Are Commodity Markets Characterized by Herd Behaviour?

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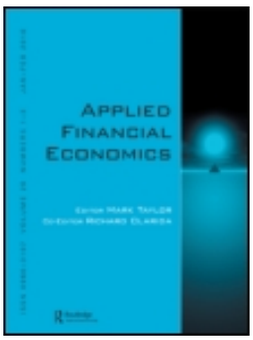

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Are commodity markets characterized by herd behaviour?

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Twenty years ago, Pindyck and Rotemberg concluded that commodity prices exhibited excessive co-movements and that commodity markets were characterized by herd behaviour. The herding hypothesis has recently experienced a revival. A number of studies have concluded that commodities have become 'financialized' and contaminated by the stock market because of the large influx of hedge funds, index trackers and financial investors. Analysing monthly prices of 20 commodities for the period 1986–2010, we find that there has been a tendency toward increased co-movements across commodities and between commodities and the stock market after 2004. However, this result is mainly driven by the extreme price movements after 2008. There is no strong evidence of financialization or contamination from the market activities of financial investors prior to 2008.

Keywords: commodity markets; herd behaviour; financialization

JEL Classification: Q02; G15

I. Introduction

Robert S. Pindyck and Julio J. Rotemberg concluded 20 years ago that commodity markets were characterized by nonrational behaviour (Pindyck and Rotemberg, 1990). Based on empirical evidence from the period 1960–1985 they found that the prices of seven generally unrelated commodities had shown a persistent tendency to move together, '*well in excess of anything that can be explained by common effects of inflation, or changes in aggregate demand, interest rates, and exchange rates*' (p. 1173). They concluded that this (seemingly) excess co-movement '*casts doubt on the standard competitive price model*,' suggesting that the observed pattern could be because of 'herd' behaviour.

Subsequent studies on commodity prices have raised doubts as regards the results and conclusions presented by Pindyck and Rotemberg. Leybourne *et al*. (1994) found that excess co-movement occurs only infrequently in monthly time series. McDermott *et al*. (1999) concluded that the excess co-movement of commodity prices was a myth. Deb *et al*. (1996) analysed excess co-movement of nine commodity prices. Based on monthly observations for two sample periods, 1960–1985 and 1974–1992, only weak evidence of excess co-movement was found. Lescaroux (2009) considered monthly prices for 51 commodities from 1980 to 2008 and confirmed that raw resources exhibit co-movement at high frequencies. Focusing on oil and six metal prices, the results suggested that the high level of correlation between cycles of commodity prices can to a large extent be explained by common shocks to inventory levels. Once the influences of supply and demand are filtered out, it appears that the links between commodity prices are rather loose. Le Pen and Sévi (2010) reinvestigated the issue of excess

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co-movements of commodity prices. They considered different measures of correlation to assess co-movement, providing evidence of excess co-movement for the price changes for a set of eight seemingly unrelated commodities. Extending the analysis to the excess co-movement of volatilities, however, they found that, contrary to the case of returns, co-movement vanishes once the effect of fundamentals has been removed.

However, the excess co-movement and herding behaviour hypothesis has gained renewed support recently. Byrne *et al*. (2011) found significant evidence of strong co-movement in commodity prices, driven by a common factor identified as the real interest rate. Singleton (2011) studied investor flows and the recent boom and bust in oil prices. He found a statistically significant effect of investor flows on oil futures prices, concluding that oil prices are driven by speculative activities rather than market fundamentals. Tang and Xiong (2010), in a paper much cited in the media, concluded that, concurrent with the rapid growth in index investment in commodities markets, futures prices of different commodities in the US have become increasingly correlated with each other after 2005. They claimed that this trend has been significantly more pronounced for commodities included in the two popular GSCI[1] and DJ-UBS[2] commodity indices. They suggested that this reflects a financialization process of commodity markets explaining the synchronized price boom and bust of a broad set of seemingly unrelated commodities. In contrast, they found that such commodity price co-movements have been absent in China, which they suggested refutes growing commodity demand from emerging economies as the main price driver.

Both the media and politicians have been quick in pointing at hedge funds and index trackers as the force behind what may appear to be commodity price herd behaviour (see, e.g. *Financial Times*, 27 May and 9 September 2011). The US Congress has organized hearings into the impact of index investors on commodity prices and the regulators are trying to assess how such funds do – or do not – affect pricing. The Commodity Futures Trading Commission is considering new curbs based on the suspicion that investors are disturbing the market. Needless to say, the idea that commodity markets are characterized by herd behaviour and that the entry of hedge funds, index trackers and traditional stock market investors into commodity markets eliminates the link between fundamentals and pricing is controversial.

An increasing number of investors have invested in commodities after 2004, either as an independent investment instrument, or as part of a wider risk management strategy, assuming that commodities have a low correlation with stocks and other traditional investments. The commodity 'financialization' hypothesis, it is claimed, has then become a victim of its own success. Chasing commodities that used to be uncorrelated to one another and uncorrelated to stocks generated higher correlations, hence reducing the diversification effect (Corsetti *et al*., 2005).

