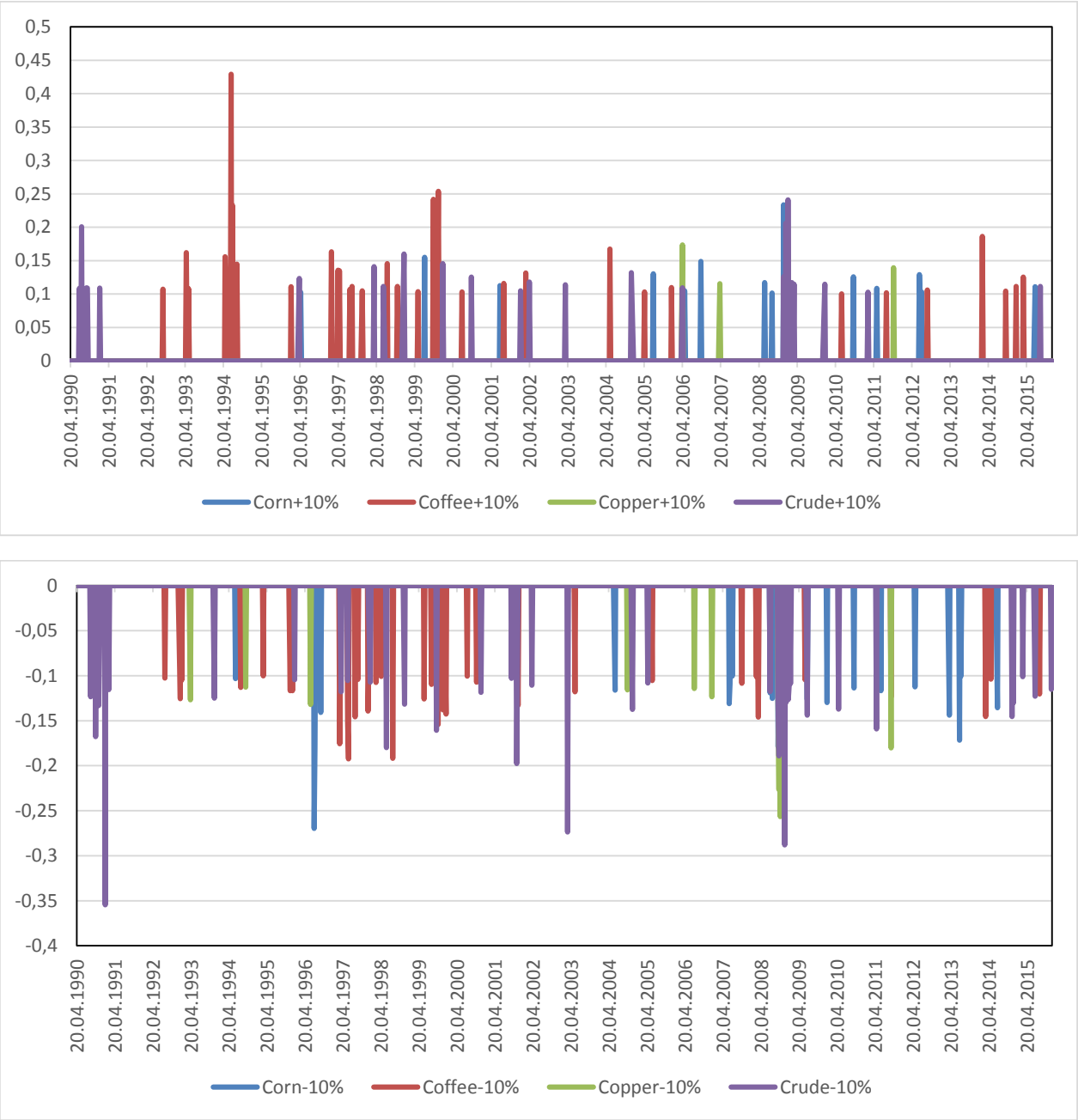


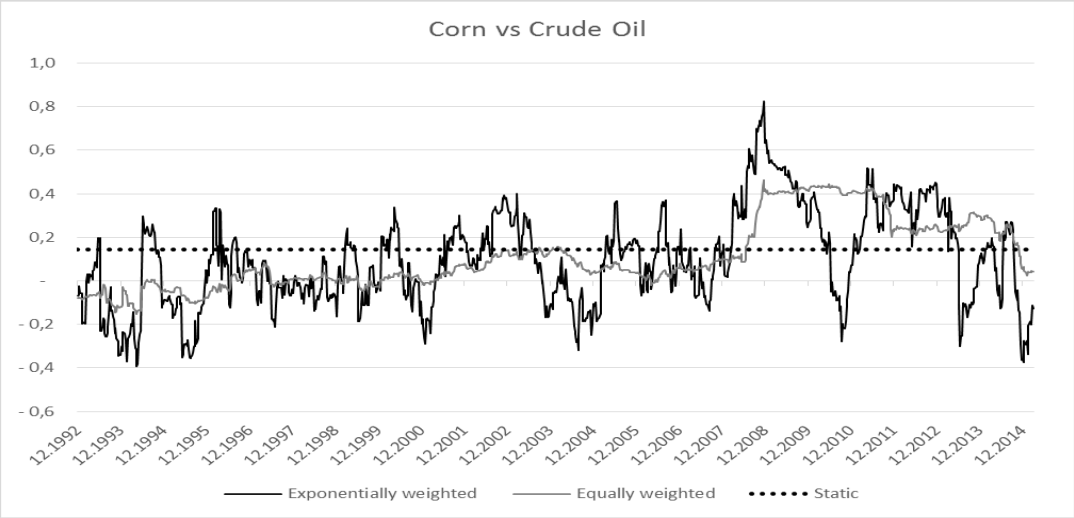
Figure 3. Time distributions of +10 per cent (top) and -10 per cent (bottom) weekly price changes

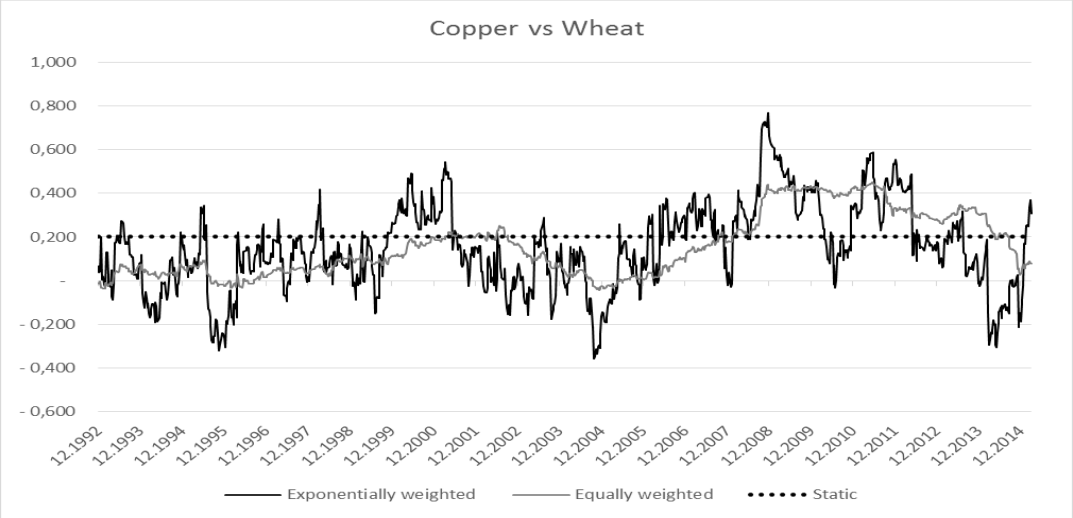
Bivariate correlations

Figure 4 visualizes the exponentially weighted (EWMA) correlations (using a smoothing parameter = 0.94) and the simple correlations for a 156 weeks window as well as the full sample ("static") bivariate correlations for three pairs of unrelated commodities (corn vs crude oil; copper vs wheat; soybeans vs silver) . For the full sample, all three pairs have significant positive but not very high correlations (roughly 0.20). There is clearly a substantial increase in the simple

