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Comovement and the Financialization of Commodities*

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Abstract

We investigate how the correlations amongst commodity futures have changed since the early 2000s. Using data from 1998 to 2011, we examine differences in the dependence structure of index and off-index commodities, and three major commodities indexes. We find that non-energy commodities included in the index exhibit an increase in comovement with the respective index, whereas commodities off the index do not. We interpret our findings as providing some evidence in support of post-2005 commodity financialization. We show that our results are robust to alternative explanations – non-trading effects and common fundamental characteristics. Finally, our results are supported by the analysis of high-frequency returns dynamics by means of the so called realised beta.

Keywords: Commodities; Comovement; Financialization; Indexing; Realized Beta.

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1 Introduction

Commodity futures markets have experienced a surge in financial investor participation over the past decade, largely due to the diversification benefits that commodities can provide while generating returns comparable to or exceeding those of other major stock indices (Cheng and Xiong (2014)). Institutional investors and private wealth managers have long sought alternative asset classes (e.g. real estate, private equity, hedge funds) to hedge against inflation and systemic stock market fluctuations (Ankrim and Hensel (1993), Edwards and Liew (1999), Campbell (2008), Dimson and Spaenjers (2011)). These asset classes are sought out given their seemingly low or even negative correlation with equity and bond markets. Before the early 2000s, commodity markets also exhibited these characteristics; there is evidence that during that period commodity markets were at least partially segmented from both outside financial markets and from each other. Using historical price data from 1982-2004, Erb and Harvey (2006) demonstrated that commodities in different sectors had little price correlation with each other, while Gorton and Rouwenhorst (2006) showed that commodity futures returns were actually negatively correlated with equity and bond returns over the 1959-2004 period.

Starting with the early 2000s, the popularity of commodity indices has increased dramatically (including the Standard & Poor's Goldman Sachs commodity index, the Dow Jones-UBS Commodity Index and the Thomson-Reuters Commodity Index), thereby providing a wide range of financial players with ready access to the commodities market (Irwin and Sanders (2012), and Adams and Gluck (2015)). Since 2004, however, a change in the behavior of commodity prices has been observed, documented amongst others by Tang and Xiong (2012) and Ohashi and Okimoto (2016). Along with a set of macroeconomic variables, Tang and Xiong (2012) carry out a panel regression of commodity futures returns on crude oil futures returns, and find that after 2004, the behavior of in-the-index commodities became increasingly different from that of off-index-commodities, with the former becoming more correlated with oil, an important index constituent. One of the main explanations for this observation has been the entry of institutional investors into the commodity futures market.[1] Indeed, an emerging literature on commodity financialization has claimed that the change in commodity behaviour is attributable to the emergence of a separate commodities asset class, widely held by institutional investors in search of diversification benefits (Tang and Xiong (2012), Cheng et al. (2014), Hamilton and Wu (2015), and Adams and Gluck (2015)).

This paper investigates whether and how the correlations amongst commodity futures have changed due to index investment over the 1998-2011 period. The current paper extends the findings of Tang and Xiong (2012), by providing further evidence in support of the claim that comovement of index commodities increased after 2004. We do so by investigating the change in the comovement of 25

[1] While some argue that the increased price correlation is due to this commodity financialization phenomenon, others maintain that the concurrent movements can be explained by fundamental supply and demand (Krugman (2008), Stoll and Whaley (2010), Irwin et al. (2009) and Fattouh et al. (2013)). Still others have argued for a combination of these explanations, where increased speculative activity acts as an enhancer, but not a fundamental driver, of commodity and equity return comovements (Bruno et al. (2015)).

commodity futures traded on US exchanges, focusing on the three most popular commodity indices - Standard & Poor's Goldman Sachs Commodity Index (S&P GSCI), the Dow Jones-UBS Commodity Index (DJ-UBS CI) and the Thomson-Reuters Commodity Index (Thomson-Reuters CI). We focus on the relationship between each commodity and the indices, thus allowing us to more accurately describe comovements effects with no pooling – an approach that differs from that of Tang and Xiong (2012).

Our empirical strategy is inspired by Barberis et al. (2005). The authors show that the comovement between a stock and the S&P 500 index increases when that stock is added to that index and decreases when that stock is excluded. In a similar vein, we focus on the differences between index and off-index commodities, and study whether the price comovements of index commodities were greater than the price comovements of off-index commodities. To uncover evidence of changes in comovement, we run a series of univariate and bivariate regressions, examining two time periods: 1998-2004 (typically considered as the pre-financialization period) and 2005-2011 (typically considered as the post-financialization period). The choice of 2005 as the break point is innocuous; it was chosen due to the general agreement in the literature that the increased price comovements between various commodities started after 2004 (Tang and Xiong (2012)).[2] The aim is to investigate the changes in the return comovements of the three main commodity indices and commodities (i) included and (ii) not included in the respective indices. We interpret the (i) increase in the price comovement of index commodities and an index or (ii) the decrease in the price comovement of off-index commodities and an index as an empirical evidence in support of financialization.

Two main theories in the literature provide the theoretical foundation of our empirical investigation - style investing and rational investing with a benchmarking effect. The first theory is proposed by Barberis and Shleifer (2003), who argue that investors form asset categories such as small-cap stocks and oil companies in order to simplify portfolio investment. As a result, style investing causes comovement among assets within a style, even though the assets may be unrelated on a fundamental level. The second theory is suggested by Basak and Pavlova (2016), who develop a theoretical model that features institutional investors (concerned with their performance relative to a commodity index) alongside traditional commodity futures market participants, and demonstrate that this addition of institutional investors can lead to an increased correlation amongst commodity futures. Our findings are compatible with either of these theories.

The results from our univariate regressions show that although there is comovement increase after 2005, it is not across the board. In particular, we find a significant increase in the comovement of index non-energy commodities and their respective indices, and either no change or a significant decrease

[2] It should be noted though that some authors argue that the shift in correlations between commodities and equities and between commodities did not begin until 2008 (e.g. Adams and Gluck (2015) and Buyuksahin and Robe (2014)). Although we maintain that evidence of increased comovement can be seen before the financial crisis, changing the cut-off date to 2008 does not materially change the results of our analysis. Data on univariate regressions run for the pre-/post-2008 periods is available upon request.

in the comovement of off-index commodities and indices. We do not, however, see an increase in the comovement of energy commodities and S&P GSCI and UBS Dow Jones CI. This could be explained by the fact that energy commodities have the greatest weights within these indices, and therefore the energy commodities are essentially regressed on themselves. We should thus not expect significant changes in comovement in this case.

These results were corroborated through a greater fine-tuning in subsequent bivariate regressions. Again, we find that index non-energy commodities exhibit an increase in comovement with the corresponding indices. However, we do not also see a significantly decreasing comovement with the corresponding 'off-index' index. Such a decrease would have provided an even stronger evidence to support the claim that the comovement of non-energy commodity and indices is a result of financialization. In contrast, we find strong evidence that off-index commodities do not exhibit increased comovement with either their respective indices or the off-index commodities. Finally, we show that the behaviors of energy and non-energy commodities differ in a way similar to the case of univariate regressions.

Although we interpret our findings as evidence in support of post-2005 commodity financialization, alternative explanations for the regression findings include non-trading effects (i.e. that the comovement results could have a spurious upward bias due to the greater liquidity and increased trading activity of index commodities), and common fundamental characteristics (i.e. that commodities sharing supply-driven common characteristic should exhibit similar correlations). We explicitly test for both of these effects and find that their impact is likely minimal. We also re-run the regressions for an earlier (pre-financialization) period and find no evidence of an increase in the comovement between (i) index or non-index commodities and (ii) the indices, which provides further support for the claim of commodity finacialization.

Our second major contribution to the literature is that, using high-frequency data, we go one step beyond daily price regressions, and calculate the so-called realized beta between each commodity and the index. These realized beta calculations are used to further explore the return-dependence structure of commodity futures post-2005. We observe a statistically significant increase in the realized betas of index non-energy commodities and the indices, and a smaller or insignificant increase in the realized betas of off-index non-energy commodities and the indices. These results support the findings from the regressions on daily returns and indicate that, on average, realized betas of index commodities increased after 2004. Moreover, this increase in realized betas tells us that the increase in return comovement can be seen not only at a daily frequency, but even at intra-day levels. Overall, the univariate regression results for index non-energy and off-index commodities, together with the bivariate regression results for off-index commodities, provide evidence that the observed comovement increase is not due to changes in fundamentals, but may instead be an effect of commodity financialization.