It is difficult to separate fundamental effects from speculative effects, and it is also difficult to explain why new participants in commodity markets do not use market fundamentals in forming expectations of prices unless, of course, they really are less informed than traditional market participants. One explanation is supplied by Veldkamp (2006). When information is costly, rational investors only buy information about a subset of assets. When investors price assets using a common subset of information, news about one asset affects other asset prices and unrelated asset prices co-move.

The body of scientific papers, newspaper articles and lobbying reports debating the effect (or noneffect) of index funds and speculators on commodity pricing is rapidly increasing. The use of fundamentals over financialization has been defended in a number of papers by Irwin and Sanders (see, e.g. Irwin *et al*., 2009; Irwin and Sanders, 2011; Sanders and Irwin, 2011a, b).

The literature on excess co-movements and herd behaviour in commodity markets is related to an older debate in finance, i.e. the issue of 'contagion' across markets and the effect on risk and return of being included in a major benchmark index (see, e.g. Bekaert and Harvey, 2003; Corsetti *et al*., 2005; Kallberg and Pasquariello, 2008). As for commodity herd behaviour, the discussion on contagion typically revolves around correlations, which is a measure that may in some cases be misleading. For one, a single dramatic event with strong economy-wide effects may generate long-lasting strong correlations, as long as the event is included in the sample, i.e. the so-called *ghost feature effect*. Furthermore, as pointed out by Forbes and Rigobon (2002), it is important to take into consideration the fact that correlation coefficients are conditional on market volatility.

[1] http://www.standardandpoors.com/indices/. The S&P GSCI is a composite index of commodity returns representing an unleveraged, long-only investment in commodity futures that is broadly diversified across a spectrum of commodities. It is, however, quite heavy in energy commodities.

[2] http://www.ibb.ubs.com/mc/etracs_US/commodities/djubs.shtml. The Dow Jones-UBS Commodity Index was also known as the Dow Jones-AIG Commodity Index before 2009.

They found that, adjusting for volatility, there was virtually no increase in the unconditional correlation coefficients (i.e. no contagion) during the 1997 Asian crisis, 1994 Mexican devaluation, and 1987 US market crash.

This article is a contribution to the commodity financialization and contagion debate. More specifically, we set out to reveal in general whether commodity prices move together and in particular whether commodity prices have behaved differently under the influence from index trackers and financial investors after 2004, as has been claimed in a number of scientific articles as well as media statements.

An analysis of commodity market co-movements should extend beyond simple bivariate correlations, which in large samples easily become significant. Correlations of groups of commodities as revealed by, e.g., principal component analysis are more informative when it comes to describing the totality of pricing behaviour. Correlations should also be supplemented with estimates of systematic risk, i.e. the product of correlations and relative volatilities between a given commodity and a broader benchmark such as a commodity price or stock market index. Commodity returns may be highly correlated but still fundamentally different in terms of risk. Furthermore, the effect from, say, the stock market on a given commodity price may be much stronger than revealed by a simple correlation alone. In this study, we expand and supplement the standard correlation analyses with analyses of systematic and unsystematic risk. We argue that if herd behaviour is present, either as contagion within a commodity market or across the stock market, this should be reflected not only in increased bi-variate correlations but also by equalization or harmonization of price volatilities and fewer common factors explaining significantly more of the variation. Furthermore, commodity financialization should show up in reduced unique risk for each commodity and generally increased systematic risk, benchmarked against both commodity markets in general and the stock market.

The article is organized as follows. In the next section, we describe the risk and return for 20 selected commodities and two major commodity indices (S&P GSCI and CCI) together with a world stock market benchmark (Morgan Stanley Capital International (MSCI) World) observed monthly from January 1986 to September 2010. The sample includes commodities that are physically related (e.g. wheat, corn, soya beans) as well as commodities for which we would assume cross-price elasticities of close to zero. To reveal possible changes in market behaviour because of hedge funds and other investors' increased interest for commodities in recent years, we split the sample at June 2004. While there has been increasing interest in commodities among investors and hedge funds for some time, there was a surge in commodity investment after 2004, partly because of the US Securities and Exchange Commission's new trading rules for bank capital requirements. This is reflected in e.g. substantial growth in the number of commodity Exchange Traded Funds (ETFs) traded and general growth in volumes on commodity futures exchanges.

