The synchronized and long-lasting structural change on commodity markets: evidence from high frequency data

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Abstract

This paper analyses the intraday co-movements between returns on several commodity markets and on the stock market in the United States over the 1997-2011 period. By exploiting a new high frequency database, we compute various rolling correlations at (i) 1-hour, (ii) 5-minute, (iii) 10-second, and (iv) 1-second frequencies. Using this database, we document a synchronized structural break, characterized by a departure from zero, which starts in the course of 2008 and continues thereafter. This is consistent with the idea that recent financial innovations on commodity futures exchanges, in particular the high frequency trading activities and algorithm strategies have an impact on these correlations.

JEL Classification: G10, G12, G13, G14, G23, O33
Keywords: Financialization, Cross-Market Linkages, Commodities, Equities, High frequency, Structural change.

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Note: The term “dollar” ($) refers to United States dollars, unless otherwise stated.

This paper analyses the short-term co-movements between returns on several commodity markets and on the US stock market over the 1997-2011 period. By exploiting the new Thomson Reuters Tick History (TRTH) database, we compute various rolling correlations at higher frequencies than the daily one, which is the standard in existing literature. More precisely, we analyse the co-movement of the returns of the front month futures contracts of energy and soft commodities with the S&P 500 futures at four high frequencies: (i) 1-hour, (ii) 5-minute, (iii) 10-second, and (iv) 1-second. Using these new data, we observe and document a synchronized structural break, which starts during 2008 and continues until the latest observation of our dataset, the end of 2011.

At daily-frequency, the distribution of the correlations between commodities and stock indices has been increasing almost steadily since 2003-2004 (UNCTAD, 2011). At higher-than-daily frequency, prior to 2008, there is no strong or long-lasting deviation from zero between the commodity and the equity markets. Afterwards, a structural break occurs in the data. During the second and third quarters of 2008, the correlations depart from zero and move temporarily to negative territories, and then move in late September, early October 2008 to positive levels, where they have remained almost constant since then.

Several studies highlight the growing cross-market correlations within different types of commodities, but also between commodities and other classes of financial assets. UNCTAD (2011), for instance, finds that over 30 days the 1-day rolling correlation between crude oil and other financial assets, like currencies and the S&P 500, has grown steadily since 2004. Tang and Xiong (2011) find similar results by looking at 1-day rolling correlations between crude oil and selected soft and hard commodities over 1-year. These two studies mostly attribute the structural change to the financialization of commodity markets. Tang and Xiong (2011) also argue that portfolio rebalancing by index investors can act as a channel to spillover shocks from outside to commodities markets and across different commodities. By contrast, Stoll and Whaley (2010) and (2011) conclude that commodity index flows, whether due to rolling over existing futures positions or establishing new ones, have little impact on futures prices.

By using daily data, Büyükşahin, Haigh and Robe (2010) document that the correlation between equity and commodity returns increases sharply in the fall of 2008. Nevertheless, the authors argue that there is little evidence of a secular increase in spillovers from equity to commodity markets during extreme events. Using non-public data from the Commodity Futures Trading Commission (CFTC), Büyükşahin and Robe (2011) show that the daily correlation between the returns on commodity and equity indices soared after the demise of Lehman Brothers, and remained exceptionally high through the winter of 2010. Their econometric analyses suggest that, besides macroeconomic fundamentals, hedge fund positions help explain changes in the strength of equity-commodity linkages. Yet, as the authors acknowledge, "hedge funds activities are very diverse", but their data do not allow them to distinguish between the types of hedge fund activities behind these positive correlations. This leaves many unanswered questions regarding the determinants of these growing co-movements, in particular the role of economic fundamentals or of other type of investing strategies.

To our knowledge, we are the first to look at the evolution of commodity markets—including oil, corn, soybeans, wheat, sugar and live cattle—at such high frequencies and to shed some light on the impact of intra-day investment strategies in the context of the new structural change of 2008. This is of importance since the emergence of full electronic trading in many commodity markets in the mid-2000s has paved the way for new types of market participants, including some with very short term investment strategies. Thus, our study adds to Büyükşahin and Robe (2011) by highlighting the growing role in commodities trading of intra-day investment strategies, which typically use algorithm strategies and robots for their operations.[2]

The rest of the paper proceeds as follows: Section I presents the broader context in which this research is incorporated and reviews other related literature. Section II describes our data and methodology. Section III shows the evolution of the co-movements between selected commodities and equities markets. Section IV discusses the results and hypothesizes what could explain this structural change. Section V concludes.

I. Broader context and other related literature

The causes behind the recent sharp price movements of many primary commodities have fuelled an intense debate among academics, asset managers, investment banks, and policy makers. The debate reflects several developments over the last decade. First, large developing economies have experienced a rapid and steady growth, boosting the global demand for primary commodities. Second, large supply shocks like adverse weather and export bans have amplified price movements on some already tight markets. Third, the growing presence of financial investors in the commodity markets has become significant. While these developments are widely acknowledged, the arguments arise when one tries to assess the impacts of these factors on the prices of commodities. In particular, there is debate whether the financialization of commodity trading—which refers to the increasing role of financial motives, financial markets and financial actors in the operation of commodity markets—de-stabilizes these markets.

Investing in commodities through futures markets has gained importance among financial investors after the burst of the dot-com bubble, as these agents looked for a new asset class to diversify their portfolio and reduce their risks. The publication of the seminal paper by Gorton and Rouwenhort (2006) entitled "Facts and Fantasies about Commodities" supported this diversification strategy. Using monthly returns spanning the period from July 1959 to March 2004, the authors found that commodity futures have historically offered the same return and Sharpe ratio as

[2] Büyükşahin and Robe (2011) data do not track the activities of market participants who do not hold position at the end of the day, because these actors do not have the obligation to report to the CFTC.

equities but are negatively correlated with equity and bond returns owing to different behaviour over the business cycle.[3] In parallel, investment in commodities became a common part of a large investor portfolio allocation, while commodity indexes saw their assets under management soar. From less than \$10 billion around the end of the last century, commodity assets under management reached a record high of \$450 billion in April 2011 (Institute of International Finance, 2011). In the meantime, commodity investment specialists, asset managers and investment banks have created new products linked to commodities to satisfy the demand from investors.

Consequently, the volumes of exchange-traded derivatives on commodity markets are now twenty to thirty times greater than physical production (Silvennoinen and Thorp, 2010). By contrast, in the 1990s, financial investors accounted, on average, for less than 25 per cent of all market participants. Today, in some extreme occurrences, financial investors represent more than 85 per cent of all commodity futures market participants (Masters, 2008).

The last decade was also characterized by significant technical developments in the trading platforms of commodity exchanges. Pit trading became more marginal and full electronic trading, which allows almost uninterrupted trading around the clock, has been introduced on the main commodity exchanges since 2005. Due to lower transaction costs, electronic trading led to an increase in the number of transactions and the volumes involved. Full electronic trading also paved the way for high frequency trading (HFT) and algorithm trading activities.

The benefits of these evolutions have been debated. On the one hand, the proponents would usually argue that the presence of these new types of agents in commodities markets would ease the price discovery problem and bring the price closer to its underlying fundamentals. In addition, it would provide further liquidity and transfer risks to agents who are better prepared to assume it. On the other hand, a growing number of studies provide evidence of price distortions linked to the financialization of commodity markets (see UNCTAD, 2011: chapter 4.5, for an overview). Most of these studies base their analysis on index trading. However, since 2008/2009, investors prefer more active investment strategies on commodity markets than simple index trading (UNCTAD, 2011). Looking at intra-day data and cross-markets correlations is one way to get a better grasp of some recent developments that have affected the commodity markets.

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[3] The Sharpe ratio is a measure of the excess return per unit of deviation in an investment asset or a trading strategy, typically referred to as risk. It is defined as: $S = \frac{E[R - R_f]}{\sqrt{\mathrm{var}[R - R_f]}}$, where R is the asset return, R_f is the return on a benchmark asset, such as the risk free rate of return, $E[R - R_f]$ is the expected value of the excess of the asset return over the benchmark return, and $\sqrt{\mathrm{var}[R - R_f]}$ is the standard deviation of the excess of the asset return.

II. Data and methodology

a. Data

The TRTH database provides financial data for a wide range of financial instruments based on the information transmitted by exchanges and market makers. TRTH contains historical data back to January 1996 of granular tick as well as lower frequency pricing data, up to the microsecond level. In particular, TRTH offers full tick, global, intra-day time and sales, time and quotes and market depth data covering an extensive range of asset classes with more than 45 million unique instruments across more than 400 exchanges. The database provides also over-the-counter (OTC) quotes and offers the most comprehensive pricing and reference data service. It provides a precise record of market behaviour and manages 2 petabytes (i.e. $2 \cdot 10^{15}$ bytes or 2 million gigabytes) of tick data.

In this study, we limit ourselves to a few instruments. We select one of the most liquid equity derivatives, the E-mini S&P 500 futures, and derivative contracts of selected commodities, namely: light crude oil WTI (NYMEX), corn (CBOT), wheat (CBOT), sugar #11 (ICE - US), soybeans (CBOT) and live cattle (CME).[4] These commodity futures contracts represent the commonly used benchmarks for the world or the United States for their respective markets.

Table 1 summarizes the main characteristics for each future contract. Each derivative contract has an underlying physical asset described in the "Specification" column and arrives at maturity on specific dates in the future, which we refer to as "Contract month". Several derivatives referring to the same underlying asset are traded in parallel during the trading sessions but are differentiated by their maturity dates (i.e. E-mini S&P500 March 2012, E-mini S&P June 2012, etc.). The front months for each derivative usually have the greatest liquidity. For each selected derivative, TRTH computes the continuous contract by taking the front month and rolling over to the next contract at expiry. We consider for our study these continuous front month futures spanning between 1996 and 2011.

For our study, we compute cross-market rolling correlation between the E-mini S&P500 and the selected commodity derivatives. The E-mini futures are traded on the Chicago Mercantile Exchange (CME) electronic platform Globex. Since its launch in 1997, the E-mini S&P 500 futures have become the most traded index futures contracts in the world. The majority of traders prefer the mini futures to the futures because of its reduced size.[5] Unlike the S&P 500 futures, which still use the open

[4] In parenthesis, the various acronyms stand for the exchanges names where the contract is traded. More precisely: CBOT (Chicago Board of Trade), ICE - US (Intercontinental Exchange - United States), NYMEX (New York Mercantile Exchange), CME (Chicago Mercantile Exchange).

[5] The value of the S&P 500 futures was originally 500 times the S&P 500 index which was too large for many traders. Consequently the CME introduced the E-mini future on the S&P 500 which trades at a value of 50 times the underlying equity index.

outcry during business hours on weekdays,[6] trading on the E-mini is only electronic. This represents another advantage for hedge funds, algorithm traders and high frequency traders wishing to implement fully automated investment strategies.

Table 1: Description of the selected instruments

Abbreviations	Specification	Exchange and Trading Platform	Contract Month	Recent monthly exchanged volumes (in million of contracts)	Remarks
E-mini S&P 500	50 x E-mini S&P 500 futures price	CME / CME Globex	March, June, September, December	45-52	The most traded index futures in the world
WTI	1,000 barrels of light sweet crude oil	NYMEX / CME Globex	Every month	10-14	The most actively traded energy product in the world
Corn	5,000 bushels (~ 127 Metric Tons)	CBOT / CME Globex	March, May, July, September and December	5-9	
Soybean	5,000 bushels (~136 metric tons)	CBOT / CME Globex	January, March, May, July, August, September and November	4-3	
Wheat	5,000 bushels (~ 136 Metric Tons)	CBOT / CME Globex	March, May, July, September and December	1-2	
Sugar #11	112,000 pounds	ICE - US / ICE electronic platform	March, May, July and October	1-3	The world benchmark for raw sugar trading
Live Cattle	40,000 pounds (~18 metric tons)	CME / CME Globex	February, April, June, August, October and December	0.8-1.5	

As we mentioned, TRTH collects ticks from the various exchange feed. Table 2 summarizes the number of ticks for each year and each derivative contract. We consider only ticks that represent an actual trade. Thus, we do not consider quotes. The emergence of full electronic trading in the course of 2006 on the considered commodity exchanges marks the beginning of an increase in the amount of ticks

