Index Investment and Financialization of Commodities*

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Abstract

This paper finds that concurrent with the rapid growing index investment in commodities markets since early 2000s, futures prices of different commodities in the US became increasingly correlated with each other and this trend was significantly more pronounced for commodities in the two popular GSCI and DJ-UBS commodity indices. This finding reflects a financialization process of commodities markets and helps explain the synchronized price boom and bust of a broad set of seemingly unrelated commodities in the US in 2006-2008. In contrast, such commodity price comovements were absent in China, which refutes growing commodity demands from emerging economies as the driver.

The synchronized rise and fall in prices of oil and a broad set of non-energy commodities in 2006-2008 has stimulated increasing public attention to commodities markets. Figure 1 depicts the price appreciations of oil, wheat, soybeans, copper, cotton, and live cattle since 1991. In particular, there is heated debate in policy circles about whether speculation caused unwarranted increases in the cost of energy and food and induced excessive price volatility. Policy makers in the US and various European countries are actively considering measures to curb speculation.

There are two opposing views. One of them attributes the boom-and-bust cycle to a simple matter of supply and demand, while the other stressing excessive speculation by index investors. According to the first view (e.g., Krugman (2008), Hamilton (2009), and Kilian (2009)), the rapid growth of emerging economies such as China propelled the quick increase of world demands and caused commodity prices to soar before the summer of 2008. Prices later fell sharply when the world recession caused demands to fade. The second view attributes the large volatility of commodity prices to distortions caused by large investment flow into commodity

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indices. According to a CFTC staff report (2008) and Masters (2008), the total value of various commodity index-related instruments purchased by institutional investors has increased from an estimated $15 billion in 2003 to at least $200 billion in mid-2008. A recent report by the US Senate Permanent Subcommittee on Investigations (2009) argues that the dramatic index investment flow had distorted prices of some commodities such as wheat.

Despite the great public attention on the large increase of commodity price volatility in recent years, the concurrent economic transition of commodities markets precipitated by the rapid growth of index investment in commodities has gone unnoticed. Prior to early 2000s, despite liquid futures contracts traded on many commodities, commodity prices behaved differently from that of typical financial assets. Commodity prices provided risk premium for idiosyncratic commodity price risk (e.g., Bessembinder (1992) and de Roon, Nijman and Veld (2000)); and commodities had little price comovements with stocks (e.g., Gorton and Rouwenhorst (2006)) and with each other (e.g., Erb and Harvey (2006)). These aspects are in sharp contrast to the price dynamics of typical financial assets, which carry premium only for systematic risk and are highly correlated with market indices and with each other. This contrast indicates that commodities markets were partially segmented from outside financial markets and from each other.

The tide changed in early 2000s, when the collapse of equity market in 2000 and the widely publicized discovery of a small negative correlation between commodity returns and stock returns led to a belief that commodity futures could be used to reduce portfolio risk. This belief allowed investment banks to successfully promote commodity futures as a new asset class for prudent investors. As a result, various instruments based on commodity indices have attracted billions of dollars of investment from institutional investors and wealthy individuals. The increasing presence of index investors precipitated a fundamental process of financialization amongst commodities markets, through which commodity prices became more correlated with prices of financial assets and with each other. In this paper, we analyze the effects of this financialization process.

We focus on the increased price comovements between different commodities after 2004, which is roughly the time when significant index investment started to flow into commodities markets, to identify the effects of growing commodity index investment. As index investors typically focus on strategic portfolio allocation between the commodity class and other asset classes such as stocks and bonds, they tend to trade in and out of all commodities in a chosen index at the same time (e.g., Barberis and Shleifer (2003)). As a result, their increasing presence should have a greater impact on commodities in the two most popular commodity indices – the Goldman Sachs Commodity Index (GSCI) and Dow-Jones UBS Commodity Index (DJ-UBS) – than those off the indices. Consistent with this hypothesis, we find that futures prices of non-energy commodities became increasingly correlated with oil after 2004. In particular, this trend was significantly more pronounced for indexed commodities than for those off the indices. While this trend intensified after the world financial crisis triggered by the bankruptcy of Lehman Brothers in September 2008, its presence was already evident and significant before the crisis.

There is also evidence of an increasing return correlation between commodities and Morgan Stanley emerging market equity index in recent years. This confirms the increasing importance of commodity demands from rapidly growing emerging economies in determining commodity prices. However, a closer comparison of commodity futures prices in China – the growth engine of emerging economies in the 2000s – with the synchronized boom-and-bust cycle in the US uncovers a sharp contrast. In 2006-2008, while futures prices of some commodities heavily imported by China, such as heating oil, copper, and soybeans, did experience similar rise and fall as those in the US; the prices of some others such as wheat, corn and cotton did not exhibit any pronounced cycle. Furthermore, the average return correlation among different commodities in China did not display any significant increase in recent years either. Taken together, demands from China may have contributed to the price boom and bust of some commodities, but unlikely to all commodities at the same time.