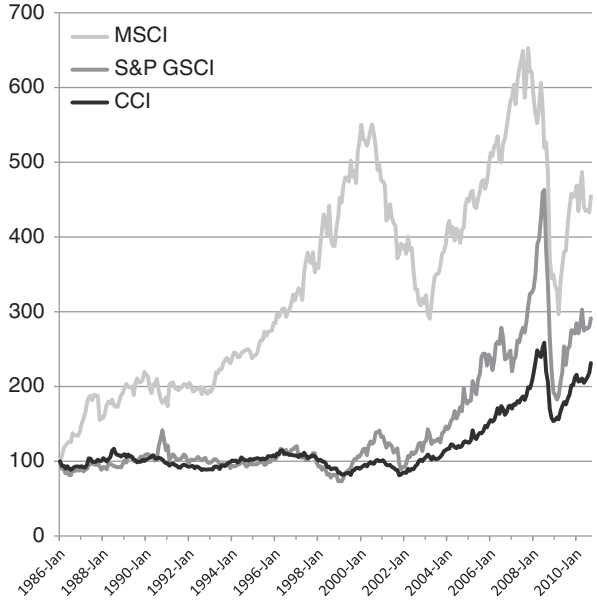

Fig. 1. MSCI World, S&P GSCI and CCI – January 1986 to September 2010 (Rebased, January 1986 = 100)

We first present the basic descriptive statistics and the standard bivariate correlations, before commenting on the results from the principal component analysis. Next, we focus on systematic and unsystematic risk in a commodity market context as well as benchmarked in a broader investment environment, i.e. the stock market.

II. Commodity Prices 1986–2010: Stylized Facts Regarding Risk and Return

Figure 1 shows the development of commodity and stock markets over the period 1986–2010, the latter represented by the MSCI World Index and the commodity markets by the S&P GSCI and CCI indexes, all rebased as January 1986 = 100. The major dramatic events, i.e. the dot-com stock market crisis around the turn of the century and the financial crisis at the end of the decade are easily identified. Despite these two large setbacks, the stock market ended the

Table 1. Commodity return and risk (annualized)

	1986(2)–2004(6)		2004(7)–2010(9)	
	Mean	SD	Mean	SD
Ammonia	0.031	0.337	0.079	0.635
Pork bellies	0.032	0.551	0.059	0.465
Ethylene	0.012	0.291	0.049	0.416
Propane	0.029	0.455	0.084	0.404
Corn	0.006	0.267	0.084	0.379
Crude oil	0.023	0.395	0.130	0.369
Silver	−0.004	0.214	0.206	0.362
Sugar	0.017	0.364	0.200	0.349
Soya beans	0.028	0.201	0.021	0.338
Rubber	0.034	0.189	0.150	0.334
Wheat	0.009	0.236	0.094	0.332
Coconut	0.026	0.338	0.108	0.321
Palm oil	0.011	0.304	0.120	0.308
Soya oil	0.019	0.235	0.046	0.307
Cotton	−0.006	0.331	0.088	0.305
Coffee	−0.069	0.398	0.152	0.293
Cocoa	−0.027	0.291	0.109	0.271
Aluminium	0.018	0.194	0.043	0.267
Gold	0.006	0.127	0.190	0.225
Wool	0.020	0.162	0.050	0.204

Note: Return $= \ln(P_t/P_{t-1})$.

Table 2. Simple correlations: top five before and after June 2004

1985(2)–2004(6)		2004(7)–2010(9)	
Soya beans/Soya oil	0.70	Gold/Silver	0.80
Soya beans/Corn	0.61	Soya beans/Soya oil	0.77
Soya oil/Palm oil	0.59	Crude oil/Propane	0.73
Crude oil/Propane	0.53	Soya beans/Corn	0.67
Gold/Silver	0.52	Soya oil/Palm oil	0.67

25-year period much higher than the commodity market. Commodities peaked during the winter of 2008, some months after the peak in the stock market. After the collapse, both stock and commodity markets experienced significant price increases in 2010.

Table 1 summarizes (annualized) mean returns and risk for commodities. During the 18 years prior to 2004, commodity prices in general did not rise, with some exceptions. Mean annual returns were 2%–3% for pork bellies, crude oil, rubber and soya beans. Most other commodities remained quite flat throughout this period, some even experienced extended periods with negative returns.

After 2004, returns were higher for most commodities, and very high for some. Gold, silver and sugar have had returns of close to 20% annually since 2004. Again, there are wide differences across commodities, with soya beans, soya oil and aluminium experiencing slower price growth (2%–4% annually). Thus, both before and after 2004, there have been large differences in returns across commodities.

With regard to volatility, there are also substantial differences across commodities. SDs range from ~13% (gold in the first period) to 63% (ammonia in the most recent period). Two commodities (pork bellies and ethylene) among the five are most risky both before and after 2004. Three (aluminium, wool and gold) are among the five least risky in both periods. Beyond this, it is difficult to see any pattern in the SDs. The average volatility increased somewhat in the latter period; however, there is no clear indication of a trend toward uniform risk across commodities. Tables A1 and A2 in the Appendix summarize the results from a pair wise test of equality in variances for all 190 commodity pairs. Although the number of nonsignificant differences increases from 24 to 50 after 2004, the majority of combinations have significantly different variances.

III. Correlations Across Commodities Before and After 2004

Table A3 in the Appendix reports the simple correlations of the monthly returns for the 20 commodities in our sample during the two periods (February 1986 to June 2004 and July 2004 to September 2010). Table 2 lists the five pairs that are most closely correlated in the two periods.