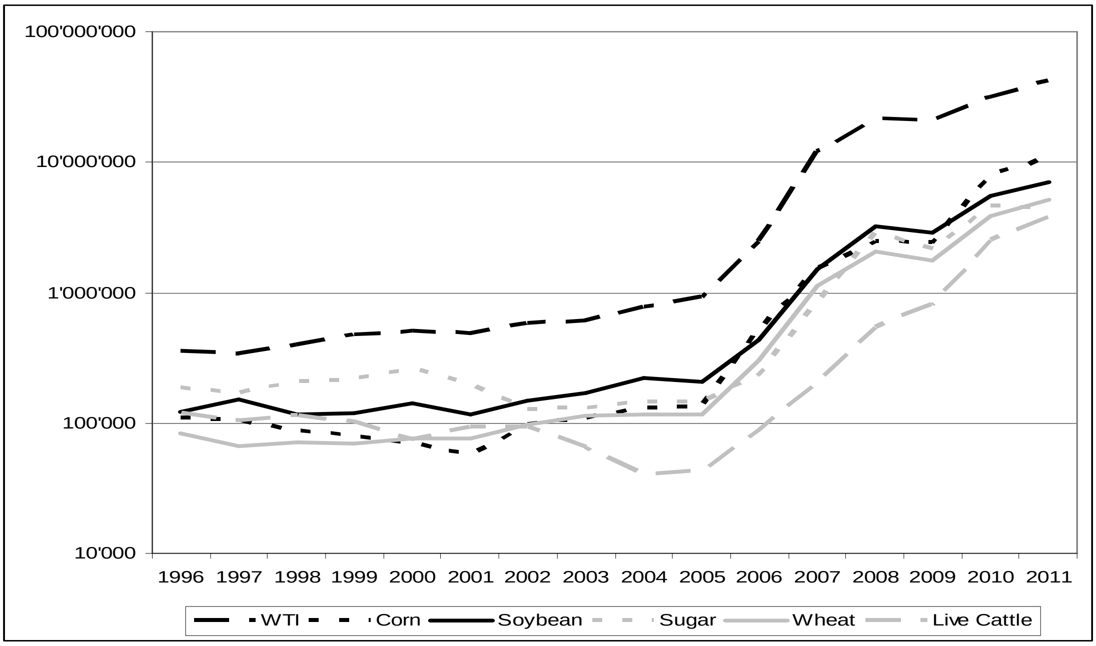
[6] Currently, the S&P 500 futures trades at a value of 250 times the index and continues to have an open outcry session during weekdays from 8:30 a.m. to 3:15 p.m. (see http://www.cmegroup.com/trading/equity-index/us-index/sandp-500_contract_specifications.html)

(Figure 1). Indeed, between 2005 and 2007, we observe an increase of ticks from about 380 per cent up to 1200 per cent. For the period between 2007 and 2011, the increase remains substantial, ranging from about 160 per cent to 1100 per cent. The overall expansion from 2005 to 2011 is situated between about 800 per cent and 6000 per cent and is largely due to the emergence of electronic trading and to some extent to the extension of the platforms opening hours.

Table 2: Number of trades recorded in the Thomson Reuters Tick History database by instruments and by year, 1996-2011

Year	E-mini S&P 500	WTI	Corn	Soybean	Sugar	Wheat	Live Cattle
1996	N/A	356'681	108'708	120'320	183'682	83'191	118'111
1997	344'463	338'510	104'159	153'111	168'981	66'190	102'963
1998	1'801'293	393'969	87'849	116'833	207'079	70'855	113'616
1999	3'826'763	477'315	79'392	118'535	216'969	70'171	101'261
2000	5'886'735	506'757	70'092	141'714	259'995	75'969	74'306
2001	8'454'680	485'506	56'622	115'783	198'621	75'368	93'263
2002	14'861'346	575'768	98'294	147'353	125'984	96'301	93'924
2003	14'087'856	606'150	107'870	171'547	128'593	112'802	64'885
2004	11'464'899	765'729	129'598	220'966	146'773	117'236	40'022
2005	11'440'985	920'636	133'390	208'292	145'053	116'062	43'618
2006	11'099'193	2'473'336	514'536	437'522	237'274	306'653	88'929
2007	22'199'625	11'977'928	1'502'759	1'513'150	853'963	1'126'673	209'100
2008	49'623'225	21'485'557	2'473'190	3'219'628	2'884'089	2'060'812	540'087
2009	41'782'313	21'157'094	2'412'398	2'871'907	2'167'801	1'765'585	803'894
2010	107’371’791	31'654'954	8'130'368	5'520'895	4'572'232	3'886'602	2'505'924
2011	121’069’682	41'943'006	10'716'091	7'021'293	4'513'119	5'101'041	3'785'946
Total	425'314'849	136'118'896	26'725'316	22'098'849	17'010'208	15'131'511	8'779'849

Figure 1: Number of trades recorded in the Thomson Reuters Tick History database by commodity, 1996-2011



Source: Thomson Reuters Tick History database

b. Methodology

We compute the log returns of the mean prices at 1-hour, 5-minute, 10-second and 1-second intervals. Then we calculate a moving-window correlation coefficient (MWC) at time (*t*) between two series (*rx* and *ry*) at frequency (*f*) with a window width set to 15:[7]

$$MWC\_rx,ry\_t = \frac{\sum_{i=0}^{14}\left(rx_{t-i}-\overline{rx}\right)\left(ry_{t-i}-\overline{ry}\right)}{\sqrt{\sum_{i=0}^{14}\left(rx_{t-i}-\overline{rx}\right)^{2}\sum_{i=0}^{15\cdot f-1}\left(ry_{t-i}-\overline{ry}\right)}}$$, where $rz_t = \ln(\frac{z_t}{z_{t-1}})$, $\overline{rz} = \frac{\sum_{i=0}^{14} rz_{t-i}}{15}$ and

z_t reflects the average of the actual trade prices taking place on the exchange of the asset *z* during the time interval $]t-f;t]$, $,\forall z = x, y$.

To avoid misleading conclusions owing to a composition effect in our data, we exclude weekend observations because there is no trade during these days in the years prior to the introduction of electronic trading.

Table 3 describes the distribution of the MWCs for each frequency over the years or the times of the day. For our lowest frequency, 1-hour, the distributions are more uniform. The higher the frequency, the less uniform the distributions according to these two parameters. The computation of one MWC requires a full set of trading transactions on both markets over five successive periods for the 1-hour MWC (see footnote 7) and fifteen successive periods for the three higher frequencies. As a result, there are few or no observations for many years prior to the introduction of electronic trading, particularly at the 10- and 1-second frequencies. For the time of the day, the distributions of the 10- and 1-second MWCs, are concentrated between 1 p.m. and 6 p.m. GMT, which coincides with the periods when the market activity is the most intense, i.e. during working hours in Europe and the United States. For lower frequencies, like the 5-minute one, the differences along these two parameters matter less. Indeed, at least one trading transaction is likely to take place during each of the 15 successive 5-minute intervals, no matter what time of the day, except between the closure of the American and the opening of the Asian markets. Basic calculations show that we obtain an almost full set of data during the last years of the sample for the two lowest frequencies we consider.[8]

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7 As we did not allow gaps within the observations of a given window when computing the rolling correlation coefficients, the width of the window could not be too long, especially in the early years of the sample, when trade was less frequent. Yet, we refrained ourselves from picking a shorter width of the window, which could potentially capture more the impact of "one time" instantaneous reaction to news, shocks, etc. For 1-hour frequency, we set the width of the window to 5, since prior to electronic trading, exchange places were not open for such a long time period on a daily basis.

8 The amount of weekdays per year is approximately 250. This means that a full set of data will correspond approximately to 6,000 (=250·24) and 72,000 (=250·24·12) for 1-hour and 5-minute data, respectively. For 2010, our sample contains 5,538 and 59,584 MWCs for 1-hour and 5-minute series, respectively.

Table 3: Distribution of the moving-window correlation coefficient between the returns on the WTI and the E-mini S&P 500 futures (front month), by years or time of day, and the total number of observations, by frequency

		Frequency			
		1-hour	5-minute	10-second	1-second
Year	1997*	0.67	0.71	0.00	-
	1998	3.24	2.62	0.06	-
	1999	3.93	2.89	0.16	-
	2000	4.10	2.91	0.20	-
	2001	4.63	2.59	0.22	-
	2002	4.71	2.45	0.35	-
	2003	7.37	2.80	0.34	-
	2004	8.28	3.60	0.62	-
	2005	8.60	4.71	0.43	-
	2006	8.89	6.35	2.04	0.07
	2007	9.05	10.97	13.16	4.31
	2008	9.13	13.39	19.53	21.70
	2009	9.15	14.32	19.39	22.32
	2010	9.12	14.82	20.38	24.27
	2011	9.13	14.89	23.11	27.34
Time of day, hour GMT	0	4.03	1.83	0.03	-
	1	3.92	2.81	0.04	0.00
	2	3.86	3.01	0.04	0.00
	3	3.71	2.73	0.02	-
	4	3.59	2.53	0.02	-
	5	3.44	2.79	0.02	-
	6	4.18	2.93	0.11	0.00
	7	4.13	3.33	0.76	0.01
	8	4.14	4.04	1.15	0.01
	9	4.16	4.55	0.75	0.00
	10	4.24	4.81	0.74	0.01
	11	4.38	4.91	1.31	0.06
	12	4.48	5.19	4.87	2.14
	13	4.39	5.20	11.02	18.39
	14	4.25	4.38	15.67	31.23
	15	4.28	6.82	16.37	20.52
	16	4.29	9.56	14.23	8.74
	17	4.27	9.90	13.38	5.14
	18	4.24	8.92	12.21	9.40
	19	4.50	6.07	6.03	4.28
	20	4.70	2.37	1.13	0.06
	21	4.43	0.45	0.09	0.01
	22	4.24	0.02	0.00	-
	23	4.14	0.85	0.00	-
# observations		60,753	402,183	2,546,114	788,625

Notes: *Our sample starts on 23 September 1997. "–" indicates no observation.
Source: Thomson Reuters Tick History database

III. Results

In this section, we use boxplots to describe the distribution of the rolling correlations between the E-mini S&P 500 and various commodity futures at various frequencies.[9] Boxplots are a convenient way to represent the evolution of the correlation distribution over time by providing five descriptive statistics. The bottom and top of the box correspond to the lower (Q1) and upper (Q3) quartiles, respectively; the

[9] Most commodity derivatives are not liquid enough to compute rolling correlation at the 1 second frequency, the only exception being crude oil.

band near the middle of the box is the median (Q2); the ends of the whiskers represent the lowest datum still within 1.5 interquartile range (IQR) of the lower quartile, and the highest datum still within 1.5 IQR of the upper quartile. Any other datum lying outside the two whiskers is considered to be an outlier and is represented by a dot.

We start by looking at crude oil by focusing mainly on 1-hour, 5-minute, 10-second and 1-second time intervals. Then, we present similar results for five types of soft commodities using correlations at 5-minute intervals.

a. Crude oil

Figures 2 *a*, *b*, *c* and *d* present the evolution between 1997 and 2011 of the rolling correlations between the WTI and the E-mini S&P 500 futures, at 1-hour, 5-minute and 10-second, respectively.[10] For the sake of comparison, we also provide the 1-day rolling correlations chart.

In contrast with daily data—which somehow show a growing positive correlation between the S&P 500 and the WTI from 2005 onwards (only temporarily interrupted in 2008)—, higher-frequency data do not exhibit any change of structure prior to 2009. The median correlation in figures 2*b* to 2*d* remains close to zero up to 2008. Afterwards, the median correlations become strongly positive and remain close to 0.5.

In order to better grasp the precise timing of this structural change, Figures 3 *a*, *b*, *c* and *d* decompose these distributions over months between January 2007 and December 2011. Focusing on this sub-period also allows us to present the 1-second rolling correlations.

Overall, there is no real departure from zero until the second quarter of 2008. At the 1-hour frequency, the median of the correlations, between January 2007 and March 2008 inclusive, corresponds to 0.11. For higher frequencies, it is even closer to zero. It corresponds to 0.06, 0.03 and 0.003, for 5-minute, 10-second and 1-second, respectively.

Afterwards, a radical change takes place. The median rolling correlations exhibit a temporary U-shaped negative pattern during the second and third quarter of 2008. Visually, the departure from zero seems to differ according to the frequency: the higher the frequency, the later and the smaller the negative pattern. Then, the correlation between both series switches to positive territory. It increases significantly in late September, and early October 2008. At the 10-second frequency, for instance, the medians of monthly correlations are closely centred on zero up to May 2008. Then, they become negative from June until early September 2008; afterwards they increase sharply, with a median of the correlations corresponding to 0.32 in October 2008. By using weekly boxplots, we find that the sharp rise of the

[10] There is not enough liquidity in the years prior to 2006 to compute any rolling-correlation at 1-second intervals.

correlations occurred during the second half of September and early October 2008, which coincides with an extremely tense period on financial markets following the collapse of Lehman Brothers.[11] This strong positive correlation persists over time with a brief exception between February and April 2011. At 10-second frequency, the median of the correlations has remained at 0.28 from November 2008 to January 2011. Afterwards, the median of the correlations decreased to 0.08 during the 2011m2-2011m4 period, which coincides with the beginning of the uprising in Libya. Later on, it moved back to previous levels and even increased in magnitude up to around 0.62 in September 2011 (the decline of the IQR reflects a smaller dispersion of the rolling correlations).