The remainder of the paper is organized as follows. The first part of Section 2 describes the data set. The second part presents the results of the univariate and bivariate regressions. The final

part of the section discusses alternative explanations for the results, and provides robustness checks. Section 3 concludes the empirical analysis by presenting the results using realized betas. Section 4 concludes.

2 Empirical strategy and data sources

The backbone of the analysis is a comparison of the return dependence structure of commodities included in major commodity indices (hereafter index commodities) and those not included in these indices (hereafter off-index commodities). To achieve this, we use simple univariate and bivariate regressions for two main reasons. First, this follows the empirical strategy employed in Barberis et al. (2005). Second, univariate and bivariate regressions are well suited for our analytical approach, and namely for examining the differences between the returns of commodities included and not included in the three major commodity indices (Standard & Poor's GSCI, the Dow Jones-UBS Commodity Index and the Thomson-Reuters Commodity Index).

2.1 Data

We consider a total of 25 commodity futures traded in the United States markets.[3] Table 1 presents these commodities along with their sectors, tickers, exchanges on which they are traded, and their weight in the three major indices considered here: S&P GSCI, the DJ-UBS CI, and the Thomson-Reuters CI.[4] The S&P GSCI features 18 US commodities, and, of the three indices, offers the least diversified investment exposure to commodities. It is heavily weighted towards energy, mostly oil. The DJ-UBS CI includes 16 US commodities with specific minimum and maximum weightings of 2% and 5% respectively. The Thomson-Reuters CI was first calculated by Commodity Research Bureau in 1957, and has the unique feature of equally weighing each of its 17 US component commodities at 5.88%.

Futures data is in continuous format meaning that as the contract expiration nears, the position is rolled over to the next available contract, provided that activity has increased. Our dataset spans the period from April 9, 1998 to March 24, 2011 for a total of 3,222 trading days, using 1-minute frequency data.[5] As discussed in the Introduction and later in footnote 7, the related empirical literature explicitly tests for and confirms a structural break around 2004. Our analysis starts at this date, and focuses on the subsequent 7 years. Thus our time series covers the 1998-2011 period, which we

[3] Tang and Xiong (2012) consider a total of 28 commodity futures traded in the United States. Differently from them, we exclude Kansas Wheat, Michigan Wheat and Palladium since their data was not available. Also, we exclude Ethanol, Canola, and Milk (tradable on the exchanges listed on Table 1) due to data unavailability.

[4] Since Kansas Wheat has positive weight for S&P GSCI but it is not available in our sample, we allocate its weight to the Chicago Wheat.

[5] The minute frequency data is constructed using the last price that occurs in the minute using data provided by Disk Trading.

select so that the year of 2004 - the 'break' year - is roughly in the middle of the available data series. In order to guarantee that our results are based on overlapping time periods, we only consider trades that occurred between 10.30 and 14.00 New York Time (NYT).[6] Daily returns close-to-close are constructed by taking the differences of the log-prices available for each commodity at 14.00. Taking the 'official' end-of-day closing price for each commodity would have distorted the returns comovement measurement because markets do not all close concurrently, and have different rules for determining their 'settlement' price.

As shown in Table 1, Soybean meal, Rough Rice, Oats in the 'Grains' sector; Lumber and Orange Juice in the 'Softs' sector; and Pork Bellies in the 'Livestock' sector are not included in any of the commodity indices. These commodities are always included in the 'off-index' commodities index - an index we will describe later when introducing the bivariate regressions. Note that other commodities appear in some indices but not in others. These are RBOB Unlead Gas (not in Thomson Reuters), Soybean oil (not in S&P GSCI), Cocoa (not in Dow Jones UBS), feeder cattle (only in S&P GSCI) and Platinum (only in Thomson-Reuters). As described later, these commodities are included in the corresponding 'off-index' commodities index as well.

2.2 Univariate regressions

We begin by examining the comovement of futures prices for index commodities and off-index commodities, and investigate whether the comovement has changed over the period 1998-2011.

To study this, we begin by considering the univariate regression and estimate for each commodity

$$R_{i,t} = \alpha_i + \beta_i R_{CMI,t} + \nu_{i,t}$$

separately for the period before 1 January 2005 and after;[7] where $R_{i,t}$ is the return of commodity i at time t and $R_{CMI,t}$ is the return of S&P GSCI or DJ-UBS CI or the Thomson-Reuters CI. In the spirit of Barberis et al. (2005), we estimate the change in the slope coefficient before and after January, 2005 ($\Delta\beta = \beta_{post} - \beta_{pre}$) and the change in the R^2 ($\Delta R^2 = R^2_{post} - R^2_{pre}$) using three data frequencies (daily, weekly, and monthly). The first period goes from April 9, 1998 to December 30, 2004, or 1,659 trading days. The second period goes from January 3, 2005 to March 24, 2011, or 1,564 days. Note that the chosen event date roughly splits the sample in two series of the same length. The index return is calculated using the (i) index-specific weights as in Table 1, and (ii) all commodities except the one being tested. Note that the sum of the weights does not equal 1. This affects the value of the β coefficient but does not affect the test statistics on $\Delta\beta$.[8]

[6] Data are at 1-minute frequency covering the trading hours of the CME and CBoT. Globex trading information (i.e. outside the markets trading hours) is at our disposal for major commodities only.

[7] Related empirical literature dates the start of the financialization of commodity futures around 2004 (Buyuksahin et al. (2008), Irwin and Sanders (2011), Tang and Xiong (2012), Hamilton and Wu (2015), among others), and some of these works explicitly test for and confirm a structural break around 2004. As such, we run our analysis pre- and post-2005.

[8] Rescaling all weights so that they sum up to 1 while keeping their proportions to the remaining weights obviously leads to a different β coefficient; the test value under the null that $\Delta\beta$ is zero is unaffected.

	Commodity	Ticker	Exchange[a]	S&P GSCI	DJ-UBS	Th.R
Energy	WTI crude oil	CL	NYMEX	40.6	15	5.88
	Heating Oil	HO	NYMEX	5.3	4.5	5.88
	RBOB unlead gas	XRB	NYMEX	4.5	4.1	-
	Natural Gas	NG	NYMEX	7.6	16	5.88
Grains	Corn	C	CME Group	3.6	6.9	5.88
	Soybeans	S	CME Group	0.9	7.4	5.88
	Chicago wheat	W	CME Group	3.7	3.4	5.88
	Soybean oil	BO	CME Group	-	2.9	5.88
	Soybean meal	SM	CME Group	-	-	-
	Rough rice	RR	CME Group	-	-	-
	Oats	O	CME Group	-	-	-
Softs	Coffee	KC	ICE	0.5	2.7	5.88
	Cotton	CT	ICE	0.7	2.2	5.88
	Sugar	SB	ICE	2.1	2.8	5.88
	Cocoa	CC	ICE	0.2	-	5.88
	Lumber	LB	CME Group	-	-	-
	Orange Juice	JO	ICE	-	-	-
Livestock	Feeder cattle	FC	CME Group	0.3	-	-
	Lean hogs	LH	CME Group	0.8	2.5	5.88
	Live cattle	LC	CME Group	1.6	4.1	5.88
	Pork bellies	PB	CME Group	-	-	-
Metals	Gold	GC	NYMEX	1.5	6.1	5.88
	Silver	SI	NYMEX	0.2	2.4	5.88
	Copper	HG	NYMEX	2.6	6.7	5.88
	Platinum	PL	NYMEX	-	-	5.88

Table 1: Commodity futures traded in the United States (sectors, tickers, exchanges, and index weights data). The S&P GSCI and DJ-UBS CI also include commodities traded in London, which were not part of our analysis. The indices weights are taken as of 2008. The Thomson Reuters CI is an equally weighted index.

[a] NYMEX denotes the New York Mercantile Exchange; CME Group the Chicago Mercantile Exchange; ICE the Intercontinental Exchange.

Our setup differs from Tang and Xiong (2012) and previous analyses of the comovement amongst commodity futures in that we consider each individual commodity. Tang and Xiong (2012) use subgroups of commodities and rely on a pooled regression across commodities; the effect of financialization is captured by introducing two additional coefficients measuring the trend in comovement after 2004 for all commodities and for index commodities. Our approach differs from Barberis et al. (2005) too. They test the *mean* of βs of the univariate regressions of all stock included in the index before and after inclusion. Here we investigate the change in comovement case by case, thus more accurately describing the effect on each single commodity and providing additional evidence that comovement increased post-2005.