As expected, the highest correlations are between those commodities that are physically related, i.e. soya beans, soya oil, corn and palm oil in the food (or feed) sector; crude oil and propane in the energy complex, and the two precious metals gold and silver. This pattern applies to both periods. For the period until mid-2004, correlations are generally low although in many cases significantly different from zero (correlation coefficient > approx. 0.11). Despite this, it is not possible to conclude based on the simple correlations that there have been any strong co-movements among nonrelated commodity returns prior to July 2004.

With regard to the period after 2004, most correlations are higher. There are fewer insignificant correlations than during the previous 18 years. Despite this, based on the simple correlations, it is not possible to conclude that there was a regime shift after 2004 as suggested in the 'financialization' literature. There are some correlations above

0.6–0.8 that previously were 10–20 basis points lower. These are typically found among the agricultural or food commodities (soya oil/soya beans; soya oil/palm oil; coconut/palm oil); as well as silver/gold and among energy commodities (crude oil/propane). Considering the physical similarities of these products, and also similarities in production costs, such an increase in correlations may occur even without the presence of index trackers and commodity speculators.

The principal component analysis supports the conclusion that commodity prices in general do not move very strongly together. To explain 60% of the variation in returns, seven principal components were required for the pre-2004 sample (Table A4 in the Appendix). Even though the required number of factors falls to five after 2004, there is a great deal of variation not accounted for by the major factors. Before 2004, grains and oil seeds cluster on the first principal component, accounting for 15% of the variation. Energy and metals score relatively high on the second component, which adds another 10% of the variation. So, these three groups seem to have been the main drivers of risk in commodity returns. After 2004, energy and agricultural commodities both score relatively high on the first component which now accounts for more than 30% of the variation. The second component, which may be defined as a metals factor now accounts for 11%. Thus energy and cereals have clearly moved more closely together after 2004. This may be explained by the increased activities of commodity investors but more likely as a stronger fundamental connection between energy and grains. Energy makes up a major cost in grain production and one of the major cereals (corn) is in high demand as bio fuel. Even after 2004, a substantial amount of variation remains after extracting the main principal components and there is no tendency towards unification beyond the fact that physically related commodities have similar eigenvalues.

The tendency towards fewer principal components is furthermore mainly driven by the observations from the dramatic market movements 2008–2010. Figure 2 plots the percentage of the variation explained by the first three principal components based on a rolling 36-month sample. All three components explain between 10% and 20% with no significant changes until 2008. When the observations from the winter of 2007–2008 are included, the explained variation from the first component increases to 40%. Two conclusions can be drawn. First, the inclusion of a number of extreme observations can easily cause substantial changes in correlations. Second, the joint correlations across commodities remained relatively low and unchanged after 2004, until the food and financial crises and boom and bust in the oil market after 2007–2008.

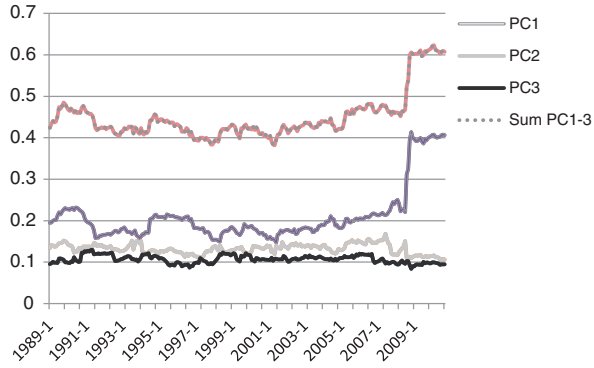

Fig. 2. Percentage explained variation, principal components 1–3, 36-month rolling sample

IV. Evidence on Systematic and Unsystematic Risk in Commodity Markets Before and After 2004

Comparing inter-commodity systematic and unsystematic risk, we use the 'Thomson Reuters Equal Weight Continuous Commodity Index' as a benchmark (hereafter CCI). The CCI is recognized as a major barometer of commodity prices, comprising 17 commodity futures that are continuously rebalanced.[3] The index that trades on the ICE Futures Exchange aggregates four major sectors, i.e. energy (17.65%), metals (23.53%), softs (29.41%) and agriculture (29.41%). Consequently, the CCI is more diversified than a number of other commodity indices, some of which are heavily tilted against energy (e.g. S&P GSCI).

Table 3 reports the results from regressing the monthly commodity returns on the CCI returns for the periods before and after July 2004, obtaining a measure of each commodity's systematic risk (β) as well as a measure of the fraction of the total variance that is not explained by general commodity market movements, i.e. the commodity's unique or unsystematic risk ($1-R^2$).

The major findings can be summarized as follows. All commodities in the sample have a substantial unique risk. Prior to 2004, only soya beans have an

[3] Cocoa, coffee, copper, corn, cotton, crude oil, gold, heating oil, live cattle, live hogs, natural gas, orange juice, platinum, silver, soya beans, sugar and wheat.