[11] Results are available upon request.

Figure 2*a*: Annual distribution of the 1-day rolling correlations computed over 15 days between the returns on the WTI and the E-mini S&P 500 futures (front month), 1997-2011

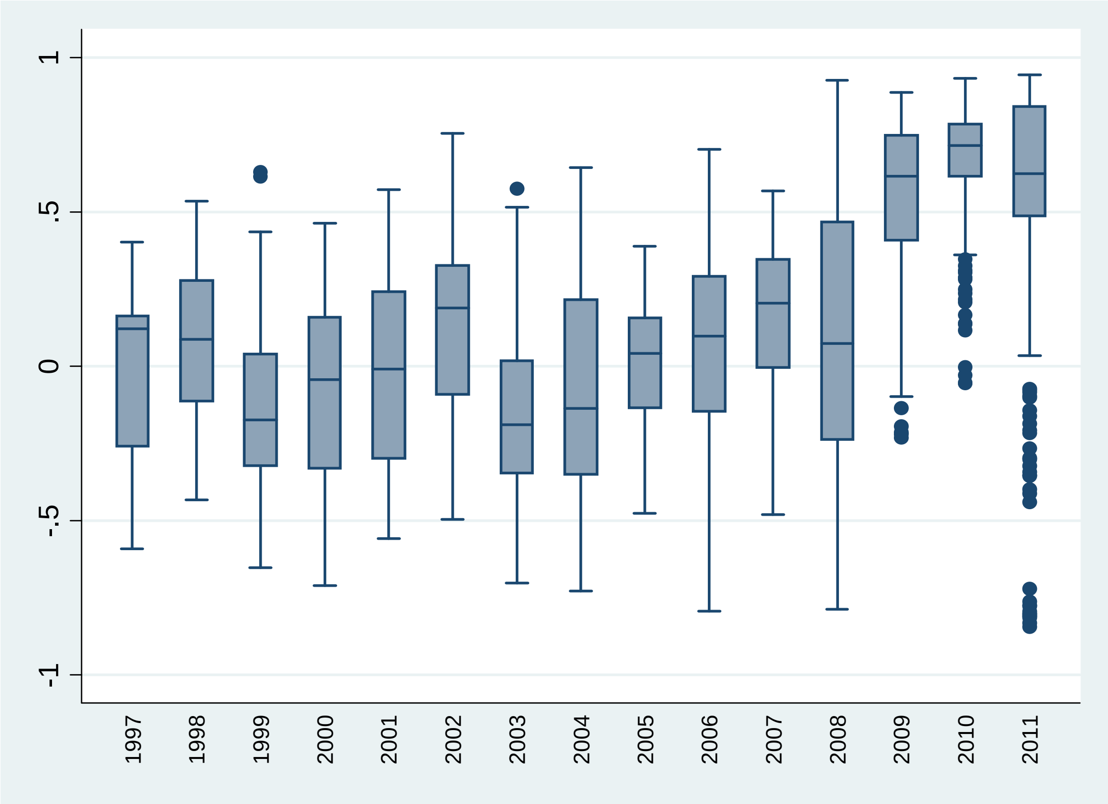
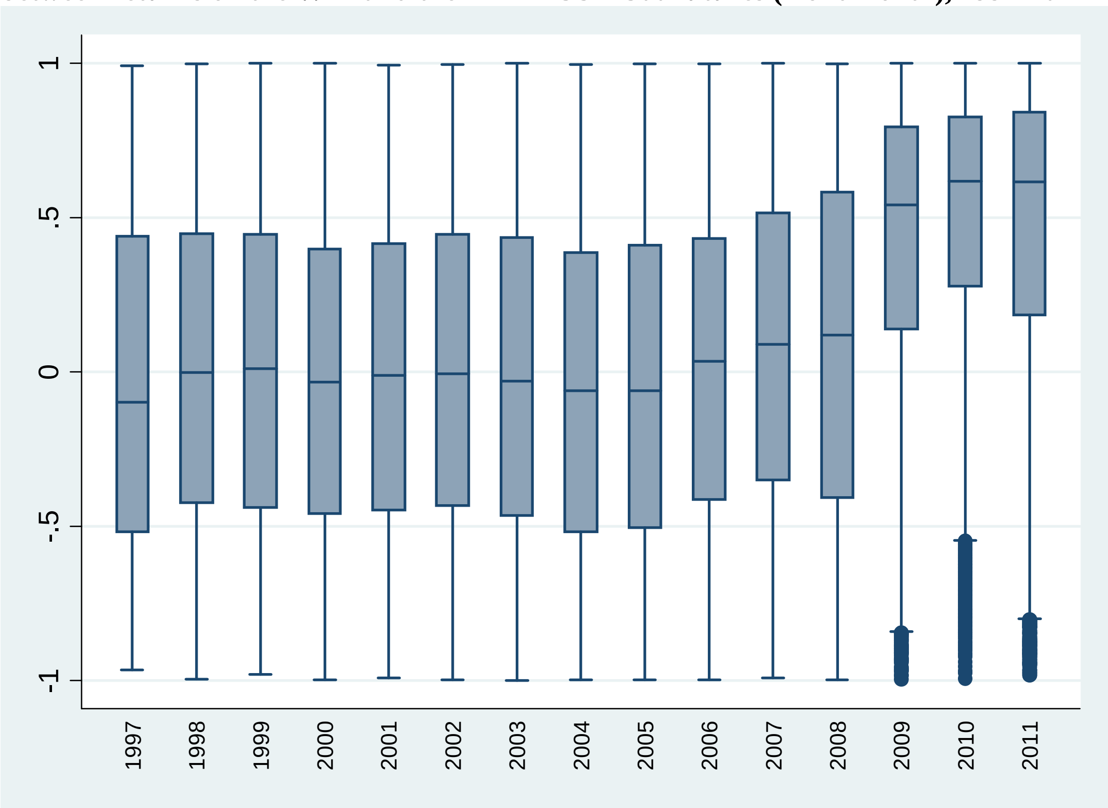


Figure 2*b*: Annual distribution of the 1-hour rolling correlations computed over 5 hours between returns on the WTI and the E-mini S&P 500 futures (front month), 1997-2011



Source: authors' calculations based on Thomson Reuters Tick History database

Figure 2*c*: Annual distribution of the 5-minute rolling correlations computed over 75 minutes between the returns on the WTI and the E-mini S&P 500 futures (front month), 1997-2011

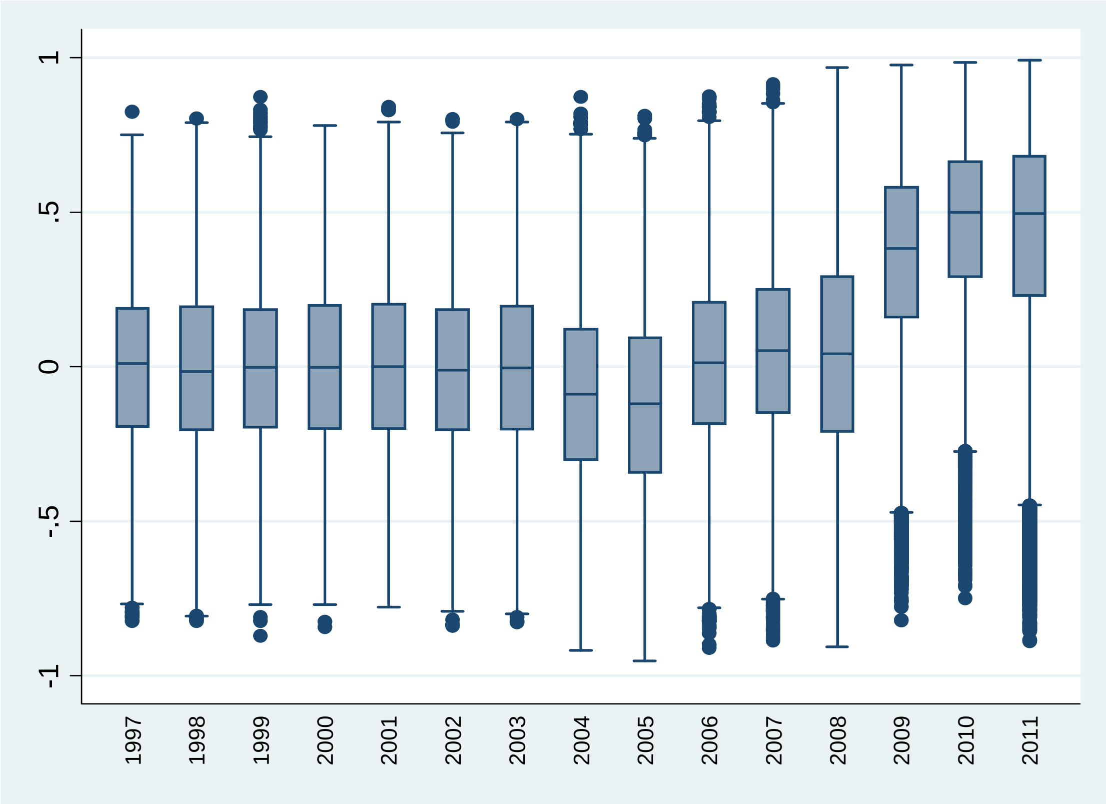
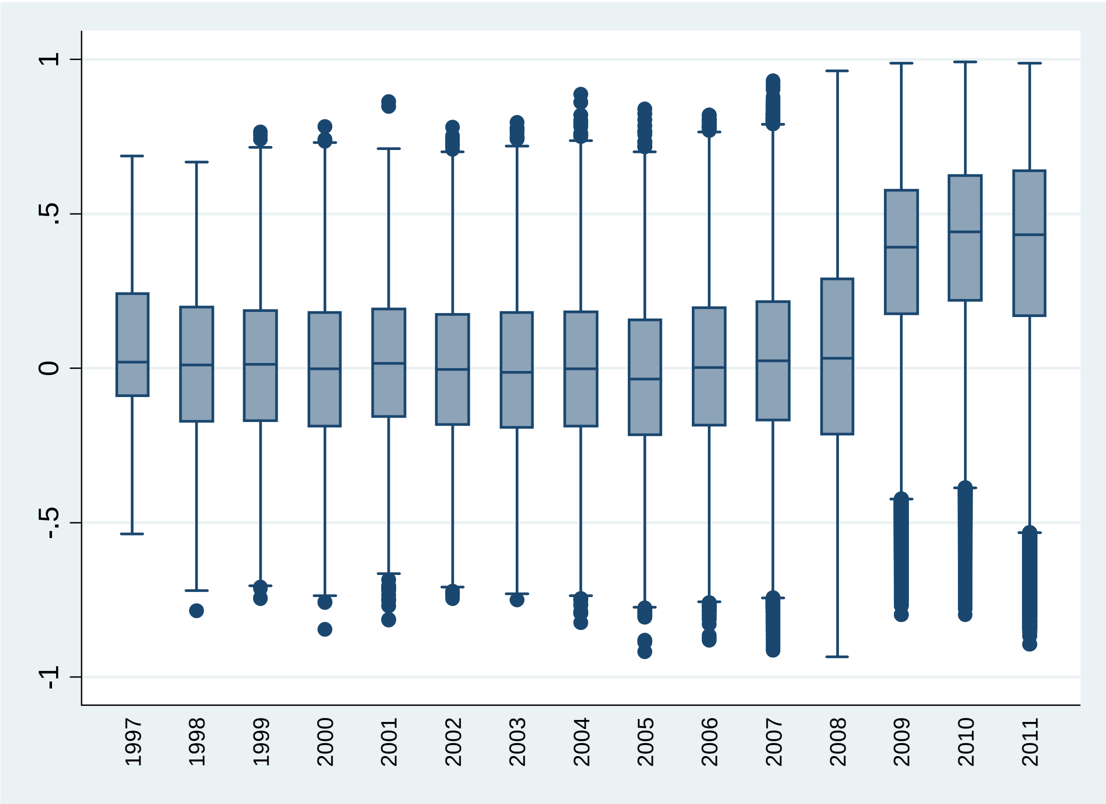


Figure 2*d*: Annual distribution of the 10-second rolling correlations computed over 150 seconds between the returns on the WTI and the E-mini S&P 500 futures (front month), 1997-2011



Source: authors' calculations based on Thomson Reuters Tick History database

Figure 3*a*: Monthly distribution of the 1-hour rolling correlations computed over 5 hours between the returns on the WTI and the E-mini S&P 500 futures (front month), 2007m1-2011m12