Price comovements among different commodities had also been high in 1970s and early 1980s. When the US economy was hit by persistent oil supply shocks and stagflation, the double-digit inflation rate and accompanied large inflation volatility coincided with a period of high return correlations among commodities (with an average around 0.3). In contrast, the increases of commodity return correlations in late 2000s were not only larger in magnitude (with an average correlation over 0.5) but also different in nature. They emerged when inflation and inflation volatility remained subdued throughout 2000s, and thus inviting explanations other than inflation.

As a result of the financialization process, the price of an individual commodity is no longer simply determined by its supply and demand. Instead, commodity prices are also determined by a whole set of financial factors, such as the aggregate risk appetite for financial assets, and investment behavior of diversified commodity index investors. On one hand, the presence of these investors can lead to a more efficient sharing of commodity price risk; on the other hand, their portfolio rebalancing can spill over price volatility from outside to commodities markets and also across different commodities (e.g., Kyle and Xiong (2001)). While the data sample after 2004 may be too short to give a reliable measure of changes in commodity risk premia, we are able to systematically examine the effects of growing index investment on commodity price volatility and comovements.

Overall, our analysis shows that return correlations of commodities with stocks, the US dollar, and with each other have significantly increased in recent years. Volatility spillover has also contributed to the large price volatility of commodities in 2008, during which indexed non-energy commodities had larger price volatility than those off-index ones; this difference was partially related to the greater return correlations of indexed commodities with oil. These changes in commodity price dynamics have profound implications for a wide range of issues from commodity producers' hedging strategies and speculators' investment strategies to many countries' energy and food policies. We expect these effects to persist as long as index investment strategies remain popular among investors.

Our emphasis on price comovements of commodities is distinct from those in the literature on returns and risk premia of commodities, e.g., Fama and French (1987), Bessembinder (1992), de Roon, Nijman, and Veld (2000), Erb and Harvey (2006), Gorton, Hayashi, and Rouwenhorst (2007), Hong and Yogo (2009), and Acharya, Lochstoer, and Ramadorai (2009). These papers focus on the roles of macroeconomic risk, producers' hedging incentives, and commodity inventories in determining cross-sectional and time-series properties of commodity risk premia.

Our analysis corroborates with Pindyck and Rotemberg (1990) who find that common macro shocks cannot fully explain comovements in commodity prices between 1960 and 1985. In contrast to their study, our analysis focuses on connecting the large inflow of commodity index investment to the large increase of commodity price comovements in recent years by examining the difference in these comovements between indexed and off-index commodities. This identification strategy builds on the finding of Barberis, Shleifer and Wurgler (2005) that after a stock is added to S&P 500 index, its price comovement with the index increases significantly.

Several recent papers, e.g., Buyuksahin, Haigh and Robe (2009) and Silvennoinen and Thorp (2010), also find that return correlation between commodities and stocks has gone up substantially during the recent financial crisis but not before. Different from these studies, our analysis highlights that the increase in commodity return correlations started long before the crisis and cannot be simply attributed to the crisis. Instead, we identify the role of index investors in linking different commodities markets with each other and with outside financial markets. On the latter dimension, our paper complements Etula (2009), who shows that the risk-bearing capacity of securities brokers and dealers is an important determinant of risk premia and return volatility in commodities markets.

The paper is organized as follows. Section I provides some background information about commodities and commodity indices. Section II documents the increasing return correlations among different commodities in recent years. We discuss several economic mechanisms including the financialization process of commodities markets for explaining these increases in Section III, and examine these mechanisms in Section IV. Section V discusses volatility spillover caused by commodity index investment and Section VI concludes the paper.

I. Commodities and Commodity Indices

We focus on commodities with active futures contracts traded in the US. There are 28 such commodities available in recent years. We obtain daily futures prices and open interests of these commodities from Pinnacle Data Corp.[1] Table 1 lists and classifies these commodities in five sectors: energy, grains, softs, livestocks, and metals.[2]

The energy sector contains 4 commodities: WTI (West Texas Intermediate grade) crude oil, heating oil, gasoline, and natural gas.[3] Crude oil is the most important component in this sector as heating oil and gasoline are refined oil products, whose prices move closely with crude oil. The grain sector contains 9 commodities: corn, Chicago wheat, Kansas wheat, Minneapolis wheat, soybeans, soybean oil, soybean meal, rough rice, and oats. These grains are substitutes for each other as food for humans and animals.[4] The soft sector is a mix of tropics that are grown primarily in tropical and subtropical regions. There are 6 commodities in this sector: coffee, cotton, sugar, cocoa, lumber and orange juice. We follow the common practice to classify them in one sector although the links between the softs are not as close as the links between commodities in other sectors. There are four commodities in the livestock sector: feeder cattle, lean hogs, live cattle and pork bellies. These commodities are substitutes for each other and are primarily used for human consumption. The metal sector contains 5 commodities: gold, silver,

[1] Futures contracts were also offered on some other commodities but were later terminated. As our analysis focuses on price comovements rather than commodity returns, survivorship bias is not a concern.