Table 3. Intercommodity systematic and unsystematic risk

	1986(3)–2004(6)			2004(7)–2010(9)		
	β	SE(β)	R^2	β	SE(β)	R^2
Cocoa	0.52	0.22	0.02	0.85	0.17	0.26
Corn	1.29	0.19	0.18	1.23	0.23	0.28
Cotton	0.57	0.25	0.02	0.87	0.20	0.21
Coffee	1.27	0.29	0.08	0.73	0.19	0.16
Rubber	0.57	0.14	0.07	1.06	0.21	0.26
Soya beans	1.22	0.13	0.29	1.23	0.20	0.35
Wheat	1.11	0.17	0.17	0.94	0.21	0.21
Soya oil	1.15	0.16	0.19	1.31	0.16	0.47
Sugar	1.26	0.27	0.09	0.88	0.23	0.16
Wool	0.06	0.12	0.00	0.72	0.12	0.32
Palm oil	0.58	0.23	0.03	1.18	0.17	0.38
Ethylene	0.59	0.32	0.04	0.65	0.29	0.06
Crude oil	1.82	0.42	0.20	1.56	0.20	0.47
Gold	0.54	0.16	0.12	0.68	0.14	0.24
Silver	0.69	0.26	0.09	1.39	0.21	0.39
Ammonia	0.68	0.46	0.03	0.66	0.45	0.03
Pork bellies	0.57	0.83	0.01	−0.04	0.34	0.00
Aluminium	0.64	0.20	0.12	1.10	0.14	0.44
Coconut	−0.03	0.43	0.00	1.07	0.20	0.29
Propane	1.13	0.47	0.21	1.62	0.22	0.42

Notes: Estimating $r_t^c = \alpha + \beta r_t^{CCI} + \varepsilon_{t,}^c$ where c denotes commodity.
Monthly observations are considered.

Table 4. Commodity–stock market systematic and unsystematic risk, 2004(6)–2010(9)

	β	SE(β)	t-value	R^2
Cocoa	0.33	0.15	2.12	0.06
Corn	0.55	0.21	2.60	0.08
Cotton	0.49	0.18	2.78	0.09
Coffee	0.50	0.17	3.03	0.11
Rubber	0.72	0.18	3.99	0.18
Soya beans	0.60	0.19	3.16	0.12
Wheat	0.39	0.19	2.06	0.05*
Soya oil	0.58	0.17	3.39	0.13
Sugar	0.19	0.21	0.93	0.01*
Wool	0.62	0.10	6.25	0.36
Palm oil	0.42	0.18	2.35	0.07
Ethylene	0.40	0.24	1.67	0.04*
Crude oil	0.79	0.20	3.91	0.17
Gold	0.00	0.13	0.01	0.00*
Silver	0.33	0.21	1.58	0.03*
Ammonia	0.26	0.38	0.70	0.00*
Pork bellies	0.19	0.28	0.68	0.01*
Aluminium	0.64	0.14	4.58	0.22
Coconut	0.53	0.19	2.83	0.10
Propane	0.75	0.22	3.38	0.13
CCI	0.42	0.08	5.07	0.26

Notes: Estimating $r_t^c = \alpha + \beta r_t^{MSCI} + \varepsilon_t^c$, where c denotes commodity.
Monthly observations are considered.

explained variance above 0.25. The unique risk decreased for most commodities after 2004. Despite this, for all commodities, unique risk represents more than 50% of total risk, and substantially more for many. For some commodities, systematic market risk increased significantly after 2004 (e.g. rubber, wool, palm oil, silver, coconut and cocoa). On the other hand, there are also commodities for which the commodity market beta decreased after 2004 (e.g. coffee, pork bellies and sugar). While there has been a trend towards somewhat greater co-movement across commodities after 2004, we conclude that different commodities are still quite different in terms of both systematic and unsystematic risk.

V. Stock Market Contagion After 2004

The financialization hypothesis maintains that a stronger link between the stock and commodity markets has developed because of the increase in commodity market activities among hedge funds and other investors. The hypothesis is based on the underlying assumption that investors with limited competence in commodities are driving commodity prices based on stock market sentiments and information, independently of commodity market fundamentals. Commodity prices are thus assumed to be contaminated by events affecting the stock market not necessarily related to commodity market fundamentals.

Table 4 reports the results by estimating commodity returns on stock market returns using MSCI World as the stock market benchmark. The estimation results for the period before 2004 are not reported, simply because no single beta was significantly different from zero and all R^2s were close to zero. After 2004, the commodity and stock markets move more in tandem. The question whether this is a result of contagion from the stock market to commodity markets has no simple answer. The covariance based on monthly returns is low, including during the most recent 5 years. Except for wool, all R^2s are below 0.25. The average R^2 is 0.26 and the CCI-beta is below 0.5. The fact that there are different price movements across commodities also after 2004 is reflected in the widely differing betas across commodities. Crude oil and propane have relatively high stock market betas (0.79 and 0.75), while seven commodities have betas below 0.4, e.g. wheat, ammonia and sugar.