correlations around 2004-2005. Before that time, correlations had for a number of years not been significantly different from zero. All simple correlations climb to 0.45-0.50 during the period leading up to 2009 and remain at a historically high level for some two years . Then, towards 2015, all correlations descend to approximately where they started around 2005, at a level not significantly different from zero. The EWMA correlations demonstrates the "ghost effect". Thus, when downplaying the most recent shock, correlations peak much higher for a shorter period before swifly moving back towards the long run level.

In summary, the high correlation between physically unrelated commodities that stirred a lot of academic and political debate, was a temporary phenomenon that disappeared quite soon. In their 2012 paper, Tong and Xiong comment that "although the correlations dropped in 2010 and 2011, they remained substantially higher than they were before 2004." Our results question this conclusion.





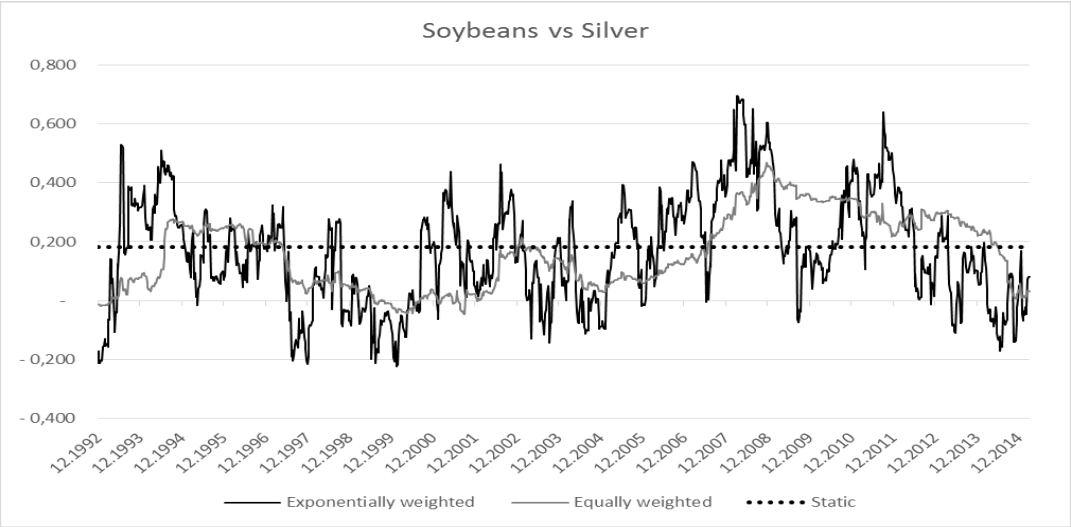


Figure 4. Exponentially weighted and simple correlations 156 weeks moving and full sample correlations ("static")

PCA analysis

In order to describe changes in the co-variance structure across the 14 commodities in our sample, we have run PCAs on the weekly price changes for the same four sub-samples as above: January 1990 – December 2006; January 2007 – December 2008, January 2009 – December 2011 and January 2012 – March 2015. The samples were selected in order to compare the boom-and-bust period co-movement structure with that during the most recent two years as well as the co-movement structure of the time when hedgers dominated futures markets and speculative activity was small compared to recent years. The major results can be seen in table 3 and figure 5, reporting the explained variation for each of the four first factors individually and accumulated. The results are easily summarized. For one, in all periods several factors are required to explain price variability across the 14 commodities. Even when cumulating over six factors there is still a substantial part of variance left unexplained for all periods. Second, the first principal component (F1) explains considerably more during the boom-and-bust as compared to the other periods. While F1 explains roughly 24% 1990-06 and 2012-15, it explains close to 50% during the boom-and-bust. This, however, appears to be a temporary situation. For the more recent periods, the picture has changed and has become more similar to what it looked like in the earliest period.