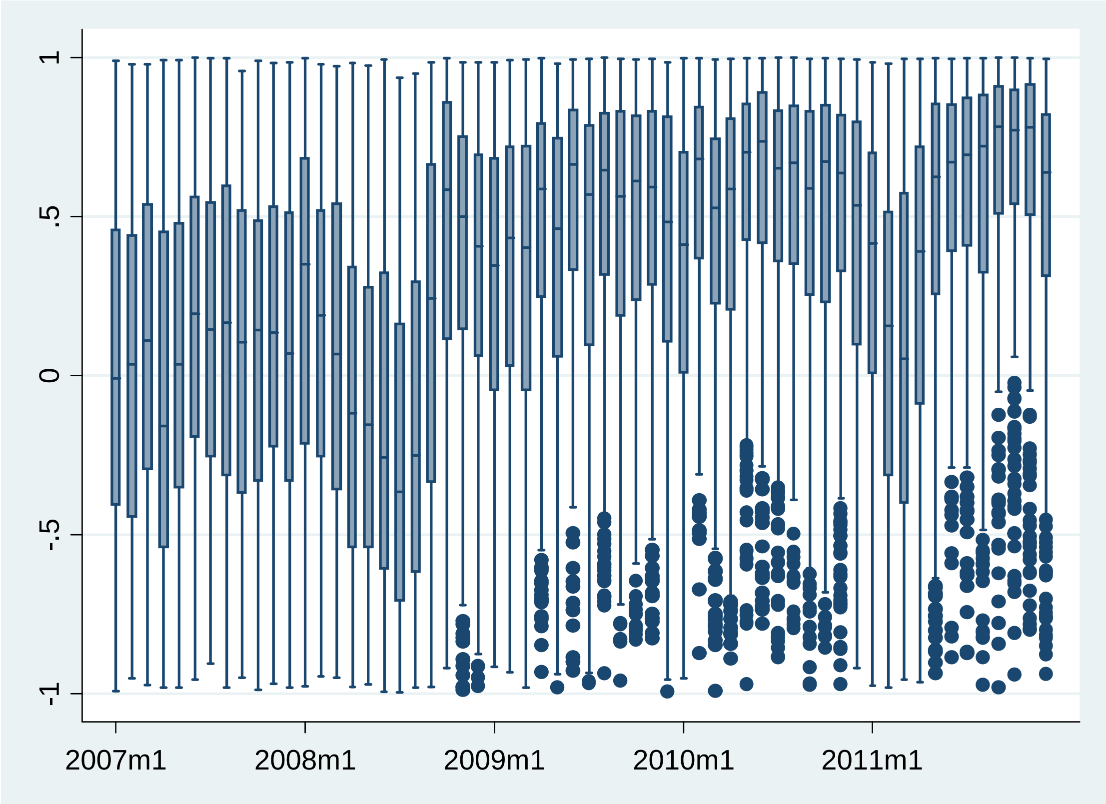
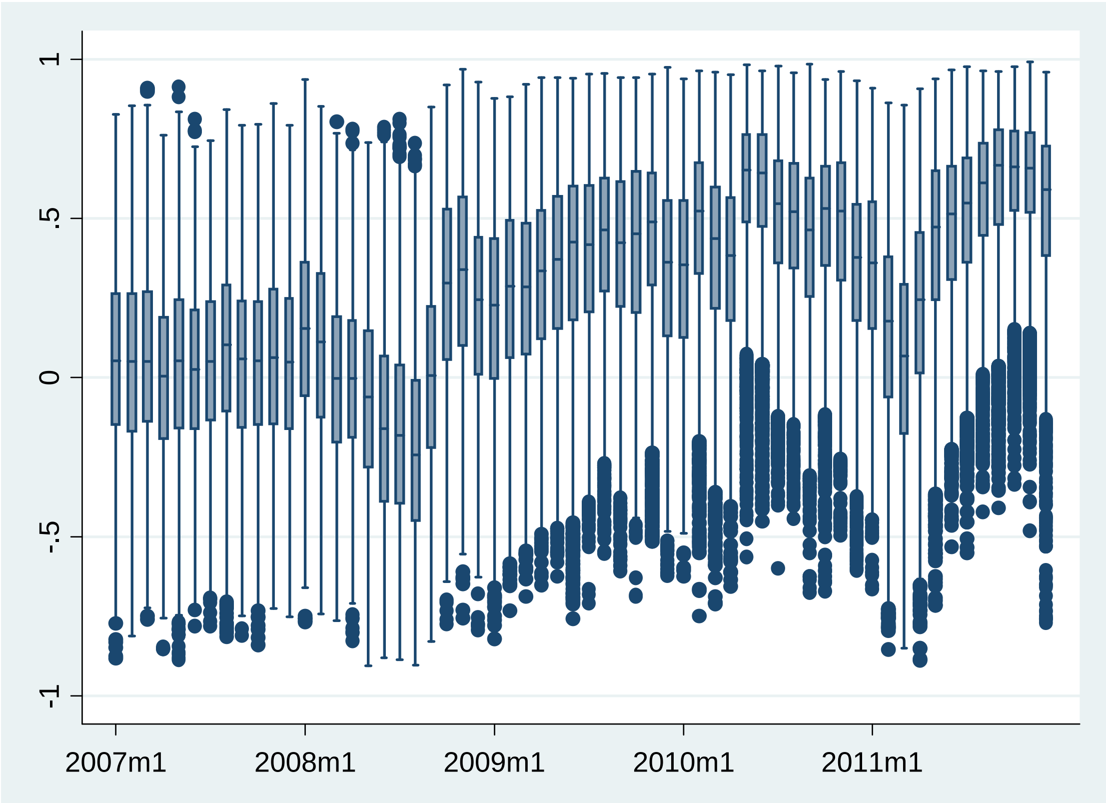


Figure 3*b*: Monthly distribution of the 5-minute rolling correlations computed over 75 minutes between the returns on the WTI and the E-mini S&P 500 futures (front month), 2007m1-2011m12



Source: authors' calculations based on Thomson Reuters Tick History database

Figure 3*c*: Monthly distribution of the 10-second rolling correlations computed over 150 seconds between the returns on the WTI and the E-mini S&P 500 futures (front month), 2007m1-2011m12

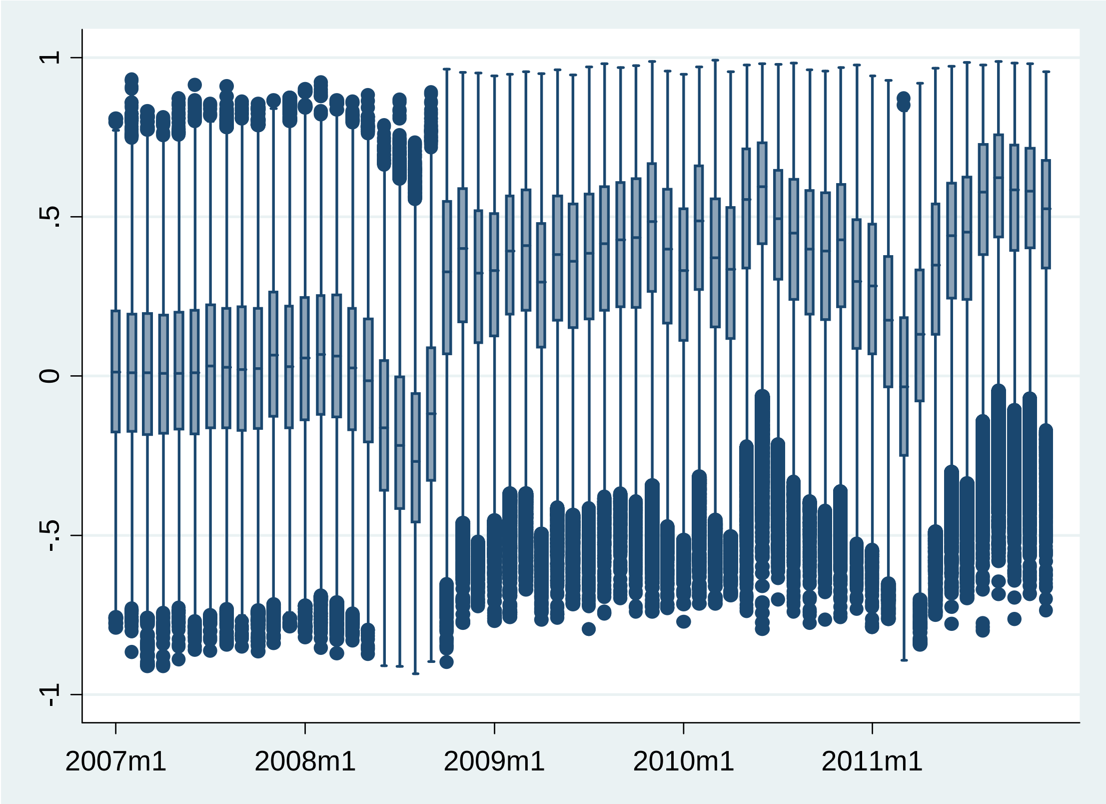
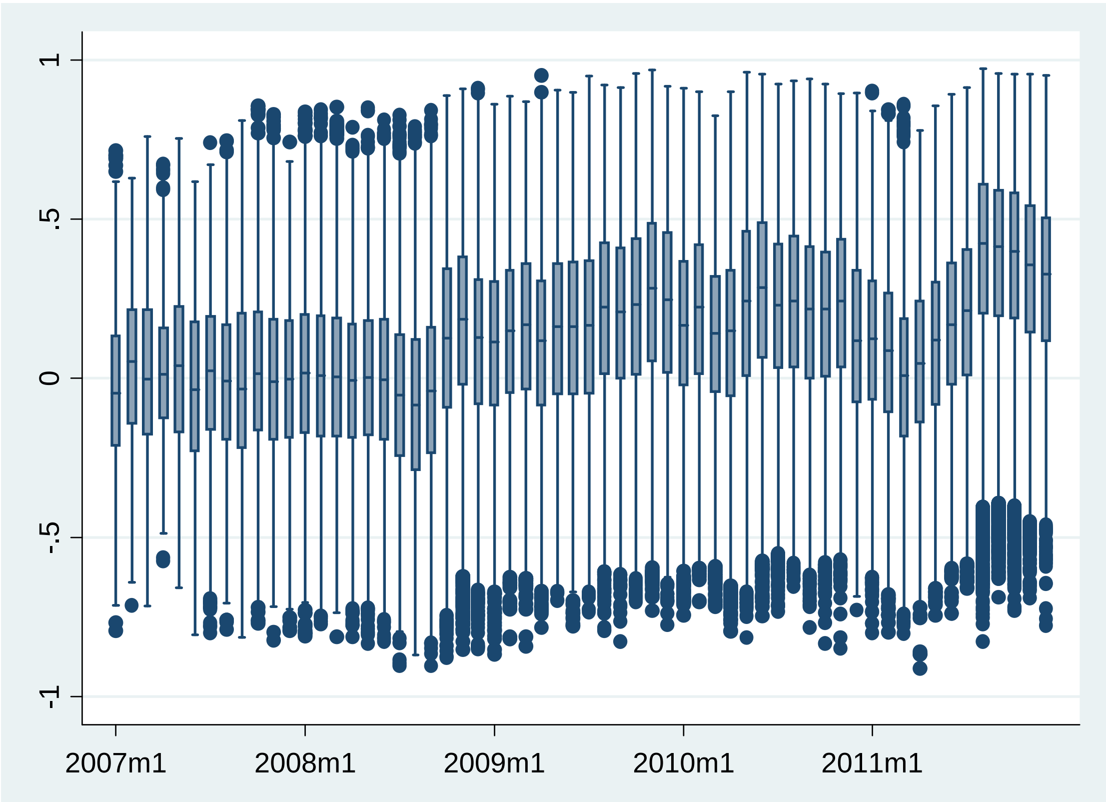


Figure 3*d*: Monthly distribution of the 1-second rolling correlations computed over 15 seconds between the returns on the WTI and the E-mini S&P 500 futures (front month), 2007m1-2011m12



Source: authors' calculations based on Thomson Reuters Tick History database

b. Soft commodities

We find similar results when we look at the correlation between the E-mini S&P 500 futures and other soft commodities futures. More precisely, we selected the five commodities included in the S&P GSCI index that have the biggest weight among the five non-energy and non-metals sub-indices. Four are part of the agriculture sub-index, namely wheat, corn, soybeans and sugar, while the fifth is part of the livestock sub-index and corresponds to live cattle. Altogether, these five components account for about three fourths of the total weight of the non-energy and non-metals sub-indices.[12]

We consider soft commodities because their economic fundamentals are supposed to differ even more from the US equities market than the ones for crude oil. Yet, all these commodities present a change in correlation levels occurring in September and October 2008. Figures 4*a* to 4*e* illustrate our point using 5-minute rolling correlation by month for corn, soybeans, wheat, sugar and live cattle, by focusing again on the 2007-2011 period. Prior to 2007, the trends are similar to the one observed for the WTI. The choice of the 5-minute interval was motivated by a trade-off between frequency and data availability. Yet, we also obtain similar patterns at the 10-second frequency, for the corn, the soybeans and the wheat futures. At 1-second, no clear change emerges, since there are too few observations at that frequency.[13]

In contrast with the WTI, there is no clear decline of the correlations during the 2011m2-2011m4 period. This reinforces our hypothesis that the temporary decline we observed during these months was related to the uprising in oil-producing Libya. Another distinction with the WTI refers to the smaller magnitude of the median correlations that emerge at the end of the third quarter of 2008 on these soft commodities, even though the co-movements remain positive. Nevertheless, in the second half of 2011, the correlations strengthen like in the WTI case.