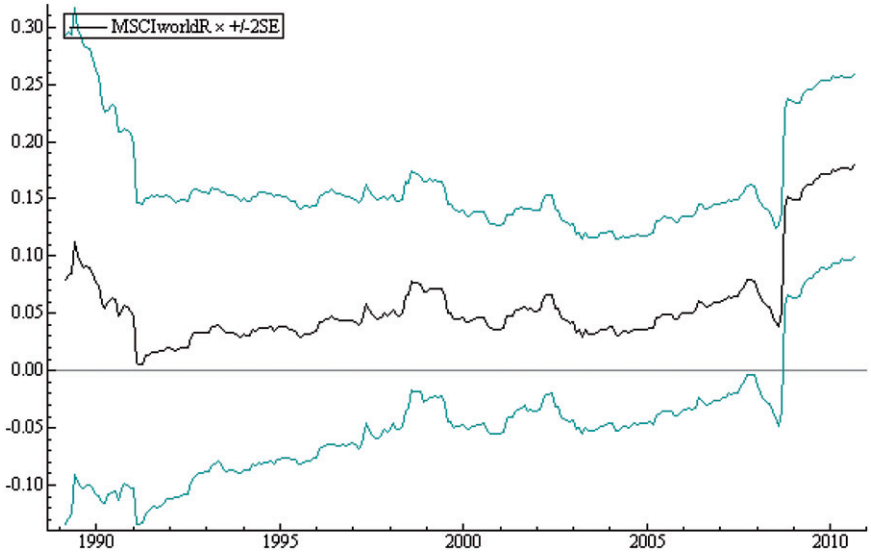

Fig. 3. Stock market beta for CCI (±2SEs), recursive estimations 1986–2010 (initialization: first 36 months)

Furthermore, the trend toward greater stock–commodity market co-movements is mainly driven by the observations from the period after 2008. This is clearly shown in Fig. 3, which presents the CCI-beta from recursive estimations over the period. The beta remains quite stable and low for all the years through 2007. When including the observations from the food and financial crises, there is a dramatic increase in commodities' stock market beta.

VI. Conclusions

There are three main conclusions to be drawn from the analyses in this article. First, during the 25 years after 1986 there has generally been a moderate covariance across (monthly) commodity returns. Despite the fact that a number of bivariate correlations are significantly different from zero, the overall picture is one of heterogeneity. Price changes as well as price risk differ quite significantly for many commodities. Second, the co-movements across commodities and between commodities and the stock market increased after 2004, as predicted by the financialization and contagion hypothesis. However, neither the correlations and the principal component analysis nor the estimates of systematic and unsystematic risk generate convincing evidence of a commodity market financialization and stock market contagion prior to 2008. Third, when including the observations from the period after the food and financial crises in 2007–2008 all measures of co-movements increase substantially. Thus, even though financial investors went heavily into commodities after 2004, co-movements within the commodity market and between commodities and the stock market remained fairly stable and low until 2008. To what extent the higher co-movements after the financial crises are a lasting feature and not a temporary deviation from the normal remains to be seen.

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Appendix

Table A1. Differences in variances, 1986(2)–2004(6)

	Cocoa	Corn	Cotton	Coffee	Rubber	Soya beans	Wheat	Soya oil	Sugar	Wool	Palm oil	Ethylene	Crude oil	Gold	Silver	Ammonia	Pork bellies	Aluminium	Coconut
Corn	=																		
Cotton	>	>																	
Coffee	>	>	>																
Rubber	<	<	<	<															
Soya beans	<	<	<	<	=														
Wheat	<	<	<	<	>	>													
Soya oil	<	<	<	<	>	>	=												
Sugar	>	>	=	=	>	>	>	>											
Wool	<	<	<	<	<	<	<	<	<										
Palm oil	=	>	=	<	>	>	>	>	<	>									
Ethylene	=	=	<	<	>	>	>	>	<	>	=								
Crude oil	>	>	>	=	>	>	>	>	=	>	>	>							
Gold	<	<	<	<	<	<	<	<	<	<	<	<	<						
Silver	<	<	<	<	>	=	=	=	<	>	<	<	<	>					
Ammonia	>	>	=	<	>	>	>	>	=	>	=	>	<	>	>				
Pork bellies	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>			
Aluminium	<	<	<	<	=	=	<	<	<	>	<	<	<	>	=	<	<		
Coconut	>	>	=	<	>	>	>	>	=	>	=	>	<	>	>	=	<	>	
Propane	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	<	>	>

Notes: *F*-test, $>/<$ variance of variable in line significantly larger/smaller than variance of variable in column. Critical values (95%): 0.80 (lower) and 1.24 (upper)

Table A2. Differences in variances 2004(7)–2010(9)