Table 3. Explained variation (%) and cumulative explained variation (%) for different sub periods, weekly data 1990(1)-2015(12)

Variation explained %

Year	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14
1990-2006	18,7	15,3	12,1	10,8	9,2	8,5	6,4	5,2	3,9	3,5	2,1	1,7	1,5	0,9
2007-2008	49,6	10,2	8,5	6,2	5,0	4,3	3,6	3,2	2,7	1,9	1,6	1,4	1,2	0,6
2009-2011	39,7	12,6	10,0	8,4	6,5	5,5	5,1	3,0	2,8	2,2	1,6	1,2	1,0	0,5
2012-2015	23,5	16,0	13,0	11,6	7,3	6,2	5,4	4,9	3,9	2,6	2,2	1,9	1,0	0,5

Variation explained, cumulative %

Year	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14
1990-2006	18,7	34,0	46,1	57,0	66,2	74,6	81,1	86,3	90,2	93,7	95,8	97,5	99,1	100,0
2007-2008	49,6	59,8	68,2	74,4	79,4	83,8	87,4	90,5	93,3	95,2	96,8	98,2	99,4	100,0
2009-2011	39,7	52,3	62,2	70,6	77,1	82,6	87,7	90,6	93,5	95,7	97,3	98,6	99,5	100,0
2012-2015	23,5	39,5	52,5	64,1	71,4	77,6	83,0	87,9	91,8	94,4	96,6	98,5	99,5	100,0