[12] Among the non-energy and non-metals components of the S&P GSCI index, corn, (Chicago) wheat, live cattle soybeans and sugar accounted for 17.6%, 16.8%, 14.2%, 12.5% and 12.2%, respectively.
[13] In the case of corn, the most liquid soft commodity we analyse, there are, for instance, only two episodes of 15 seconds in December 2009 with at least one trade taking place at every second.

Figure 4*a*: Monthly distribution of the 5-minute rolling correlations computed over 75 minutes between the returns on the CBOT Corn and the E-mini S&P 500 futures (front month), 2007m1-2011m12

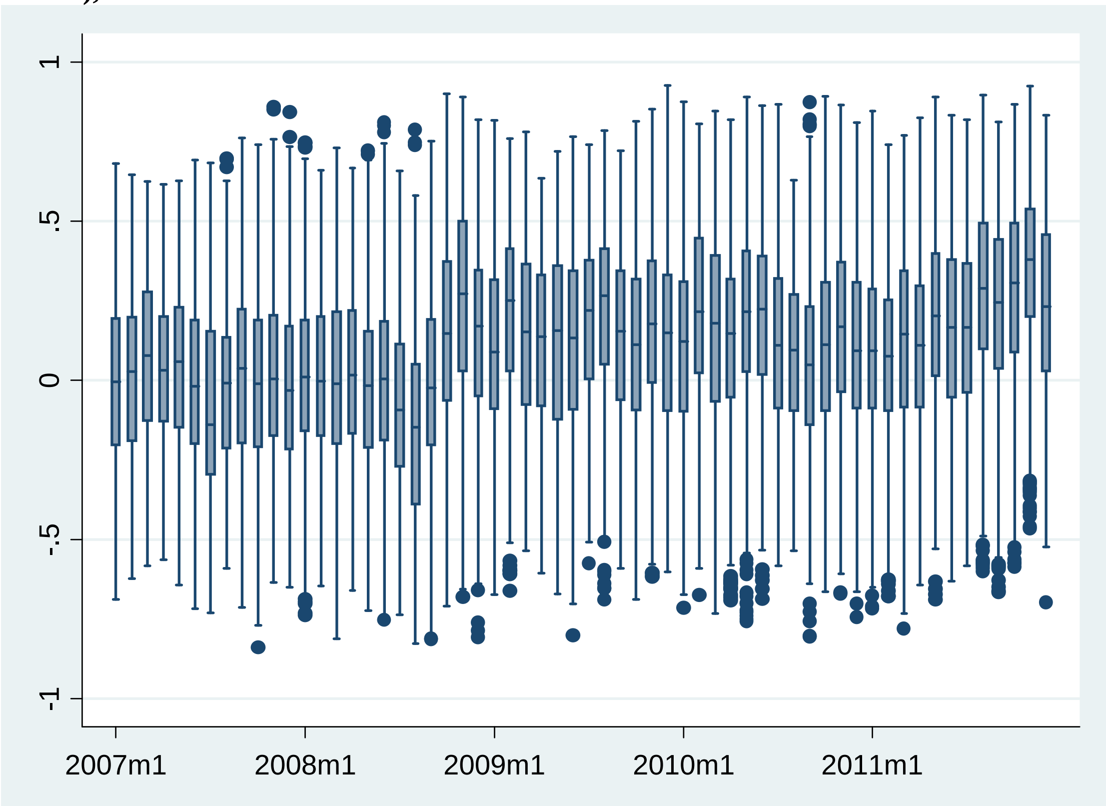
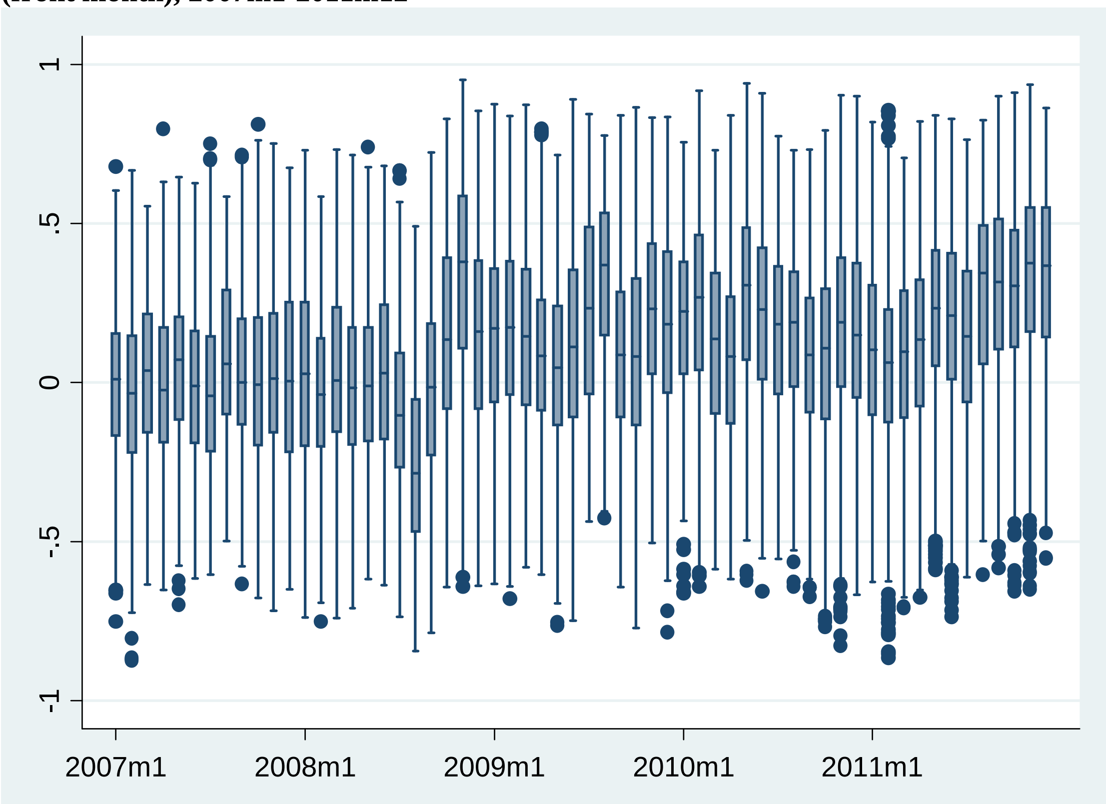


Figure 4*b*: Monthly distribution of the 5-minute rolling correlations computed over 75 minutes between the returns on the CBOT soybeans and the E-mini S&P 500 futures (front month), 2007m1-2011m12



Source: authors' calculations based on Thomson Reuters Tick History database

Figure 4*c*: Monthly distribution of the 5-minute rolling correlations computed over 75 minutes between the returns on the CBOT wheat and the E-mini S&P 500 futures (front month), 2007m1-2011m12

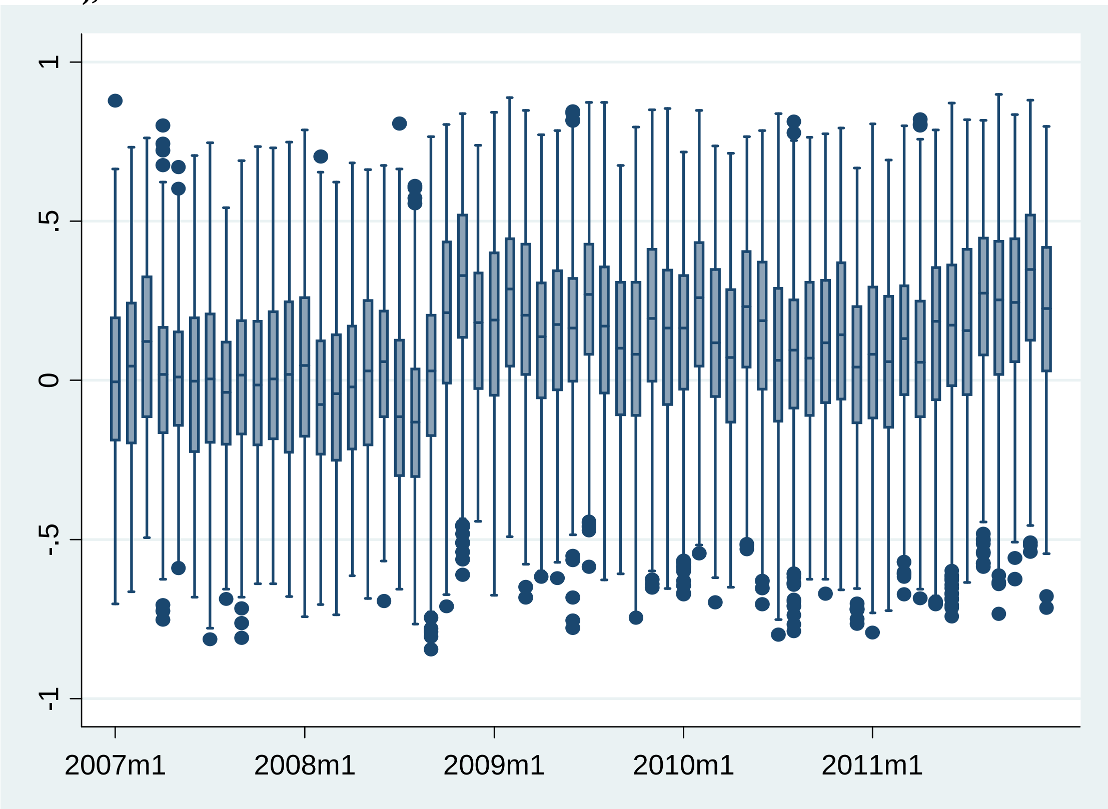
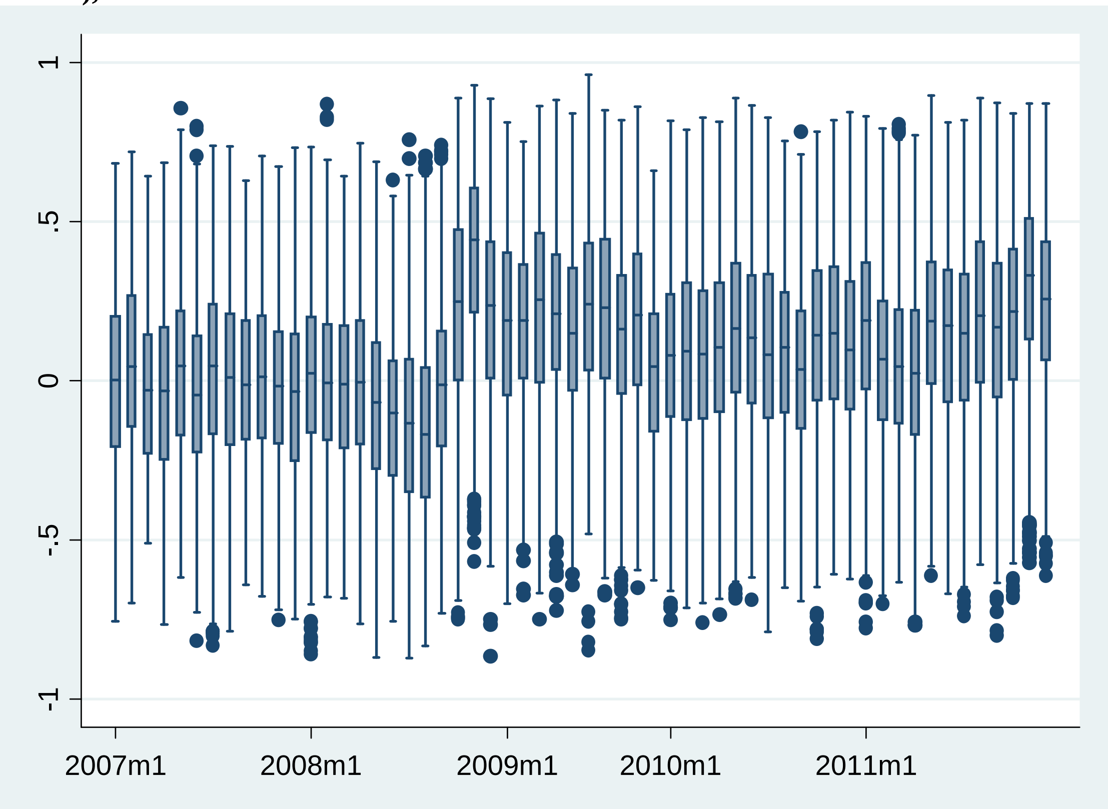
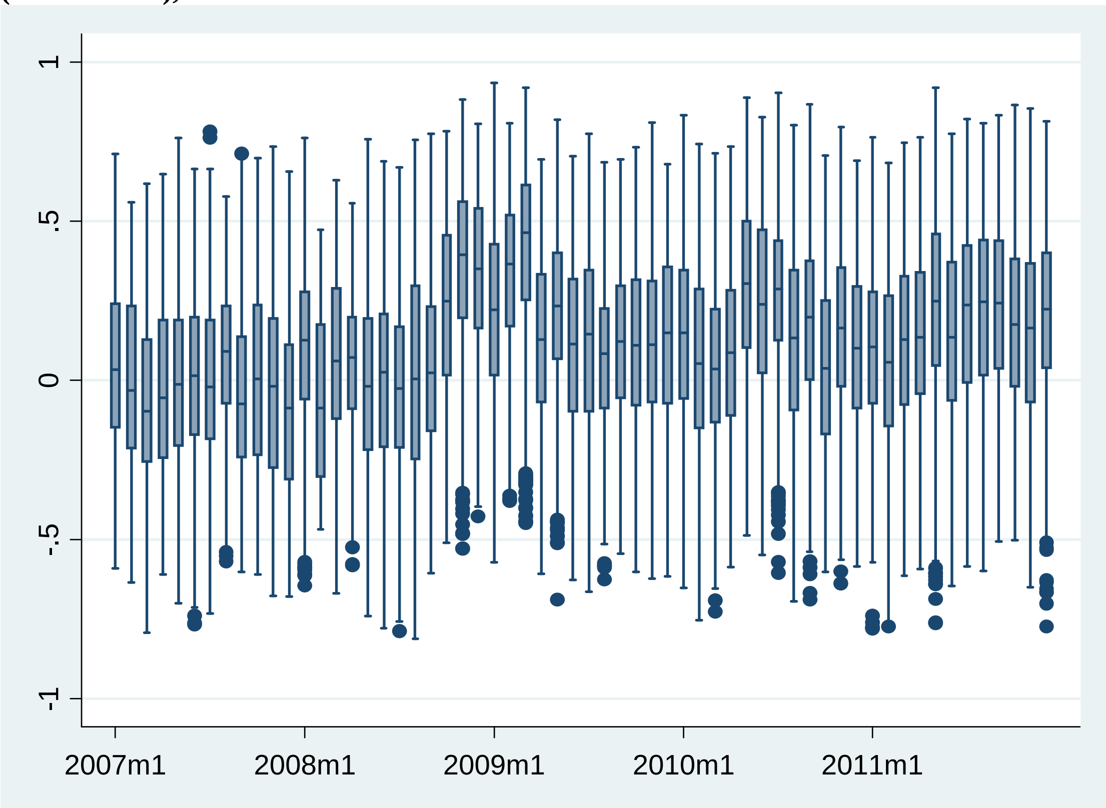