Table 2 reports the change in the slope coefficient β and the change in R^2 for each of the commodity indices. A number of interesting features are evident. First, we observe a statistically significant increase in comovement between index non-energy commodities and heavy-energy indices (positive $\Delta\beta$). Energy commodities have by far the greatest weight in S&P GSCI and DJ-UBS CI (58% and 40%, respectively - Table 1), thus making them 'heavy-energy' indices. This contrasts with Thomson-Reuters CI, which is an equally-weighted index. We also observe a statistically significant increase in comovement between index non-energy commodities and the equally weighted index (Thomson Reuters CI), although the effect is less pronounced. Moreover, the increase in comovement between off-index commodities and all three indices is smaller (Soybean meal, Rice, Oats) or statistically less significant (Lumber, Orange juice and Pork bellies) than the comovement between the index commodities and the index.

However, in contrast to the index non-energy commodities, there is no increase in comovement between the index energy commodities and the respective indices (the $\Delta\beta$'s observed are generally negative and not statistically significant). For S&P GSCI and UBS Dow Jones CI, this could be explained by the fact that energy commodities have the greatest weights within the indices (58% and 40%, respectively). In these cases, we are essentially regressing the energy commodities on themselves, with the regression coefficient for one energy commodity becoming heavily conditioned by the returns on the remaining three. For these two energy-heavy indices we should thus not expect significant changes in comovement – although we should for the equally-weighted one. We argue that the lack of an increase of comovement between index energy commodities and their respective indices is largely due to the financialization effect that was already taking place before 1998. Indeed, the 1990s are commonly associated with financial deregulation and the advance of marketization, which greatly contributed to the financialization of oil including due to the emergence of new commodity indices (e.g. Goldman Sachs' GSCI, which is heavily weighted on oil and related products). Given this early financialization through increased index trading, we should thus not expect large changes in the correlation between energy commodities and energy-heavy or equally-weighted indices - as the new correlation structure had already been 'discovered.'

Focusing back on the non-energy commodities, our results suggest – consistent with the findings from Tang and Xiong (2012), who use Oil return as a proxy for index return – that the increased co-

movement between the index non-energy commodities and the indices (oil being the most important in the two indices) is an effect of index investment. We interpret these results as evidence for the financialization of non-energy commodities.

To confirm the effect of non-energy commodity financialization, and also to isolate the comovement effect produced by Heating Oil, RBOB Unlead Gas and Natural Gas, we repeat the analysis keeping Oil as the only energy commodity. In this case, we obtain results (see Table 3) in line with what we find in the literature (Nazlioglu et al. (2013) and Sadorsky (2014)). Namely, we observe a statistically significant increase in the comovement between non-energy commodities and "oil", both index and off-index. For off-index commodities, however, the increase in comovement is smaller. By contrast, for the S&P GSCI, we see a general β increase across all its constituent commodities. In particular, for this index, Oil is shown to display a significant increase in comovement with the other index non-energy commodities ($\Delta\beta = 3.40$). For the other two indices, which have an equal or lower allocation to Oil, we see that except for Lumber and Oats (in one case only for both), none of the off-index commodity displays a significant increase in β; in fact, the result involving Pork Bellies shows a significant decrease. Note also that Feeder Cattle is off-index for these two cases and does not display any slope change.

Tables 4 and 5 report the results for weekly and monthly regressions, respectively.[9] As the data frequency decreases (from daily to weekly to monthly), the comovement weakens ($\Delta\beta$'s decrease and become less statistically significant). This effect is reported in Barberis et al. (2005) as well. The weakening of the β increase at sufficiently low frequencies is consistent with the predictions of the alternative behavioural theory of comovement. In particular, the end returns are expected to more closely align with the fundamentals in the long run.

An interesting supplement to this analysis would be to test how commodity index recompositions affect commodity prices and comovement. This would parallel a similar question asked in the context of equities (e.g., by Greenwood and earlier by Shleifer (1986) and Harris and Gurel (1986)) or foreign exchange (Hau et al. (2010)). To the best of our knowledge, such a question has not yet been raised in the context of commodities. In a way, our use of three different indices, each with different commodity weightings, already explores this question, as each index hosts a unique composition. However we are not able to directly investigate the impact of time-varying, continuous recomposition. To partially address this question, we performed a series of tests in which the weightings of the commodities in the S&P GSCI were slightly changed each year (while keeping the total weight constant). The results obtained with this index recomposition were not materially different from the original results (data available upon request); the impact of index recomposition is thus likely to be minimal.

In summary, starting with 2005, comovement between index non-energy commodities and the corresponding indices has significantly increased. For off-index commodities, either no change or a significant decrease in comovement is observed. We thus conclude that after 2005, commodities included in the major indices experience higher comovement than off-index commodities. This is

[9] Weekly and monthly series are generated by taking the price in the last minute of the week and month, respectively.

comparable to the findings of Tang and Xiong (2012), who document that after 2004, index commodities have become more correlated with oil. Overall, we interepret our results as evidence of financialization resulting from index investing in the commodities market.

Table 2: Univariate regressions - daily returns

	S&P GSCI		DJ-UBS CI		Th. Reuters CI	
Commodity	$\Delta\beta$	ΔR^2	$\Delta\beta$	ΔR^2	$\Delta\beta$	ΔR^2
WTI crude oil	-0.27	0.10	0.07	0.20	0.12	0.28
Heating Oil	-0.25	0.01	-0.35	0.11	-0.13	0.24
RBOB un. gas	-0.06	0.01	-0.12**	0.11	-0.21	0.18
Natural Gas	-0.13	0.00	-0.64	-0.01	-0.45	0.02
Corn	0.52	0.15	0.54	0.19	0.39	0.21
Soybeans	0.55	0.21	0.57	0.26	0.37	0.29
Chicago wheat	0.46	0.11	0.46	0.14	0.36	0.16
Soybean oil	0.67	0.31	0.65	0.37	0.53	0.39
Soybean meal	0.42	0.12	0.36	0.17	0.12*	0.17
Rough rice	0.16	0.03	0.16	0.04	0.07	0.05
Oats	0.37	0.09	0.30	0.11	0.02	0.11
Coffee	0.36	0.08	0.43	0.11	0.29	0.16
Cotton	0.37	0.10	0.39	0.12	0.43	0.17
Sugar	0.49	0.10	0.55	0.13	0.52	0.16
Cocoa	0.32	0.08	0.35	0.1	0.31	0.14
Lumber	0.12**	0.01**	0.12**	0.01*	0.11	0.02**
Orange Juice	0.13*	0.01**	0.12**	0.02**	0.09	0.02*
Feeder cattle	0.10	0.03	0.06**	0.02	0.01	0.02
Lean hogs	0.07	0.01	0.01	0.01	-0.10	0.01
Live cattle	0.14	0.05	0.12	0.05	0.12	0.07
Pork bellies	0.04	0.00	-0.03	0.00	-0.28	-0.01
Gold	0.26	0.13	0.27	0.14	0.22	0.19
Silver	0.59	0.19	0.63	0.21	0.63	0.24
Copper	0.73	0.25	0.80	0.25	0.86	0.31
Platinum	0.38	0.16	0.39	0.20	0.40	0.26

Table 3: Univariate regressions, Oil only - daily returns

	S&P GSCI		DJ-UBS CI		Th. Reuters CI	
Commodity	$\Delta\beta$	ΔR^2	$\Delta\beta$	ΔR^2	$\Delta\beta$	ΔR^2
WTI crude oil	3.40	0.25	1.59	0.29	1.03	0.30
Corn	0.68	0.16	0.61	0.22	0.29	0.19
Soybeans	0.70	0.22	0.62	0.30	0.22	0.26
Chicago wheat	0.61	0.12	0.44	0.16	0.30	0.16
Soybean oil	0.84	0.32	0.66	0.41	0.38	0.35
Soybean meal	0.54	0.13	0.10	0.17	-0.07	0.15
Rough rice	0.20	0.03	0.09	0.05	0.00	0.05
Oats	0.46	0.09	0.00	0.11	-0.19	0.10
Coffee	0.44	0.08	0.48	0.13	0.15	0.15
Cotton	0.50	0.11	0.59	0.17	0.49	0.19
Sugar	0.63	0.10	0.79	0.15	0.55	0.15
Cocoa	0.42	0.08	0.45	0.13	0.29	0.14
Lumber	0.18**	0.01 **	0.22	0.02	0.14	0.02
Orange Juice	0.17**	0.01 **	0.19	0.02	0.11	0.02
Feeder cattle	0.13	0.03	0.08	0.02	0.00	0.01
Lean hogs	0.10	0.01	-0.12	0.01	-0.17	0.01
Live cattle	0.19	0.05	0.20	0.07	0.15	0.07
Pork bellies	0.06	0.00	-0.22	0.00	-0.45	-0.02
Gold	0.34	0.14	0.33	0.17	0.21	0.19
Silver	0.76	0.20	0.83	0.25	0.66	0.24
Copper	0.94	0.26	1.27	0.31	0.94	0.31
Platinum	0.50	0.18	0.52	0.26	0.42	0.27

Reported are the β and R^2 differences pre and post Januay 1, 2005. Positive significant differences from zero at the 10% and 5% levels in two-sided tests, respectively are denoted by * and **. Light gray cells denote that the difference is not significant at 10% level or higher; dark gray cells denote negative significant differences at 10% level. Rest significant at 1% level. Standard errors are computed using the White robust covariance matrix. Commodities in bold are those not included in any index.