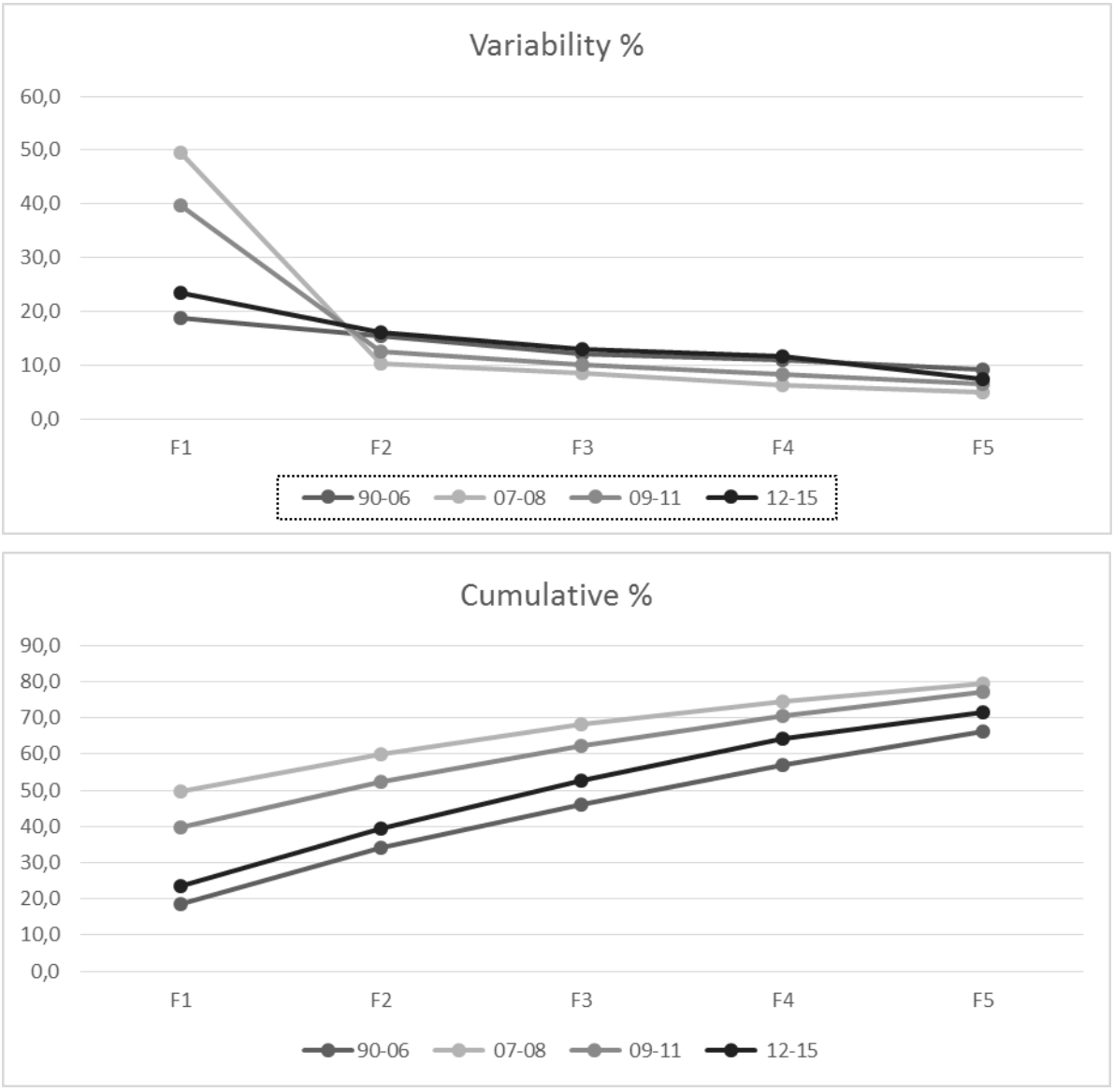


Figure 5. Explained variation (top) and cumulative explained variation (bottom) (%), factors F1-F5 for the four sub periods, weekly data, 1990(1) – 2015(12).

In order to supplement the results for the four sub-periods, we have run a series of rolling PCAs for a two years (104 weeks) window that is rolled forward in one week steps. In doing so, each factor's contribution to the explanation of total variation is mapped over time. Figure 6 graphs the development for the first two factors (F1 and F2). The graphs reveal a number of interesting features. For one, all through the period 1990-2015, the two first principal components explain a relatively modest fraction of the variations in commodity prices. F1 reaches a peak in the window covering the observations January 2007 – December 2008 when the first factor explains slightly more than 40 per cent of total variation. Up to 2006/07, the first component is moving between 16 and 27 per cent explained variation. After the winter of 2008/09, the trend towards increased co-movements is rapidly reversed. At the end of 2013, F1's explained variability is practically back to where it used to be before 2006. As regards the second component (F2), it has been relatively stable throughout all 25 years, explaining roughly 15 per cent of total variation.

In summary, the covariance structure across the 14 commodities has reverted back to what it looked like during the 1990s and early 2000s. Different commodities move differently, most likely because different commodities are driven by different fundamentals and not by financial markets sentiments and contagion from one commodity to another.