Figure 4*d*: Monthly distribution of the 5-minute rolling correlations computed over 75 minutes between the returns on the ICE Sugar and the E-mini S&P 500 futures (front month), 2007m1-2011m12



Source: authors' calculations based on Thomson Reuters Tick History database

Figure 4*e*: Monthly distribution of the 5-minute rolling correlations computed over 75 minutes between the returns on the CME live cattle and the E-mini S&P 500 futures (front month), 2007m1-2011m12



Source: authors' calculations based on Thomson Reuters Tick History database

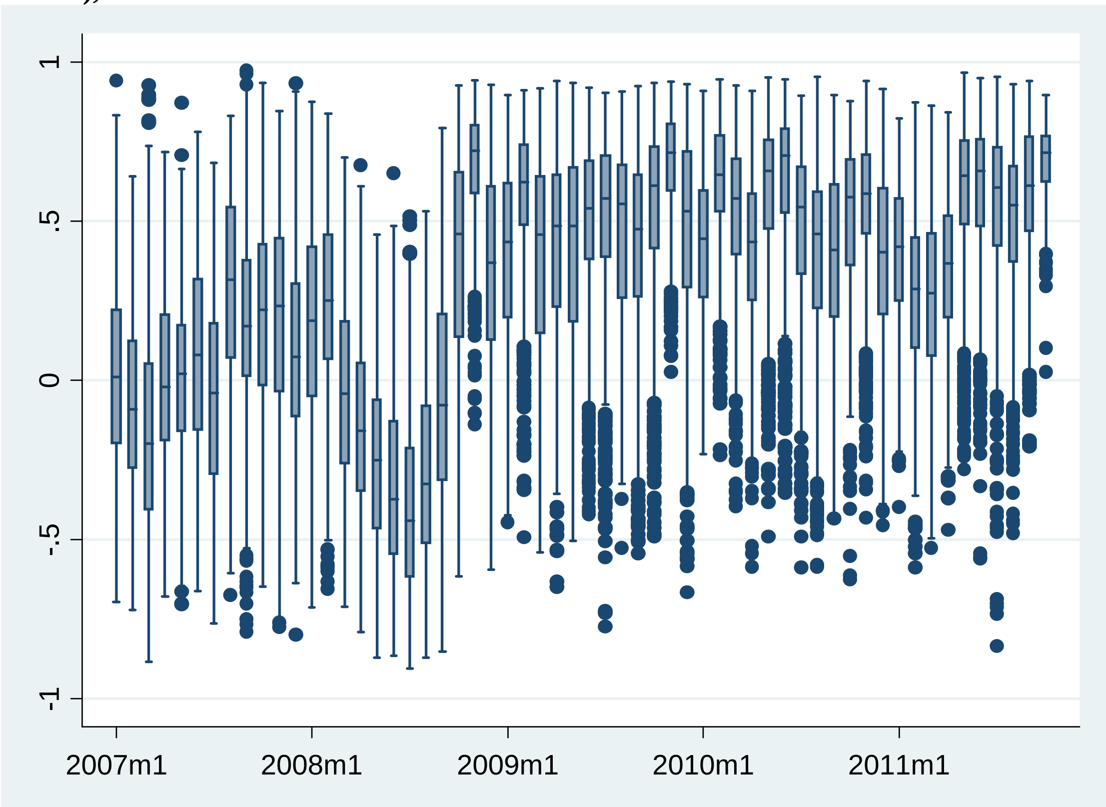
IV. Discussion

The new structural change just described is remarkable from many aspects: (i) the wide range of commodities involved; (ii) the synchronization of this phenomenon; and (iii) the similarity of the evolution across commodities.

Moreover, these phenomena were not restricted to the relationship between the stock index and the commodity markets. Figure 5 illustrates the co-movements between the EUR/USD futures (CME) and the E-mini S&P 500 futures, at 5-minute intervals, which exhibits a similar pattern to the one observed between the WTI and the E-mini S&P 500 futures, except for the period 2007m8-2008m2. Indeed, the chart plots an additional discontinuity that does not appear clearly in the commodities and S&P 500 correlations. We observe a slightly positive correlation between the EUR/USD and the E-mini S&P 500, prior to the negative U-shaped pattern, which we observe during the second and third quarters of 2008.[14]

[14] Here, we use observations at 5-minute intervals. Similar results were obtained using 10-second intervals, even though the additional phase described here is less clear. At 1-second, the traditional overall pattern also appears, although in a less pronounced manner, probably due to the fewer observations in the first years succeeding the introduction of electronic trading.

Figure 5: Monthly distribution of the 5-minute rolling correlations computed over 75 minutes between the returns on the EUR/USD and the E-mini S&P 500 futures (front month), 2007m1-2011m12

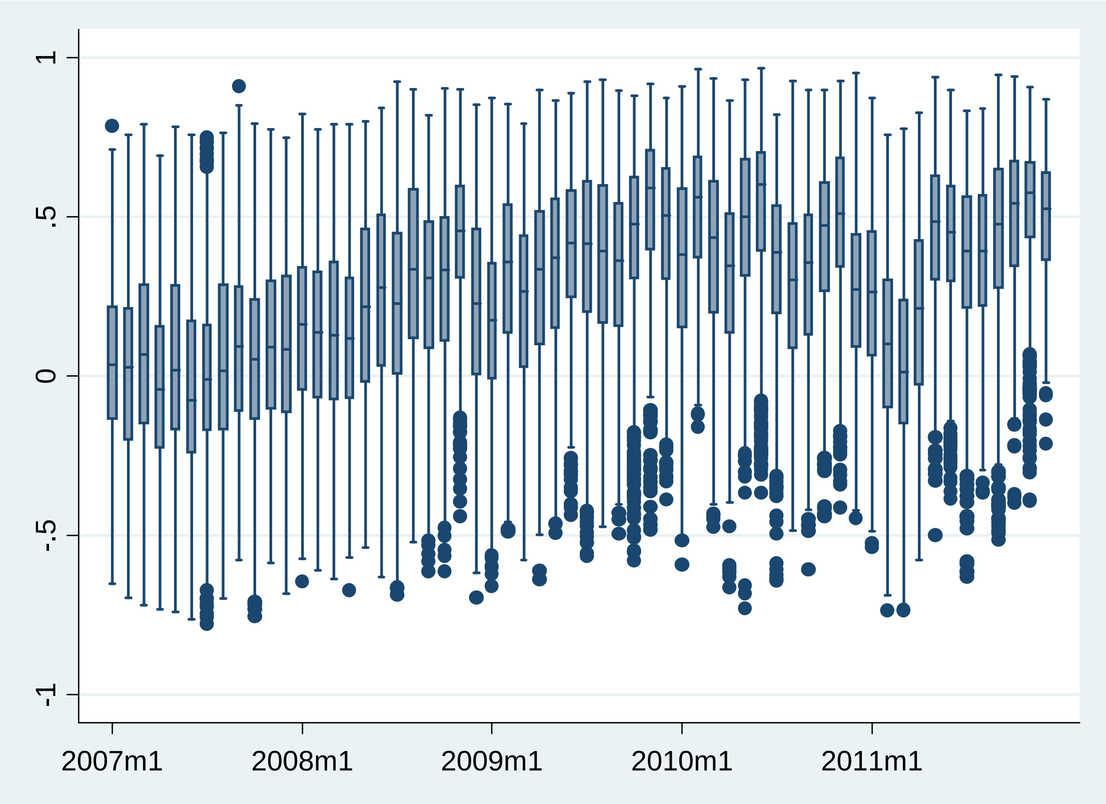


Source: authors' calculations based on Thomson Reuters Tick History database

For the correlations between commodities and the E-mini S&P500, the inflection points of the two negative and positive phases (2008m3 and 2008m9) coincides with two major events that impacted stock markets worldwide: the Bear Stearns' bailout and the Lehman Brothers' collapse. If we consider the additional phase that appears in Figure 5, from 2007m8 to 2008m2, we realize that its starting month corresponds to another significant financial shock: the burst of the subprime bubble in the summer of 2007.

By looking at Figure 6, we notice the increasing correlation between the WTI and EUR/USD pair starts slowly around the summer of 2007. Unlike the correlation between the WTI and the E-mini S&P500, the structural change in the correlation between the WTI and EUR/USD pair is more gradual and does not exhibit a shift from negative to positive territories in the course of 2008. Also, the timing of the recent temporary decline differs as it takes place before the Libyan uprising. Hence, it is probably due to a new phase of the euro zone crisis starting in November 2010. As time passed on, the market realized that the euro crisis would widely affect the world economy. This can plausibly explain the return to a positive correlation between the EUR/USD pair and the WTI.

Figure 6: Monthly distribution of the 5-minute rolling correlations computed over 75 minutes between the returns on the EUR/USD and the WTI futures (front month), 2007m1-2011m12



Source: authors' calculations based on Thomson Reuters Tick History database

These elements suggest that one needs to look beyond the strict relationship between the stock and commodity markets to find the root cause of these structural shifts. In theory, shocks on commodities markets could affect the EUR/USD pair since the observed commodities are quoted in dollar. In practice, it is unlikely that commodity traders have a significant and permanent influence on this currency pair given the large share of non-commodity participants present on the forex market. In fact, in 2010, the daily turnover on currency markets was estimated to be $3.98 trillion (BIS, 2010), well above the daily average of $67 million on the WTI. Although a causal link from commodities to the EUR/USD pair is unlikely, changes in the EUR/USD exchange rate (or another omitted variable) could affect both, the WTI and the E-mini S&P 500 futures, and thus create the correlation between the two series. Yet, the question remains why this phenomenon did not exist prior to mid-2007 between the EUR/USD and the S&P 500 and before 2008 between the most traded currency pair and the most traded commodity. Commodities and S&P 500 futures traders would hardly start, almost suddenly, to take into account this information in there daily routine. Likewise, it is unlikely that traders across commodity and other financial markets changed their routine in such a synchronized manner.