Table 4: Univariate regressions - weekly returns

	S&P GSCI		DJ-UBS CI		Th. Reuters CI	
Commodity	$\Delta\beta$	ΔR^2	$\Delta\beta$	ΔR^2	$\Delta\beta$	ΔR^2
WTI crude oil	-0.31	0.09	0.03	0.21	0.04	0.27
Heating Oil	-0.24	0.02	-0.31	0.17	-0.07	0.30
RBOB unlead gas	0.02	0.07	-0.06	0.15	-0.20	0.20
Natural Gas	-0.02	0.03	-0.56	0.02	-0.24	0.06
Corn	0.42	0.10	0.44	0.14	0.26	0.15
Soybeans	0.58	0.24	0.55	0.27	0.33	0.32
Chicago wheat	0.18	0.02	0.18	0.04	-0.02	0.04
Soybean oil	0.77	0.33	0.76	0.42	0.70	0.48
Soybean meal	0.37	0.13	0.24*	0.16	-0.07	0.15
Rough rice	0.27	0.03	0.23	0.05*	0.02	0.06*
Oats	0.41	0.10	0.41	0.14	0.21	0.15
Coffee	0.57	0.13	0.60	0.17	0.40**	0.23
Cotton	0.40	0.10	0.47	0.14	0.55	0.21
Sugar	0.20	0.03	0.24	0.06*	0.01	0.07
Cocoa	0.50	0.10	0.62	0.15	0.55	0.21
Lumber	0.10	0.01	0.17	0.02	0.23	0.04*
Orange Juice	0.21	0.02	0.23*	0.04	0.14	0.04
Feeder cattle	0.18	0.05*	0.16	0.05*	0.17*	0.05*
Lean hogs	0.07	0.00	0.03	0.00	0.12	0.00
Live cattle	0.17	0.07	0.17*	0.08	0.22	0.10
Pork bellies	0.11	0.00	0.00	0.00	-0.34	-0.02
Gold	0.43	0.23	0.43	0.24	0.36	0.28
Silver	0.78	0.27	0.81	0.30	0.73	0.32
Copper	0.71	0.27	0.76	0.28	0.66	0.31
Platinum	0.49	0.27	0.52	0.33	0.44	0.36

Table 5: Univariate regressions - monthly returns

	S&P GSCI		DJ-UBS CI		Th. Reuters CI	
Commodity	$\Delta\beta$	ΔR^2	$\Delta\beta$	ΔR^2	$\Delta\beta$	ΔR^2
WTI crude oil	0.03	0.04	0.15	0.16	-0.19	0.15
Heating Oil	-0.13	-0.01	-0.12	0.15	-0.09	0.26**
RBOB unlead gas	0.00	-0.01	0.19	0.19	-0.28	0.17
Natural Gas	-0.31	-0.01	-1.04	-0.02	-0.95	0.00
Corn	0.56	0.21*	0.68	0.29	0.53*	0.29
Soybeans	0.70	0.25	0.69	0.32	0.57*	0.39
Chicago wheat	0.01	-0.03	0.00	-0.05	0.05	0.01
Soybean oil	0.71	0.29	0.77	0.45	1.00	0.55
Soybean meal	0.55	0.18	0.35	0.23*	0.19	0.27
Rough rice	0.41	-0.01	0.39	0.03	0.15	0.06
Oats	0.54	0.19	0.66	0.31	0.75	0.34
Coffee	0.44*	0.07	0.59	0.13	0.58*	0.19**
Cotton	0.33	0.08	0.38	0.12	0.37	0.18
Sugar	0.23	0.03	0.37	0.05	0.46	0.07
Cocoa	0.15	0.03	0.37	0.06	0.52	0.14
Lumber	0.40	0.13	0.60	0.13*	0.67*	0.18*
Orange Juice	0.46	0.07	0.66	0.16	0.86	0.14
Feeder cattle	0.04	0.01	0.03	0.01	0.04	0.02
Lean hogs	-0.27	0.04	-0.28	0.03	0.04	0.01
Live cattle	-0.06	-0.02	-0.04	-0.01	-0.10	-0.01
Pork bellies	-0.38	0.04	-0.57	0.03	-0.91	-0.01
Gold	0.20	0.08	0.19	0.08	0.18	0.12
Silver	0.60	0.19	0.78	0.26	0.82	0.29
Copper	0.67	0.24*	0.68	0.20*	0.67	0.22
Platinum	0.26	0.14	0.33	0.22*	0.26	0.28

Reported are the β and R^2 differences pre and post Januay 1, 2005. Positive significant differences from zero at the 10% and 5% levels in two-sided tests, respectively are denoted by * and **. Light grey cells denote that the difference is not significant at 10% level or higher; dark grey cells denote negative significant differences at 10% level. Rest significant at 1% level. Standard errors are computed using the White robust covariance matrix. Commodities in bold are those not included in any index.

2.3 Bivariate regressions

We continue our empirical analysis by investigating the commodity comovement effect using a bivariate regression. As discussed earlier, commodity index investing involves the simultaneous purchase of index commodities as part of portfolio construction. Because index commodities should load more heavily on index returns than on non-index returns, if index investment increased financialization, we would expect an increase in the comovement of returns for commodities within the index, and a decrease in the comovement between commodities in and off the index, when controlling for the returns of off-index commodities. In other words, the commodity i in the index (IND) increases the covariance of its return with the return on the index and hence also its beta loading on the index return, $\beta_{i,IND}$. At the same time, it decreases the covariance of its return with the return on the 'off-index' commodity index (OFF) and hence also its beta loading on the off-index return, $\beta_{i,OFF}$.

In the bivariate regression, two independent variables are used: one for the returns of index commodities ($\beta_{i,IND}$) and one for the returns of off-index commodities ($\beta_{i,OFF}$). The variable representing the off-index commodity returns was created by equally weighting the returns of all the off-index commodities studied here. As a reminder, the six commodities not included in the three indices are always included in the 'off-index': Soybean meal, Rough Rice, Oats in the 'Grains' sector; Lumber and Orange Juice in the 'Softs' sector; and Pork Bellies in the 'Livestock' sector. The commodities that are included in some indices but not in others[10] were included in the 'off-index' corresponding index.

For each commodity we estimate the bivariate regression:

$$R_{i,t} = \alpha_i + \beta_{i,IND} R_{IND,t} + \beta_{i,OFF} R_{OFF,t} + \nu_{i,t}$$

where

$$R_{OFF,t} = \frac{1}{m} \sum_{k=1}^{m} R_{k,t}, \quad k \notin IND$$

and IND denotes the set of commodities included in an index. For ease of exposition, we restricted our analysis to a daily return frequency.