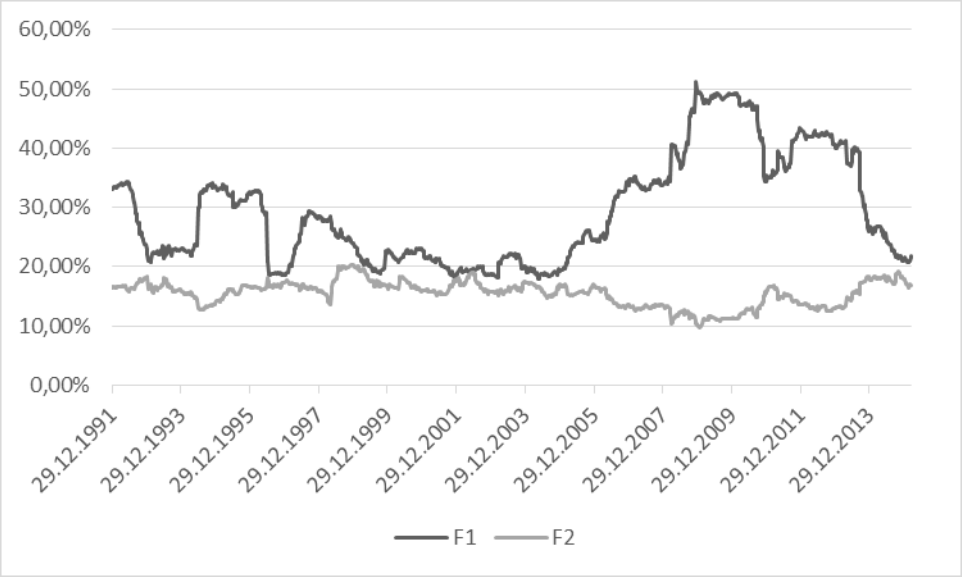


Figure 6. Explained variation Factor 1(F1) and Factor 2(F2), 104 weeks rolling window, 1990(1) – 2015(3), one week roll.

Conclusion

Disregarding a relatively brief period before and after commodity boom-and-bust and the financial crisis, commodity price changes do not co-move strongly. In order to explain a substantial part of price variations across a selection of 14 major commodities, several factors are required. Different commodities do not cluster on a few common factors. To the extent that clustering is found, these clusters are typically involving related commodities, which confirms the recent results presented by Brooks and Prokopczuk (2013). Although there was a tendency

towards stronger co-movement during the boom-and-bust, not even during this period commodities were behaving as "one" asset. After 2009, the move towards more uniform variation across different commodities is reversed. By 2015, the covariance structure is almost back to where it was between 1996 and 2006 with relatively low correlations across physically different commodities. Again the first principal component explains less than 25 per cent of total variation and several factors are required to capture total variation across the commodity market. The relatively high correlations during the boom-and-bust appear to have been a temporary phenomenon not reflecting a permanent structural change in the commodity market.

Commodities are different assets and the commodity market is far from being a market of "one". Different commodity prices behave differently and it is hard to see any excessive co-movements. To the extent that high co-movement is taken as evidence of herd behavior among commodity speculators, our results suggest that herding does not seem to be a major problem in the commodity markets. If so, stricter regulations and position limits may seem redundant.

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Appendix: Commodities in sample and sources

Commodity	Product specification	Contract months	Unit
Corn (C1)	#2 Yellow Corn	March, May, July, September, December	US Cent/Bushel
Wheat (W1)	#2 Soft Red Winter Wheat	March, May, July, September, December	US Cent/Bushel
Soybeans (S1)	#2 Yellow Soybeans	January, March, May, July, August September, November	US Cent/Bushel
Crude Oil (CL1)	West Texas Intermediate, light sweet crude oil	All calendar months	USD/Barrel
Heating Oil (HO1)	No. 2 Fuel Oil	All calendar months	USD/gallon
Cotton (CT1)	ICE Cotton No. 2 Futures	March, May, July, October, December	US Cent/pound
Copper (HG1)	Grade 1 Electrolytic Copper Cathodes (full-plate or cut) conforming ASTM standard B115-00	All calendar months	US Cent/pound
Gold (GC1)	Gold assayed to a minimum of 995 fineness	All calendar months	USD/troy ounce
Silver (SI1)	Silver assayed to a minimum of 999 fineness	All calendar months	USD/troy ounce
Platinum (PL1)	Platinum delivered under this contract shall be a minimum of 99.95% pure.	Trading is conducted over 15 months beginning with the current month and the next two calendar months before moving into the quarterly cycle of January, April, July, and October.	$0.10 per troy ounce
Palladium (PD1)	Palladium delivered under this contract shall be a minimum of 99.95% pure.	Trading is conducted over 15 months beginning with the current month and the next two calendar months before moving into the quarterly cycle of March, June, September, and December.	$0.05 per troy ounce
Cocoa (CC1)	Exchange-Grade Cocoa	March, May, July, September, December	USD/metric ton
Coffee (KC1)	Arabica Coffee in the form of exchange-grade green beans	March, May, July, September, December	USD/metric ton
Sugar (SB1)	Raw Centrifugal Cane Sugar	March, May, July, October	US Cent/pound

Note: 1 after the ticker code indicates front contract