The explanation of the structural change documented in this paper is challenging in many aspects and raises many questions. These include:

a) Why do the median correlations depart from zero and become negative at the end of the first quarter of 2008, and why does this trend then switch into positive territories in late September 2008?
b) Why do the median correlations remain so high from September 2008 onwards?
c) And more generally, what is the main driving force behind this structural change?

While providing final answers to these questions is beyond the scope of this paper, we present some facts and discuss some hypotheses that could guide future research.

The decoupling of emerging market economies has often been proposed by market participants or researchers as a possible answer to the above mentioned questions.[15] This hypothesis refers to the idea that business cycles in emerging market economies have recently become more independent of business cycles in advanced economies. In 2007 to early 2008, the decoupling hypothesis became popular among investment practitioners (Kaiser and Plumberg, 2007). At the same time, China, India and other large emerging market economies were considered to be among the key players behind the price boom in commodities, owing to their growing demand for raw materials. Many investors thought, at first, that the sub-prime crisis would be confined to the advanced economies only. This belief might explain the negative correlation observed during the second and third quarter of 2008 between commodities and the S&P 500. As the initial decoupling hypothesis proved to be wrong when the crisis also affected the world real economy, the co-movement would have reversed and become positive. Yet, this hypothesis does not provide any satisfying explanation for the lasting co-movements observed afterwards.

Another possible answer to the above mentioned questions regards the oscillation between safe vs. risky assets. As uncertainties regarding the future increase in 2008, market participants would have increased their position in safe assets, like United States Treasuries, while in parallel reducing their exposure to risky assets. At the eve of Lehman's bankruptcy, the risk perceptions regarding commodities might have differed from the ones regarding equities. Afterwards, both would have been perceived similarly. Later on, a lasting positive co-movement between commodities and equities would result from a kind of pendulum movement between risky and safe assets following good or bad news.

Fear of inflation has also been mentioned as an explanation for the growing correlation between the commodity and the equity markets. After the central banks massive intervention around the world, both markets have been associated with inflation hedge characteristics.

[15] Between mid-December 2010 and mid-February 2011, UNCTAD staffs conducted 22 interviews with various commodity market participants in the grain, cocoa, sugar and oil markets, ranging from physical traders to financial investors, but also including a broker, representatives of a price reporting firm and two consultants. For more detailed results, see UNCTAD (2011).

Liquidity or volatility changes are other factors suspected of causing cross-market correlations. An argument commonly invoked to explain cross-market correlation relates to the massive central banks interventions that followed the financial crisis, namely quantitative easing. Again, the problem with this view lies in the lasting positive correlations observed since September 2008 at such high frequencies. In addition, deviation from zero started earlier than the massive intervention of the central banks (see Figures 5 and 6). While one should expect growing co-movements across the board after the three financial shocks mentioned above or in other periods of financial stress, it remains unclear why these co-movements continue for months or even years after the shock took place. For instance, the economic recovery was clearly in the air after the second quarter of 2009 until fears of a sovereign debt crisis developed among investors. A striking fact from the data shows that this period of green shoots did not affect the strong positive co-movements observed between the stock and commodities markets. The subsequent swings of mood of market participants until the end of 2011 have also left it almost intact.

Figure 7 plots the monthly relationship between (i) the VIX monthly average and (ii) the median of the 5-minute correlations between the WTI and E-mini S&P 500 futures that appear in Figure 3*b*. While positive and significant, this coefficient slope is rather weak and the R^2 equals only 0.05. In our view, changes in volatility are far from fully explaining the lasting positive correlations we observed.

Overall, the above four explanations do not convince us. In particular, they fail to explain how economic fundamentals or the risk appetite of financial investors changed so quickly. Indeed, news frequencies or human investors' reaction is certainly not as high as 1-second.

The very existence of cross market correlations at such high frequencies is consistent with the idea that recent financial innovations on commodity futures exchanges, in particular the high frequency trading activities and algorithm strategies, have an impact on these correlations. This provides new evidences regarding the impact of the financialization of commodity markets. Apart from the increasing amount of transactions described in Table 2, an indication of the growing presence of HFT strategies in these markets is reflected by the ever-larger volumes traded in an even larger number of transactions. Figure 8 illustrates this point by representing with a black line the ratio between the volumes and the number of ticks. As we observe, the monthly volume per tick has declined since 2007, first gradually and then more steps by step-by-step.

Figure 7: Relationship between the VIX monthly averages and the monthly median of the 5-minute rolling correlations between the returns on the WTI and the E-mini S&P 500 futures (front month), 2007m1-2011m12

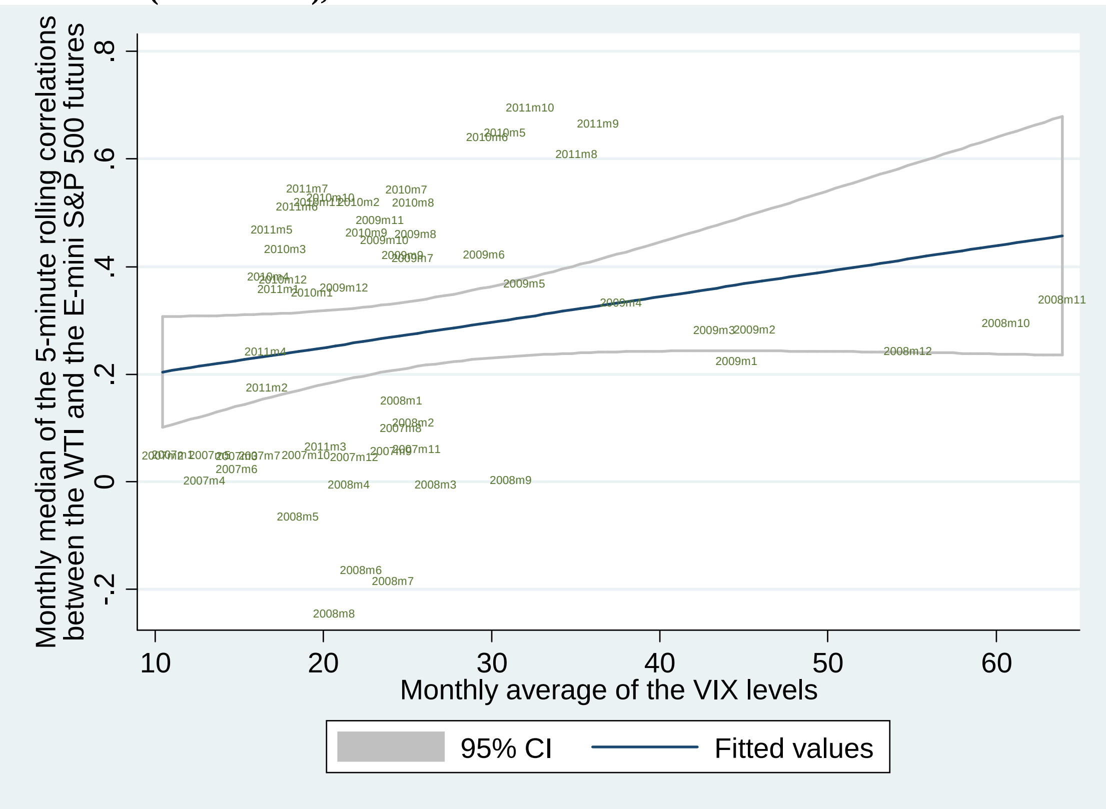
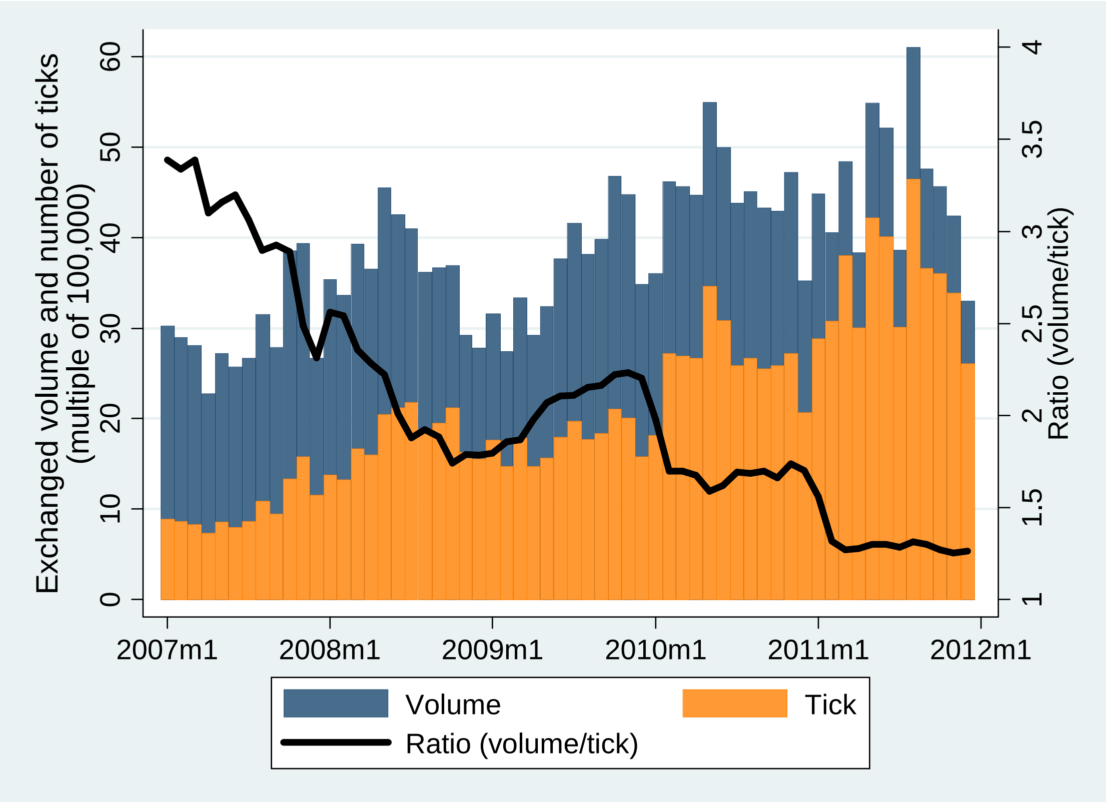


Figure 8: Monthly WTI front month contract volumes and tick, as well as the ratio between the two, 2007m1-2011m12



Source: authors' calculations based on Thomson Reuters Tick History database

Indeed, HFT funds gained impetus following the bear market of 2007-2008 because they were able to continue to generate profits while the financial sector wreaked havoc. Moreover, algorithm funds, or “algo funds”, have developed tremendously since then. For the United States equities markets, the HFT funds generated 73 per cent of the volume exchanged of all United States equities in 2009 (Iati, 2009). In early 2011, Reuters quoted the chief executive officer of the CME Group, saying that 45 per cent of volume exchanged on the NYMEX was computer driven (*Reuters*, 2011), which probably represents a conservative estimate. Anecdotal evidence of HFT affecting financial markets started to emerge fairly recently. The Wall Street Journal online blog "Market Beat" reported on two well-known HFT funds using "strategies based on obscure mathematical correlations" (Rogow, 2009). It explains that "with the rise of these automated funds, the stock market is more prone than ever to large intraday moves with little or no fundamental catalyst". The Flash Crash of 6 May 2010 provides a well-known example. That afternoon, the Dow Jones Industrial Average plunged about nine per cent within 5 minutes only to recover partly those losses within the next 20 minutes. The CFTC and Security Exchange Commission (SEC) joint report (2010) describes how HFT accelerated the effect of a mutual fund's initial selling and contributed to the sharp price declines that day. HFT is also believed to trigger unusual commodity market events. Reuters reported of recent accidents in 2011 linked to HFT funds on commodities derivatives (Sheppard and Spicer, 2011). For instance, on 5 May 2011, despite the absence of major news or macroeconomic announcement and in a matter of minutes, a $13 intraday plunge on the oil market surprised traders. The Reuters report relates also experiences where HFT firms have shift prices either by practice or by design.

Yet, HFT activities are far from being monolithic.[16] They are complex in nature, often secretive and encompass a broad range of strategies. Drawing up an exhaustive list of these strategies is behind the scope of this paper. Nevertheless, they are often divided into two broad categories: the market-making operations and the statistical arbitrage strategies (Haldane, 2011).

Market-making strategies refer to one particular market and do not create correlation by definition. On the contrary, statistical arbitrage strategies seek to benefit from assets fluctuations and volatility to gain quick profits (Smith, 2010). As already mentioned, in times of financial distress, co-movements between stocks and markets tend to increase significantly and these strategies become most profitable during those times. During the crisis, the relative importance of statistical arbitrage strategies among market participants likely grew. UNCTAD (2011) emphasized that investors had moved away from passive strategies and opted for active and sometimes even aggressive strategies. As a result, the relative importance of passive index trading declined significantly since 2007. In fact, although commodity investments reached new historic highs in 2011, the part of index trading declined from 65-85 per cent between 2005 and 2007 to about 35 per cent in October 2011 (Barclays Capital, 2011). Among the investment vehicles following an active strategy, a non-negligible number of investors favoured those using trend-following strategies

[16] See also Rose (2010) for an interesting discussion about the techniques used by HFT in relation to “dark pools” and “flash orders”.

at high speed (Haldane, 2011). This change of market participants can affect the price discovery mechanism. In the context of the forex market in the early 1980's, Frankel and Froot (1990) explain how the market shifted weight away from its fundamentals due to a composition change in market participants towards the technical analysts and trend-following strategies. While we expect these shifts to be gradual, some threshold effects could have been reached during the financial crisis, which later created some hysteresis effects.