The results of this bivariate regression are presented in Table 6. The first observation is that there is a statistically significant increase in comovement between index non-energy commodities and the index (β_{IND} is generally increasing), as seen in the univariate regressions. Examining the off-index regression coefficients for the same commodities, we see that although β_{OFF} is significant and increasing for the indices with heavy Oil allocation (S&P GSCI and UBS-DJ CI), no significant change in β_{OFF} is observed for the equally weighted Thomson-Reuters index. This may be because the indices heavily weighted in oil cannot adequately capture price changes in non-energy commodities (given that 40-60% of the index is comprised of energy commodities); these price changes are instead captured by the off-index returns. Thus, when comovement between the index commodity and the

[10] RBOB Unlead Gas (not in Thomson Reuters), Soybean oil (not in S&P GSCI), Cocoa (not in Dow Jones UBS CI), feeder cattle (only in S&P GSCI) and Platinum (only in Thomson-Reuters CI)

index increases, the comovement with off-index commodities also increases. The increasing β_{OFF} observed for the S&P GSCI and DJ-UBS CI indices is therefore most likely an artefact of the composition of the index, and not an actual increase in the correlation with the off-index returns. When an equally weighted index is used, only the comovement between an index commodity and the index increases; the comovement with the off-index commodities does not change.

The second major finding is that, in contrast to the results of the univariate regression, commodities that are off-index do not display an increase in β with the off-index and also do not show a significant increase in comovement with the index returns. Hence, off-index commodities do not display any significant change in comovement. This suggests that off-index commodities remained partially segmented from each other post-2005, while the index commodities experienced a significant increase in comovement. This provides evidence for the financialization of U.S. commodity markets through index investment.

Finally, as observed in the univariate regressions, the index energy commodities do not exhibit the same behaviour as the index non-energy commodities. Although the $\Delta\beta_{IND}$ values are generally significant and positive, for the index non-energy commodities the $\Delta\beta$'s for index energy commodities are generally negative and not statistically significant. Again, this observation could be an artefact of heavy loading of energy commodities in the S&P GSCI and DJ-UBS CI indices (weighted at 58% and 40%, respectively). This heavy energy weighting could significantly skew any measurement of covariation between an energy commodity and the index. Thus, the apparent differences between energy and non-energy commodities must be interpreted with care.

In summary, the bivariate regressions demonstrate that for those non-energy commodities that are included in a commodity index, comovement with the respective index increased after 2005. Off-index commodities, on the other hand, do not exhibit increased comovement with the index or the 'off-index' commodities index. These findings could be interpreted as evidence of commodity financialization. However, a necessary condition for the financialization effect would be for index commodities to have a decreasing comovement with the 'off-index' (decreasing β_{OFF}). In contrast, we observe either an increase in β_{OFF} (for the oil-heavy indices, explained above) or no change. Thus, although some of these results hint at the influence of financialization, we cannot confidently interpret the bivariate off-index findings as definitive evidence for or against financialization across the board and more studies are needed to confirm this.

Table 6: Bivariate regressions

	S&P GSCI		DJ-UBS CI		Th. Reuters CI	
Commodity	$\Delta\beta'^{ind}$	$\Delta\beta'^{off}$	$\Delta\beta'^{ind}$	$\Delta\beta'^{off}$	$\Delta\beta'^{ind}$	$\Delta\beta'^{off}$
WTI crude oil	-0.44	0.40	-0.07	0.46	0.24	-0.21
Heating Oil	-0.24	0.07	-0.36	0.22	-0.06	-0.12
RBOB un. gas	-0.05	0.12	-0.12	0.22	-0.32	0.29
Natural Gas	-0.12	-0.17	-0.53	-0.14	-0.30	-0.23
Corn	0.18	0.22	0.29	0.20	0.33	0.09
Soybeans	0.20	0.11	0.31	0.16	0.32	0.07
Chicago wheat	0.16	0.26	0.25	0.22	0.33	0.05
Soybean oil	0.50	0.10	0.51	0.04	0.47	0.10
Soybean meal	0.21	0.07	0.27	0.04	0.13	-0.02
Rough rice	0.05	0.02	0.09	0.01	0.11	-0.05
Oats	0.15	0.08	0.19	0.05	-0.05	0.14
Coffee	0.21	0.23	0.29	0.16	0.22	0.13
Cotton	0.17	0.31	0.21	0.34	0.38	0.09
Sugar	0.36	0.24	0.43	0.22	0.48	0.06
Cocoa	0.21	0.13	0.31	0.03	0.43	-0.21
Lumber	0.04	0.13	0.05	0.08	0.07	0.06
Orange Juice	0.06	0.13	0.08	0.07	0.05	0.07
Feeder cattle	0.10	-0.02	0.06	-0.01	-0.01	0.03
Lean hogs	0.02	-0.39	0.02	-0.49	0.23	-0.60
Live cattle	0.08	0.09	0.04	0.09	0.10	0.04
Pork bellies	-0.01	-0.02	-0.07	-0.02	-0.32	0.06
Gold	0.17	0.14	0.19	0.14	0.28	-0.11
Silver	0.37	0.41	0.42	0.42	0.64	-0.02
Copper	0.54	0.38	0.61	0.40	0.80	0.11
Platinum	0.28	0.19	0.30	0.19	0.38	0.03

Bivariate regressions. Positive significant difference from zero at 10% and 5% level in two-sided test are denoted by $*$ and $**$ respectively. Dark grey cell negative and significant at the 10%; light grey cell denote difference is not significant at the 10%. Rest significant at 1% level. Commodities in bold are those not included in any index.

2.4 Alternative explanations and robustness checks

We now consider some alternative explanations for the results of the univariate and bivariate regressions – and namely, the non-trading and common fundamental characteristics. Below we discuss how these alternative explanations could impact our analysis of the commodities market.

Non-trading effects

The first alternative explanation we explore is the potential impact of 'non-trading effects'. The basic premise of this argument is that since index commodities are generally more liquid and more frequently traded than off-index commodities, the correlation results might have some spurious upward bias. To see this, assume that some important commodity market information is revealed toward the end of the trading day. Because index-commodity futures are more liquid, it is possible for such contracts to be traded again before the end of the day and thus assimilate such new information. By contrast, off-index commodities, which are traded less often, might not trade again before the end of the day. As a result, returns $R_{i,t}$ on off-index commodities would not reflect such news and the regression of $R_{i,t}$ on $R_{IND,t}$ would produce an artificially low β coefficient.

We address this possible issue in two ways: by restricting the trading time analysed, and by investigating changes in trading activity. First, recall that in our analyses we considered the day trading time between 10:30 and 14:00. This is the overlapping period in which all commodities futures trade across different US markets. Restricting ourselves to the overlapping trading day should reduce the occurrence of non-trading since it is likely that off-index commodities also trade frequently during this time. Had we chosen a different period, non-trading effects would surely be observed for commodities with a narrower trading day. Lastly, news arriving after 14:00 will be traded on by all commodities the next day, because such news will be reflected in the next day's market opening price.

To explicitly test for the impact of 'non-trading' effects, we investigate the average daily contract volume of each commodity pre- and post-2005. According to the non-trading effect hypothesis, we would observe an increase in β simply because an index commodity trades more frequently than the off-index one. In order to test this hypotheses, for each commodity we consider the average daily contract volume from 1998 to 2011 as a measure of how frequently the commodity is traded. This measure is constructed using volume data provided by Quandl.com. Table 7 reports these quantities and Figure 1 illustrates average daily volume of off-index commodities; volume data is standardized to improve graph readability. Consider the case of Grains. All grain index commodities (corn, soybeans, wheat, and soybean oil) show an increase in daily contract volume in 2005-2011 compared to 1998-2004. The case of off-index commodities, however, is less clear-cut. Soybean meal shows an increase in the daily contract volume, whereas oats' daily contract volume decreases. Consider now the case of Softs. All soft index commodities (coffee, cotton, sugar, cocoa) show an increase in daily contract volume in 2005-2011 compared to 1998-2004, whereas lumber and orange juice do not show a systematic increase or decrease in daily contract volumes. Because the impact of

non-trading effect on off-index commodities cannot be unambiguously determined, we conclude that the theory on 'non-trading' effects cannot explain the results of our daily-frequency regressions.