	Cocoa	Corn	Cotton	Coffee	Rubber	Soya beans	Wheat	Soya oil	Sugar	Wool	Palm oil	Ethylene	Crude oil	Gold	Silver	Ammonia	Pork bellies	Aluminium	Coconut
Corn	>																		
Cotton	>	<																	
Coffee	=	<	=																
Rubber	>	<	=	>															
Soya beans	>	<	=	>	=														
Wheat	>	<	=	>	=	=													
Soya oil	>	<	=	=	=	=	=												
Sugar	>	=	>	>	=	=	=	>											
Wool	<	<	<	<	<	<	<	<	<										
Palm oil	>	<	=	=	=	=	=	=	<	>									
Ethylene	>	=	>	>	>	>	>	>	>	>	>								
Crude oil	>	=	>	>	=	=	=	>	=	>	>	<							
Gold	<	<	<	<	<	<	<	<	<	=	<	<	<						
Silver	>	=	>	>	=	=	=	>	=	>	>	<	=	>					
Ammonia	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>				
Pork bellies	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	<			
Aluminium	=	<	<	=	<	<	<	<	<	>	<	<	<	>	<	<	<		
Coconut	>	<	=	=	=	=	=	=	=	>	=	<	<	>	<	<	<	>	
Propane	>	=	>	>	>	>	>	>	>	>	>	=	=	>	=	<	<	>	>

Notes: See notes in Table A1.

Table A3. Simple correlations monthly returns

	Cocoa	Corn	Cotton	Coffee	Rubber	Soya beans	Wheat	Soya oil	Sugar	Wool	Palm oil	Ethylene	Crude oil	Gold	Silver	Ammonia	Pork bellies	Aluminium	Coconut	Propane
Cocoa		0.15	0.16	0.18	0.08	0.27	0.13	0.32	0.24	0.26	0.33	0.09	0.37	0.45	0.42	0.13	0.02	0.27	0.29	0.36
Corn	−0.02		0.25	0.28	0.34	0.67	0.45	0.56	0.08	0.42	0.31	0.02	0.16	0.13	0.18	−0.03	−0.16	0.25	0.34	0.17
Cotton	−0.01	0.21		0.12	0.27	0.33	0.27	0.13	0.26	0.32	0.05	0.11	0.16	0.24	0.08	−0.15	0.31	0.33	0.06	0.20
Coffee	0.13	−0.02	0.02		0.12	0.27	0.33	0.27	0.13	0.26	0.32	0.05	0.11	0.16	0.24	0.08	−0.15	0.31	0.33	0.06
Rubber	−0.04	−0.02	0.06	0.17		0.42	0.13	0.51	0.17	0.40	0.34	0.31	0.39	−0.01	0.10	0.23	−0.01	0.55	0.27	0.51
Soya beans	0.01	0.61	0.22	0.05	0.17		0.38	0.77	0.13	0.49	0.42	−0.04	0.24	0.07	0.15	−0.10	−0.07	0.34	0.44	0.30
Wheat	0.07	0.42	−0.01	0.09	0.06	0.20		0.37	0.11	0.19	0.28	0.09	0.16	0.05	0.10	0.05	−0.11	0.15	0.21	0.14
Soya oil	0.04	0.45	0.20	0.04	0.07	0.70	0.17		0.12	0.53	0.67	0.13	0.39	0.22	0.25	0.09	−0.15	0.47	0.66	0.39
Sugar	−0.02	0.18	−0.03	0.09	0.00	0.15	0.11	0.20		0.23	0.12	0.14	0.21	0.37	0.35	0.10	0.04	0.34	0.00	0.22
Wool	0.12	−0.02	0.07	0.09	0.07	−0.06	0.03	−0.06	0.01		0.54	0.22	0.37	0.18	0.30	0.07	0.03	0.36	0.47	0.36
Palm oil	−0.04	0.19	0.13	−0.10	0.07	0.29	0.10	0.59	0.15	−0.03		0.26	0.46	0.33	0.47	0.16	−0.11	0.41	0.78	0.44
Ethylene	0.00	0.00	0.03	0.15	0.20	0.03	0.01	−0.01	−0.04	−0.09	0.01		0.07	0.07	0.15	0.40	0.10	0.21	0.09	0.24
Crude oil	−0.01	−0.10	−0.21	−0.02	0.18	−0.01	−0.02	−0.08	0.05	−0.01	−0.01	−0.02		0.30	0.45	0.18	−0.03	0.58	0.38	0.73
Gold	0.08	0.00	−0.13	0.12	0.25	0.09	0.10	0.05	0.05	0.04	0.05	−0.04	0.22		0.80	0.14	0.04	0.30	0.28	0.16
Silver	0.02	0.10	−0.08	0.11	0.14	0.15	0.07	0.12	0.09	0.07	0.05	−0.01	0.05	0.52		0.11	0.00	0.45	0.39	0.30
Ammonia	−0.04	−0.04	0.09	−0.04	0.08	−0.08	0.03	−0.01	−0.13	−0.04	0.06	0.23	0.09	0.04	−0.09		0.08	0.27	0.21	0.12
Pork bellies	0.03	0.09	0.04	0.05	−0.07	0.19	−0.15	0.17	−0.01	0.08	0.01	0.01	0.04	−0.07	0.00	−0.03		−0.06	−0.11	0.02
Aluminium	0.07	−0.02	0.05	0.19	0.21	0.16	0.03	0.17	0.03	0.10	0.07	0.16	0.17	0.13	0.20	−0.09	0.03		0.37	0.46
Coconut	−0.06	0.18	0.10	−0.04	0.06	0.17	0.12	0.35	0.02	−0.09	0.60	0.03	−0.08	0.12	0.16	0.00	0.00	−0.01		0.27
Propane	−0.02	−0.10	−0.07	−0.04	0.11	−0.05	0.04	−0.10	−0.07	0.03	−0.04	−0.03	0.53	0.23	−0.01	0.13	0.05	0.10	−0.06	

Note: 1985(2) to 2004(6) (southwest triangle) and 2004(7) to 2010(9) (northeast triangle).