Smith (2010) highlights that statistical arbitrage strategies normally have feedback characteristics that could be self-reinforcing. Trend following strategies, for instance, typically try to benefit from upward and downward trends by herding. Contrary to common wisdom, where first mover may enjoy a monopoly rent, trend-following strategies potential returns actually increase with the increasing number of imitators and increasing momentum, because the greater the number of trend-followers, the stronger the trend. The competition among trend-followers lies in identifying first changes in trends: first to invest at the trend inception, first to reverse position when the trend fades. Slower competitors may still reap benefits by bandwagoning, as long as they exit trades on time, because the alternative of swimming against the tide can be very costly. Although individually rational, the overall effect of trend following strategies may destabilize markets (De Long, Shleifer, Summers and Waldmann, 1990). Interestingly, Alt, Kaniel and Yoeli (2012) find evidence that trend chasing is more likely when information quality is low. Arguably, great uncertainties have plagued the financial markets during the last three years.

The period following the financial crisis has been characterized by high uncertainties regarding the economic outlook and pessimism owing to the severe reduction of saving and wealth worldwide. These put heavy pressure on asset managers to deliver performance to their customers. Yet, performance is often a relative concept in finance: fund performances are compared with respect to a benchmark index or with other rival funds. Given the risk aversion for new losses, many asset managers may have well decided to remain close to the benchmark rather than trying to beat the market which could also result in underperforming it. By sticking to their benchmark or by herding, they would preserve their reputation: they cannot beat the market but, at least, they do not underperform. This thinking may create another reason why there would have been a shift towards trend following strategies.[17]

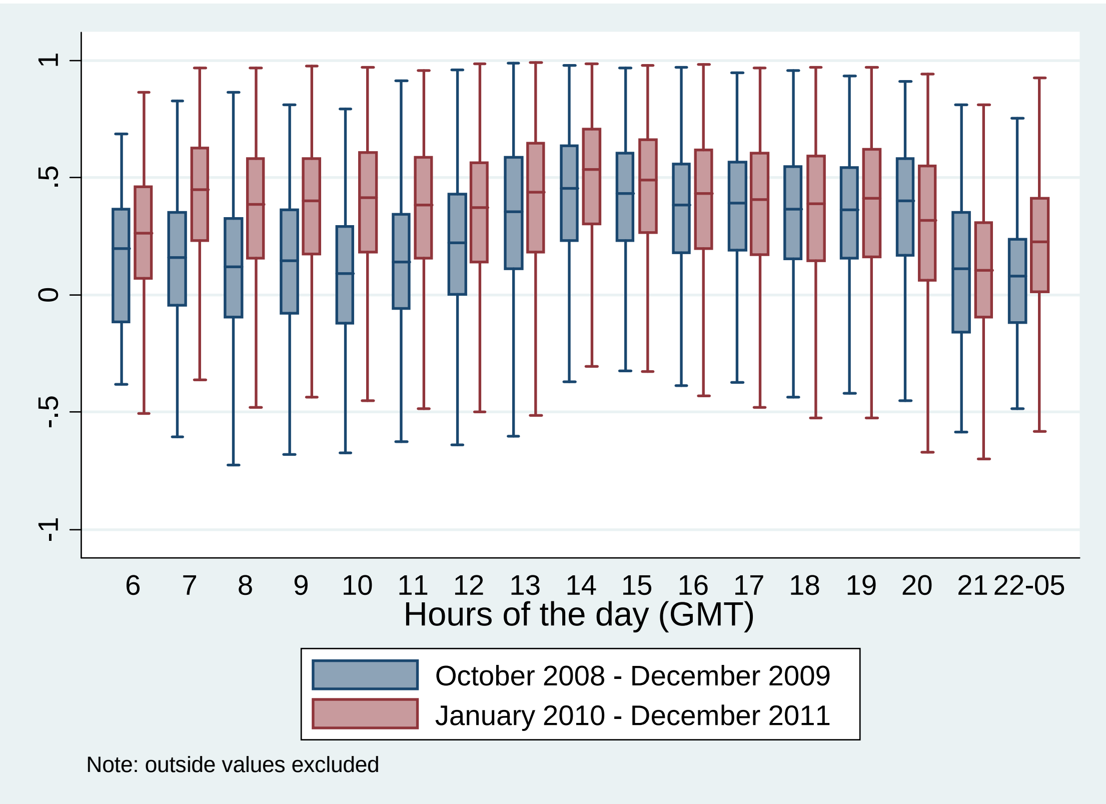
Our last comment refers to the hours of the day when the strongest co-movements are observed and how these have changed over the last years. By using the 10-second rolling correlation between the WTI and the E-mini S&P 500 futures, presented in Figure 3c, Figure 9 plots these data according to the time of day (GMT). As shown in Table 2, observations are rare after 10:00 p.m. and before 6:00 a.m. (GMT), thus we regroup them in the "22-05" category on the chart. Figure 9 shows that the "October 2008-December 2009" co-movements are higher between 1 p.m. and 8 p.m. (GMT). This corresponds broadly to the United States working hours. Earlier, during the day, when the European markets open, the co-movements are still

[17] See UNCTAD (2011) chapter 4.4 for a discussion about intentional herding.

positive, but tend to be lower. The "January 2010 – December 2011" co-movements depict a different picture. As we observe, difference between the working hours in Europe and in the United States is blurred.

Two explanations behind this change come to mind. The first regards the liquidity of the market. For HFT to work, one needs a large number of transactions. Since the selected instruments we observe are traded in the United States, the number of ticks is larger during the United States working hours (Table 2). As the number of transactions gradually increases, liquidity becomes also sufficient at 10 seconds during the European working hours. The other hypothesis relates to the fact that the leading HFT firms were first mainly based and active in the United States. Since HFT requires constant monitoring, in case the algorithms spiral out of control; it is possible that there were more US-based-monitored algorithms at the beginning and that Europe-based-monitored HFT started to catch up afterwards.

Figure 9: Time-of-day distribution of the 10-second rolling correlations computed over 150 seconds between the WTI and the E-mini S&P 500 futures (front month), 2008m10-2011m12



Source: authors' calculations based on Thomson Reuters Tick History database

V. Conclusion

This paper documented striking similarities in the evolution of the rolling correlations between the returns on several commodity futures and the ones on the US stock market, computed at high frequencies. It also highlighted a structural change that took place recently in these markets. Prior to 2008, high-frequency co-movements between commodity and equity markets did not usually differ from zero over a long-lasting period at such high frequencies. In the course of 2008, these correlations departed from zero and became strongly positive after the collapse of Lehman Brothers.

The persistence of this trend until December 2011—except for crude oil in early 2011, which coincides with the uprising in Libya—remains difficult to explain. Further research is needed to get a complete understanding of the mechanisms at work behind this structural change. Yet, given the high frequencies, we think that HFT strategies, in particular the trend-following ones, are playing a key role. We believe a conjunction of factors made that change possible. First, financial technical innovation spurred HFT through the gradual introduction of full electronic trading on exchange platforms since 2005. Second, investors moved away from passive strategies and opted for active ones when the rising trends on equity and commodity markets stopped, in particular since the fall of 2008. Third, lasting uncertainties and positive feedback effects reinforced this trend.

In our view, this finding adds to the growing empirical evidence supporting the idea that the financialization of commodity markets has an impact on the price determination process. Indeed, the recent price movements of commodities are hardly justified on the basis of changes of their own supply and demand. In fact, the strong correlations between different commodities and the S&P 500 at very high frequency are really unlikely to reflect economic fundamentals since these indicators do not vary at such speed. Moreover, given the large selection of commodities we analyse, we would expect to have different behaviours due to their seasonality, fundamentals and specific physical market dynamics. Yet, we do not observe these differences at any frequency. In addition, the fact that these correlations at high frequencies started during the financial shocks provides additional support for financial-based factors behind this structural change. Therefore, the very existence of cross-market correlations at high frequencies favours the presence of automated trading strategies operated by robots on multiple assets. Our analysis suggests that commodity markets are more and more prone to events in global financial markets and likely to deviate from their fundamentals.

This result is important for at least two reasons. First, it questions the diversification strategy and portfolio allocation in commodities pursued by financial investors. Second, it shows that, as commodity markets become financialized, they are more prone to external destabilizing effects. In addition, their tendency to deviate from their fundamentals exposed them to sudden and sharp corrections.

References

Alt A, Kaniel R and Yoeli U (2012). Why Do Institutional Investors Chase Return Trends?, CEPR Discussion Paper No. 8773.

Bank for International Settlements (BIS) (2010). Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity in 2010 - Final results, December 2010.

Barclays Capital (2011). The Commodity Investor, November.

Büyükşahin B, Haigh MS and Robe MA (2010). Commodities and Equities: Ever a "Market of One"? *Journal of Alternative Investments.* 12(3):76-95.

Büyükşahin B and Robe MA (2011). Speculators, Commodities and Cross-Market Linkages. *Mimeo*. Available at: http://www.ou.edu/content/dam/price/Finance/Oklahoma_conference/2011/Michel%20Robe%20paper.pdf

CFTC & SEC (2010). Findings Regarding the Market Events of May 6 2010, Report of the staffs of the CFTC and SEC to the joint advisory committee on emerging regulatory issues, September 30, 2010.

De Long JB, Shleifer A, Summers LH and Waldmann RJ (1990). Positive Feedback Investment Strategies and Destabilizing Rational Speculation. *Journal of Finance*, 45(2): 379-95.

Frankel JA and Froot KA (1990). Chartists, Fundamentalists, and Trading in the Foreign Exchange Market. *The American Economic Review*, 80(2): 181-185.

Gorton G and Rouwenhorst KG (2006). Facts and Fantasies about Commodity Futures. *Financial Analysts Journal,* 62(2): 47-68.

Haldane Andrew G (2011). The Race to Zero, Speech given at the International Economic Association Sixteenth World Congress, Beijing, China, 8 July 2011.

Iati R (2009). The Real Story of Trading Software Espionage. *Advanced Trading*, July.

Institute of International Finance (2011). IIF Commodities Task Force Submission to the G20: Financial Investment in Commodity Markets: Potential Impact on Commodity Prices & Volatility, September.

Kaiser E and Plumberg K (2007). Subprime saga strains economic decoupling theory, *Reuters.* 31 August. Available at: http://www.reuters.com/article/2007/08/31/businesspro-usa-economy-decoupling-dc-idUSN3041834520070831

Masters WM (2008). Testimony of Michael W. Masters before the Committee on Homeland Security and Governmental Affairs, United State Senate, May 20, 2008.

Sheppard D (2011). NYMEX oil trade 45 percent computer-driven, *Reuters*, 3 March. Available at: http://www.reuters.com/article/2011/03/03/us-finance-summit-nymex-volume-idUSTRE7225RV20110303.

Rogow G (2009). Rise of the (Market) Machines - *MarketBeat - Wall Street Journal*. 19 June. Available at: http://blogs.wsj.com/marketbeat/2009/06/19/rise-of-the-market-machines/.

Rose C (2010). Dark Pools And Flash Orders: The Secret World Of Automated High-Frequency Trading. *Journal of Business & Economics Research*, 8(8):11-16.

Sheppard D and Spicer J (2011). Analysis: High-Frequency Trade Fires up Commodities, *Reuters*, June 17, 2011. Available at http://www.reuters.com/article/2011/06/17/us-commodities-highfrequency-idUSTRE75G0MT20110617.

Silvennoinen A and Thorp S (2010). Financialization, Crisis and Commodity Correlation Dynamics, Research Paper 267, Quantitative Finance Research Centre, University of Technology Sydney.

Smith RD (2010). Is high-frequency trading inducing changes in market microstructure and dynamics? *arXiv:1006.5490,* working paper.

Stoll HR and Whaley RE (2010). Commodity Index Investing and Commodity Futures Prices, *Journal of Applied Finance,* 20(1): 7–46.

Stoll HR and Whaley RE (2011). Commodity Index Investing: Speculation or Diversification?, *The Journal of Alternative Investments*, 14(1): 50-60.

Tang K and Xiong W (2011). Index Investment and Financialization of Commodities, March 2011, Princeton University, Mimeo.

UNCTAD (2011). Price Formation in Financialized Commodity Markets: The Role of Information. New York and Geneva, United Nations, June.