Table 7: Average daily volume per commodity.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
WTI crude oil	53,671	65,162	65,862	66,968	79,123	78,264	92,759	98,883	122,254	231,091	275,619	275,531	328,647	352,932
Heating Oil	15,476	16,549	16,985	16,451	19,637	20,913	23,411	23,895	24,988	27,261	31,804	32,738	41,657	45,364
Natural Gas	33,778	39,909	36,072	31,543	44,570	36,326	31,956	32,357	34,234	50,069	75,055	95,098	111,975	129,854
Corn	22,068	24,002	30,768	28,863	30,711	33,434	32,479	40,419	66,270	42,384	78,432	87,570	109,513	139,012
Soya beans	16,670	16,659	20,237	18,356	22,352	24,737	25,339	27,203	29,516	22,641	15,809	28,439	52,709	67,243
Chicago wheat	8,616	9,873	11,335	12,105	12,373	12,215	13,734	17,512	24,660	16,421	7,091	18,235	37,514	45,550
Soybean oil	6,662	6,406	7,478	7,793	9,448	8,946	7,473	8,251	10,112	7,579	19,421	23,667	26,792	37,104
Soyabean meal	8,066	7,963	9,124	8,750	9,913	9,761	8,674	9,666	10,762	6,456	15,897	17,673	17,330	22,750
Rough rice	208	177	241	199	314	380	261	365	381	287	86	316	728	1,181
Oats	638	581	711	810	906	645	743	676	660	390	215	311	633	777
Coffee	3,124	4,206	3,483	3,487	3,890	4,845	6,922	6,112	6,888	7,903	7,468	5,938	7,031	7,585
Cotton	3,552	3,628	4,121	3,307	3,562	4,178	5,610	6,075	6,986	8,774	7,364	4,948	6,192	9,546
Sugar	11,791	26,564	21,042	12,587	14,203	16,364	21,424	26,757	29,459	44,725	47,058	45,791	45,535	49,579
Cocoa	2,591	2,802	2,962	2,836	2,893	2,884	3,691	3,776	4,655	5,092	5,064	4,333	4,620	6,447
Lumber	560	631	482	448	375	523	537	504	525	653	775	587	543	451
Orange Juice	1,776	1,622	1,313	1,203	1,142	1,275	1,797	1,745	1,737	1,640	1,230	1,246	1,268	865
Feeder cattle	977	812	756	838	725	951	910	1,342	1,534	1,309	1,252	1,201	1,290	1,797
Lean hogs	3,384	3,847	3,477	3,585	3,317	3,552	4,917	6,088	8,739	9,175	8,747	8,201	10,025	15,350
Live cattle	5,474	5,636	5,352	5,898	5,323	5,806	5,895	7,899	9,572	10,238	10,800	10,150	12,660	19,519
Pork bellies	1,219	979	795	551	405	430	409	321	268	179	129	65	11	0
Gold	10,048	14,432	9,632	10,977	13,535	18,558	24,399	24,405	27,265	39,268	60,857	54,019	78,244	112,575
Silver	452	369	475	329	278	6,018	252	37	9,740	10,859	13,395	13,359	22,487	23,658
Copper	675	688	734	784	683	505	583	720	651	562	659	861	1,276	1,901
Platinum	1,195	1,392	690	478	529	646	714	945	1,033	1,468	1,737	1,945	113	158

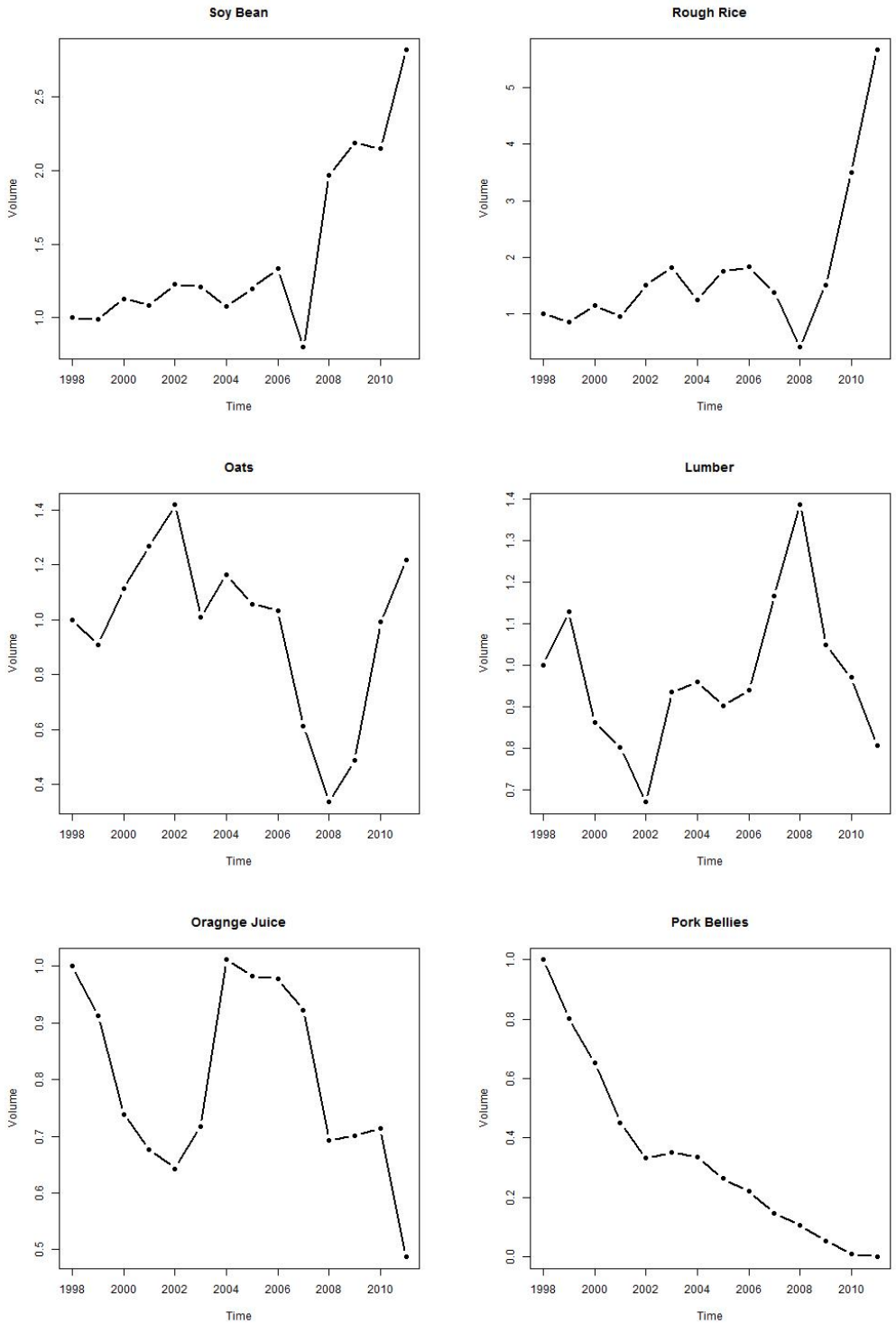

Figure 1: Standardized average daily volume per off-index commodity.

Common fundamental characteristics

Common fundamental characteristics describe the idea that an increase in comovement could arise simply because index commodities show some common characteristics at a fundamental level. In this case, the presence of the common characteristic could explain the increase in the comovement of the index-commodity returns. Barberis et al. (2005) explore this effect with a matching exercise. The idea is to find similar securities off the index, and test if they exhibit correlations similar to those of the matching index securities. If the comovement pattern differs, the conclusion is that the common characteristic alone cannot explain the comovement of index securities. Based on this approach, for each event stock included in the S&P 500 during the sample period, Barberis et al. (2005) search for a "matching" stock by selecting stocks outside the index, with similar market capitalization and from the same industry as the event stock. In other words, the authors use stock size as the basis for their 'matching' exercise. We perform a similar 'matching' exercise by focusing on soybeans (included in the main indices), soybean oil (again, indexed), and soybean meal (off-index). We select this group from our list of commodities because soybean and soybean by-products have a clear common fundamental characteristic; namely, they share the same underlying forces of supply. Indeed, the processing of soybeans necessarily results in the production of both soybean oil and soybean meal, with the latter resulting from the grinding of soybean to extract soybean oil. Thus the total supply of each derivative commodity will always remain constant relative to the other by-product commodities, meaning that the prices of both soybean meal and oil will be heavily influenced by the total supply of soybeans. Our objective is to test whether the effect of a common supply characteristic can alone explain the comovement of index soybean products.

Our findings are presented in Table 2. In particular, the table shows that the off-index commodity, soybean meal, exhibits much smaller shifts in βs than the indexed soybeans and soybean oil. Table 3 reports the more stastistically-relevant results. Accordingly, soybeans and soybean oil exhibit increase in comovement, whereas the increase in β between soybean and soybean meal is statistically insignificant (for DJ-UBS CI and Thomson Reuters CI). Given that these three commodities can be considered as 'matching', this finding suggests that the increase in comovement post-2005 is not entirely due to common fundamental characteristics. We interpret these results as evidence in support of commodity financialization.