Table A4. Eigenvalues and eigenvectors

	1986(3)–2004(6)								2004(7)–2010(9)					
	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC1	PC2	PC3	PC4	PC5	PC6
Eigenvalues	3.09	2.14	1.54	1.45	1.35	1.25	1.10	1.02	6.33	2.24	1.68	1.33	1.16	1.07
Proportion of variation explained														
% variation	15	11	8	7	7	6	6	5	32	11	8	7	6	5
% cumulative	15	27	35	42	49	55	61	66	32	43	51	58	64	69
Eigenvectors														
Energy														
Crude oil	−0.07	**−0.42**	−0.27	−0.08	**0.38**	0.00	0.10	−0.17	**−0.26**	−0.22	0.13	−0.33	−0.18	0.16
Propane	−0.08	**−0.37**	−0.31	−0.02	**0.39**	−0.04	−0.16	−0.06	**−0.24**	−0.16	0.28	−0.35	−0.11	0.02
Metals														
Gold	0.10	**−0.46**	0.01	−0.24	−0.21	−0.01	−0.14	0.27	−0.18	**−0.39**	−0.39	0.08	0.03	−0.07
Silver	0.16	**−0.33**	0.19	−0.26	−0.29	0.10	−0.01	**0.40**	−0.227	**−0.37**	−0.32	0.03	−0.01	0.01
Aluminium	0.12	**−0.31**	0.18	0.22	0.02	0.22	0.15	−0.16	−0.27	**−0.16**	0.15	−0.140	0.16	0.22
Grains and oil seeds														
Corn	**0.39**	0.12	0.09	−0.03	0.24	−0.35	−0.05	0.21	**−0.22**	0.31	−0.14	−0.12	0.29	−0.04
Wheat	**0.21**	−0.06	0.07	−0.07	0.01	**−0.63**	−0.21	−0.15	**−0.16**	0.23	−0.12	0.10	0.39	0.10
Soya beans	**0.45**	0.00	0.07	0.08	0.27	−0.04	0.10	0.21	**−0.27**	0.33	−0.08	−0.21	0.10	−0.199
Soya oil	**0.48**	0.07	−0.04	0.02	0.10	0.13	0.06	−0.07	**−0.33**	0.23	0.00	−0.04	−0.09	−0.03
Palm oil	**0.37**	0.06	−0.33	−0.08	−0.16	0.26	−0.09	−0.345	**−0.31**	0.01	−0.04	0.17	−0.32	0.06
Softs and fibre														
Cotton	0.17	0.17	0.02	0.36	0.05	0.08	−0.31	0.17	−0.21	0.22	0.05	0.32	−0.13	−0.23
Coffee	0.05	−0.20	**0.40**	0.27	−0.15	−0.05	0.16	−0.18	−0.18	0.12	−0.21	0.32	0.23	0.22
Sugar	0.17	−0.04	0.14	−0.23	0.10	−0.11	0.37	**−0.40**	−0.13	−0.27	−0.08	−0.08	**0.52**	−0.17
Cocoa	0.01	−0.06	0.31	0.06	−0.01	0.01	−0.35	−0.37	−0.20	−0.22	−0.21	−0.05	−0.06	−0.13
Coconut	0.31	0.05	−0.30	−0.13	−0.35	0.21	−0.12	−0.15	−0.29	0.09	−0.09	0.24	**−0.41**	0.07
Wool	−0.01	−0.11	0.30	0.04	0.10	0.19	**−0.57**	−0.18	−0.27	0.08	0.06	0.02	−0.03	−0.27
Meat and livestock														
Pork bellies	0.07	0.04	0.11	0.14	0.41	**0.43**	0.06	0.21	0.04	−0.17	0.17	0.11	0.00	**−0.76**
Others														
Rubber	0.12	−0.36	−0.07	0.27	−0.14	−0.01	0.04	0.05	−0.23	0.07	**0.44**	−0.17	0.14	0.03
Ethylene	0.03	−0.10	−0.10	**0.54**	−0.22	−0.12	0.28	−0.04	−0.11	−0.15	**0.40**	**0.40**	0.19	−0.01
Ammonia	−0.03	−0.05	−0.39	**0.36**	−0.06	−0.21	−0.24	0.07	−0.09	−0.22	0.32	**0.42**	0.10	0.24

Notes: Principal components with eigenvalues smaller than 1 are dropped. The figures in boldface highlight the main drivers for each principle component (and do not necessarily indicate statistical significance).