Robustness checks

To conclude this Section, we test whether our methodology delivers results consistent with the view that commodity-index investing also increases comovement amongst index commodities in a pre-financialization period. We consider the interval from 1998 to 2004 (inclusive), split the time period into two equally-long time series and re-run the regressions as in Section 2.2. Note that the time period is prior to the start of commodity-futures financialization (higher activity in the commodity index investing). We therefore expect no changes in comovement.

The results from this additional test are displayed in Table 8. For nearly all commodities, no significant change in β nor in R^2 is observed between the two periods. This contrasts with the findings for the pre- and post-2005 periods, where a significant increase in β is generally observed for the index commodities. The change in comovement as a proxy of financialization is not evidenced in this prior time period. These results further corroborate our previous findings: correlations amongst index-commodity futures increase after 2004 with financialization.

	S&P GSCI		DJ-UBS CI		Th. Reuters CI	
Commodity	$\Delta\beta$	ΔR^2	$\Delta\beta$	ΔR^2	$\Delta\beta$	ΔR^2
WTI crude oil	-0.06	0.14	0.22	0.15	0.14	0.09
Heating Oil	0.06	0.03	0.02	0.08	0.10	0.06
RBOB unlead gas	0.16	-0.02	0.15	0.05	0.09	0.03
Natural Gas	0.58	0.12	0.57	0.08	0.25	0.03
Corn	0.03	0.00	-0.04	-0.01	-0.18	-0.04
Soybeans	0.04	0.00	0.00	-0.01	-0.04	-0.05
Chicago wheat	0.06	0.01	-0.05	-0.02	-0.18	-0.05
Soybean oil	0.08	0.00	0.09	0.01	0.12	0.02
Soybean meal	0.01	0.00	-0.01	-0.02	-0.08	-0.05
Rough rice	0.02	0.00	-0.02	0.00	0.01	0.00
Oats	0.00	0.00	-0.08	-0.02	-0.14	-0.05
Coffee	0.18	0.00	0.21	0.01	0.33	0.03
Cotton	0.12	0.01	0.10	0.01	0.17	0.01
Sugar	-0.01	0.00	-0.07	0.00	-0.12	-0.01
Cocoa	0.07	0.00	0.10	0.01	0.02	0.00
Lumber	-0.08	0.00	-0.12	0.00	-0.13	-0.01
Orange Juice	0.04	0.00	0.03	0.00	0.06	0.01
Feeder cattle	-0.03	0.00	0.00	0.00	0.04	0.00
Lean hogs	0.01	0.00	0.00	0.00	0.04	0.01
Live cattle	-0.03	0.00	0.00	0.00	0.02	0.00
Pork bellies	-0.08	0.00	-0.13	0.00	-0.30	-0.01
Gold	0.07	0.02	0.10	0.04	0.12	0.05
Silver	0.10	0.01	0.17	0.03	0.30	0.05
Copper	0.09	0.01	0.18	0.03	0.28	0.05
Platinum	0.04	0.01	0.07	0.02	0.02	0.03

Table 8: Robustness checks: univariate regressions run during the 'prefinancialization' 1998-2004 period as a control. The 1998-2004 period was split into two equally long time series to calculate the change in β and R^2. Light gray cells denote that the difference is not significant at 10% level or higher; dark gray cells denote negative significant differences at 10% level. Commodities in bold are those not included in any index.

3 Realized betas

To conclude the empirical analysis, we present a new approach to investigate whether comovement of index commodities has changed. Instead of running regressions on daily returns, we use price

information at intra-day frequency and directly estimate the so-called 'realized beta'. This is possible because of the availability of price information at intra-day frequency.

The concept of realized betas was first introduced by Bollerslev and Zhang (2003). They carried out a large-scale estimation of the Fama-French three-factor model using 5-minute data on 6,400 stocks over a period of 7 years. They show that using high-frequency data can improve the pricing accuracy of asset pricing models. In a related paper, Andersen et al. (2006) investigate the time variation in realized variances, covariances and betas using daily returns to construct quarterly realized measures. They found evidence of strong persistence in the variance and covariance processes, but less persistence in the beta process. This indicates that realized volatility and realized covariance are fractionally cointegrated.[11]

We calculate the realised betas as follows: defining R_{i,t_k} and R_{CMI,t_k} as the intra-day returns at time $t_k = 1, \ldots, m$, of the i-th commodity and the commodity index, respectively, and with m the number of intra-day returns, the realized beta is:

$$\beta_{i,t} = \frac{\sum_{k=1}^{m} R_{i,t_k} R_{CMI,t_k}}{\sum_{k=1}^{m} R_{CMI,t_k}^2}. \tag{1}$$

The numerator in Equation (1) is the classical estimator of the realized covariance, the denominator is the classical estimator of the realized variance.

Before discussing the results, an important caveat to this analysis is that an increase in realized betas indicates an increase in return comovement in the absence of micro-structure noise. In the presence of jumps and micro-structure noise (e.g. stale prices, asynchronous trading), the realised variance estimator (denominator of the realised beta) is not longer efficient. Additionally, as the sample frequency increases, the realized covariance estimator is biased toward zero, the so-called Epps (1979) effect. Following Hansen et al. (2014), in this paper we rely on the multivariate kernel estimator proposed in Barndorff-Nielsen et al. (2011). This consistent estimator is guaranteed to be positive semi-definite, and is robust to measurement noise and to non-synchronous trading.

With this proviso, the results are presented in Tables 9 (all commodities) and 10 (only Oil as energy commodity). We observe a statistically significant increase in the realized betas of index non-energy commodities and corresponding indices, and a smaller or insignificant increase in realized betas of off-index commodities and the resepctive indices. These results support the findings based on regressions on daily returns, and indicate that, on average, realized betas of index commodities increase after 2004. Moreover, this increase in realized betas tells us that the increase in return comovement can be seen not only at a daily frequency, but even at intra-day levels. This provides further evidence of a change in commodity price behaviour, and, in particular, of an increase in the index-commodity comovement as a result of financialization.

[11] Other related studies include Barndorff-Nielsen and Shephard (2004), who derived asymptotic results for realized beta and Dovonon et al. (2013), who established a theory for bootstrapping inference.

Table 9: Average Realized Betas

	S&P GSCI	DJ-UBS CI	Th.Reuters CI
Commodity	$\Delta\beta$	$\Delta\beta$	$\Delta\beta$
WTI crude oil	-0.14	0.16	0.28
Heating Oil	-0.02	-0.11	0.17
RBOB unlead gas	0.12	0.02	0.07**
Natural Gas	0.35	0.21	0.27
Corn	0.33	0.39	0.49
Soybeans	0.28	0.31	0.25
Chicago wheat	0.21	0.21	0.23
Soybean oil	0.25	0.22	0.19
Soybean meal	0.20	0.14	0.06**
Rough rice	-0.01	-0.01	-0.03
Oats	0.01	-0.10	-0.24
Coffee	0.16	0.20	0.29
Cotton	0.16	0.20	0.31
Sugar	0.25	0.28	0.37
Cocoa	0.09	0.10	0.12
Lumber	0.02	0.02	-0.01
Orange Juice	0.03	0.03	0.00
Feeder cattle	-0.01	-0.03	-0.10
Lean hogs	0.03*	0.02	0.00
Live cattle	0.04	0.04	0.02
Pork bellies	-0.03	-0.11	-0.41
Gold	0.26	0.28	0.36
Silver	0.43	0.48	0.64
Copper	0.35	0.38	0.52
Platinum	0.16	0.18	0.23

Table 10: Average Realized Betas - Oil only

	S&P GSCI	DJ-UBS CI	Th.Reuters CI
Commodity	$\Delta\beta$	$\Delta\beta$	$\Delta\beta$
WTI crude oil	3.30	1.51	1.03
Corn	0.60	0.66	0.57
Soybeans	0.54	0.40	0.21
Chicago wheat	0.57	0.37	0.34
Soybean oil	0.52	0.26	0.20
Soybean meal	0.42	0.10	0.09*
Rough rice	-0.01	-0.10	-0.12
Oats	0.09	-0.44	-0.46
Coffee	0.29	0.42	0.41
Cotton	0.29	0.36	0.33
Sugar	0.46	0.61	0.54
Cocoa	0.11	0.19	0.17*
Lumber	0.06	0.02	0.00
Orange Juice	0.04	0.15	0.05
Feeder cattle	-0.04	-0.16	-0.20
Lean hogs	0.04	-0.10	-0.12
Live cattle	0.06	0.03	-0.02
Pork bellies	-0.13	-0.60	-0.93
Gold	0.35	0.43	0.39
Silver	0.58	0.77	0.71
Copper	0.49	0.66	0.59
Platinum	0.27	0.33	0.31

Reported are the realized betas differences pre and post chosen date. Positive significant differences from zero at the 10% and 5% levels in two-sided tests are denoted by * and **, respectively. Light grey cells denote that the difference is not significant at 10% level or higher; dark grey cells denote negative significant differences at 10% level. Remaining cell denote difference significant at 1% level. Commodities in bold are those not included in any index.

4 Conclusions

Over the last decade, and following the 2000 equity market crash in particular, the popularity of commodity investing has increased dramatically, as investors have sought out commodity financial assets (especially commodity indices) as a means to diversify their portfolios. This process is often referred to as the financialization of commodities, and since 2005 it has been accompanied by a noticeable increase in the returns comovement of different commodity classes.

This paper seeks to add to the literature on commodity financialization by studying the comovements between the three main US commodity indices and commodities in or off the indices. We use both univariate and bivariate regressions to examine two time periods: 1998-2005 (pre-financialization) and 2005-2011 (post-financialization).

In the univariate regressions, starting with 2005 we observe a significant increase in comovement between index non-energy commodities and indices, and either no change or a significant decrease in the comovement of off-index commodities and indices. We do not, however, observe an increase in comovement between the index energy commodities and the indices. These results were corroborated by the bivariate regressions. In this setup, index non-energy commodities again exhibit an increase in comovement with the indices. The comovement with the 'off-index' commodities index, however, does not decrease. In contrast, we find strong evidence that off-index commodities do not exhibit increased comovement with either their respective indices or the 'off-index' commodities index. We interpret these results as evidence of an increased financialization post-2005. We note, however, that alternative explanations for the regression findings may also be considered. These include non-trading effects (i.e. that the comovement results could have a spurious upward bias due to the greater liquidity and increased trading activity of indexed commodities) and common fundamental characteristics (i.e. that commodities sharing supply-driven common characteristic should exhibit similar correlation strucutres). We explicitly test for both of these effects and find that their impact is likely to be minimal. As an additional check of the robustness of our findings, we re-run the regressions for an earlier (pre-financialization) period and find no evidence of an increase in comovement between index or non-index commodities and the indices, which provides further support for the finacialization effect. Finally, to further corroborate the regression findings, we extend our analysis to account for high-frequency returns dynamics by means of the so-called realized beta, and reach similar results.

Our findings provide new evidence in support of the theories on style investing and benchmarking effect, which explain the changes in commodity behaviour due to increased commodity index investing. Our results thus further back the claim that the return comovement is a result of commodity financialization.

References

Adams, Z. and Gluck, T. (2015). Financialization in Commodity Markets: A Passing Trend or the New Normal? *Journal of Banking and Finance*, 60:93–111.

Andersen, T., Bollerslev, T., Diebold, F., and Wu, G. (2006). Realized beta: persistence and predictability. In Fomby, T. and Terrel, D., editors, *Advances in Econometrics: Econometric analysis of economic and financial time series.*, volume 20, pages 1–37. Elsevier Sciences: Amsterdam.

Ankrim, E. M. and Hensel, C. R. (1993). Commodities in asset allocation: A real-asset alternative to real estate? *Financial Analysts Journal*, 49(3):20–29.

Barberis, N. and Shleifer, A. (2003). Style investing. *Journal of Finacial Economics*, 68:161–199.

Barberis, N., Shleifer, A., and Wurgler, J. (2005). Comovement. *Journal of Financial Economics*, 75:283–317.

Barndorff-Nielsen, O., Hansen, P., Lunde, A., and Shephard, N. (2011). Multivariate realised kernels: consistent positive semi-definite estimators of the covariation of equity prices with noise and non-synchronous trading. *Journal of Econometrics*, 162:149–169.

Barndorff-Nielsen, O. and Shephard, N. (2004). Econometric analysis of realized covariation: high-frequency based covariance, regressions, and correlation in financial economics. *Econometrica*, 72(3):885–925.

Basak, S. and Pavlova, A. (2016). A model of financialization of commodities. *The Journal of Finance*, 21(4):1511–1556.

Bollerslev, T. and Zhang, B. (2003). Measuring and modeling systematic risk in factor pricing models using high frequency data. *Journal of Empirical Finance*, 10(5):533–558.

Bruno, V., Buyuksahin, B., and Robe, M. (2015). The financialization of food? *Working Paper*.

Buyuksahin, B., Haigh, M., Harris, J., Overdahl, J., and Robe, M. (2008). Fundamentals, trader activity and derivative pricing. Working paper.

Buyuksahin, B. and Robe, M. (2014). Speculation, commodities and cross-market linkages. *Journal of International Money and Finance*, 42:38–70.

Campbell, R. (2008). Art as a financial investment. *The Journal of Alternative Investments*, 10(4):64–81.

Cheng, I., Kirilenko, A., and Xiong, W. (2014). Convective Risk Flows in Commodity Futures Markets. *Review of Finance*, 1:1–49.

Cheng, I.-H. and Xiong, W. (2014). Financialization of commodity markets. *Annual Review of Financial Economics*, 6(1):419–441.

Dimson, E. and Spaenjers, C. (2011). Ex post: The investment performance of collectible stamps. *Journal of Financial Economics*, 100(2):443 – 458.

Dovonon, P., Goncalves, S., and Maddahi, N. (2013). Bootstrapping realized multivariate volatility measures. *Journal of Econometrics*, 173:49–65.

Edwards, F. R. and Liew, J. (1999). Hedge funds versus managed futures as asset classes. *The Journal of Derivatives*, 6(4):45–64.

Epps, T. (1979). Comovements in stock prices in the very short run. *Journal of the American Statistical Association*, 74:291–296.

Erb, C. and Harvey, C. (2006). The strategic and tactical values of commodity futures. *Financial Analyst Journal*, 62(2):69–97.

Fattouh, B., Kilian, L., and Mahadeva, L. (2013). The role of speculation in oil markets: What have we learned so far? *The Energy Journal*, 34(3).

Gorton, G. and Rouwenhorst, K. (2006). Facts and fantasies about commodity futures. *Financial Analyst Journal*, 62(2):47–68.

Hamilton, J. D. and Wu, J. C. (2015). Effects of index-fund investing on commodity futures prices. *International Economic Review*, 56(1):187–205.

Hansen, P., Lunde, A., and Vove, V. (2014). Realized beta garch: a multivariate garch model with realized measures of volatility. *Journal of Applied Econometrics*, 29:774–799.

Harris, L. and Gurel, E. (1986). Price and volume effects associated with changes in the sp 500 list: new evidence for the existence of price pressures. *The Journal of Finance*, 41(4):815–829.

Hau, H., Massa, M., and Peress, J. (2010). Do demand curves for currencies slope down? evidence from the msci global index change. *The Journal of Finance*, 23(4):1681–1717.

Irwin, S. and Sanders, D. (2011). Index funds, financialization, and commodity futures markets. *Applied Economic Perpsectives and Policy*, 33:1–31.

Irwin, S., Sanders, D., and Merrin, R. (2009). Devil or angel? the role of speculation in the recent commodity price boom (and bust). *Journal of Agricultural and Applied Economics*, 41:377–391.

Irwin, S. H. and Sanders, D. R. (2012). Testing the masters hypothesis in commodity futures markets. *Energy Economics*, 34(1):256 – 269.

Krugman, P. (2008). More on oil and speculation. *New York Times*.

Nazlioglu, S., Erdem, C., and Soytas, U. (2013). Volatility spillovers between oil and agricultural commodity markets. *Energy Economics*, 36:658–665.

Ohashi, K. and Okimoto, T. (2016). Increasing trends in the excess comovement of commodity prices. *Journal of Commodity Markets*, 1(1):48–64.

Sadorsky, P. (2014). Modeling volatility and correlations between emerging market stock prices and the prices of copper, oil and wheat. *Energy Economics*, 43:72–81.

Shleifer, A. (1986). Do demand curves for stocks slope down? *The Journal of Finance*, 41(3):579–590.

Stoll, H. and Whaley, R. (2010). Commodity index investing and commodity futures prices. *Journal of Applied Finance*, 1:1–40.

Tang, K. and Xiong, W. (2012). Index investment and the financialization of commodities. *Financial Analysts Journal*, 68(6):54–74.