[2] See Geman (2005) for a comprehensive description of these commodity sectors and distribution of the global supply and demand of each of the commodities.

[3] The New York Mercantile Exchange (NYMEX) offers futures contracts on each of them with expirations in every month of a year. The WTI crude oil contracts specify a type of light and sweet oil (with 38-40° API and 0.3% sulfur) to be delivered at Cushing, Oklahoma. These contracts are heavily traded and their prices are widely used as benchmarks for determining the prices of crude oil of different grades and at different locations. The Brent crude oil contracts specify a similar grade of oil to be delivered at Shetland Islands, UK. Their prices move closely with those of the WTI contracts. The demand and supply fluctuations in the local markets of North America and Europe could also cause some variations between the prices of Brent and WTI contracts. We do not include the Brent contracts in our sample to avoid potential complications from asynchronous daily closing prices of different commodities between the US and London markets.

[4] Soybeans are crushed to produce meal and oil. The three forms constitute the so-called "soybean complex", each of which underlies futures contracts traded on Chicago Mercantile Exchange (CME). Corn is mostly used as animal feed, competing with wheat and soybean meal. In the recent years, corn is also used in the U.S. for producing ethanol and other alternative fuels. Wheat is traded on three exchanges: the CME, the Kansas City Board of Trade (KCBOT), and the Minneapolis Grain Exchange (MGE). Chicago wheat is a soft winter wheat, grown primarily in the central states. It is a low-grade wheat mostly used as livestock feed or as flour for cheap bread. Kansas wheat is a hard, red, winter wheat, grown primarily in the southern states, and is used mainly for human food. Minneapolis wheat is the highest-grade wheat, planted in the northern states. Rice is the second largest crop in planting acreage across the world after wheat. It is primarily used for human consumption. While oats are suitable for human consumption as oatmeal and rolled oats, its primary use is as livestock feed.

copper, platinum and palladium.[5] They are used both as investments and as inputs for industrial production.

An increasingly popular investment strategy in the recent years is to invest in a basket of commodities following a certain commodity index. A commodity index functions like an equity index, such as the S&P 500, in that its value is derived from the total value of a specified basket of commodities. Each commodity in the basket is assigned a specified weight. Commodity indices typically build on the values of futures contracts, which are typically nearby contracts with delivery time longer than one month,[6] to avoid the cost of holding physical commodities. When a first-month contract matures and the second-month contract becomes the first-month contract, a commodity index specifies the so-called "roll" – i.e., replacing the current contract in the index with a following contract. In this way, commodity indices provide returns comparable to passive long positions in listed commodity futures contracts. By far the largest two indices by market share are the S&P Goldman Sachs Commodity Index (GSCI) and the Dow-Jones UBS Commodity Index (DJ-UBS) [7]. There is also a proliferation of other smaller indices operated by other institutions, such as the Rogers International and Deutsche Bank Liquid Commodity Indices. These indices differ in terms of index composition, commodity selection criteria, rolling mechanism, rebalancing strategy, and weighting scheme.[8]

Table 1 provides the weights of the GSCI and DJ-UBS indices in the 28 commodities traded in the US. Both indices incorporate a wide range of commodity futures. There are some commodities in neither index: Minneapolis wheat, soybean meal, rough rice, and oats in the grain sector; lumber and orange juice in the soft sector; pork bellies in the livestock sector; and platinum and palladium in the metal sector. These two indices use different selection and weighting schemes: GSCI is weighted by each commodity's world production, while DJ-UBS relies on the relative amount of trading activity of a particular commodity. As a result, commodities in these indices tend to be large in terms of world production and liquid in terms of trading in the futures markets. The composition of these indices is stable and has stayed the same

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[5] We exclude several popular metals that are only traded in London, such as aluminum, lead, nickel, zinc, and tin , to avoid potential complications from asynchronous daily closing prices of different commodities between the US and London markets.

[6] As shown in Gorton and Rouwenhorst (2006) and Hong and Yogo (2009), commodity futures contracts often become illiquid in the delivery month. This is because many traders are reluctant to deliver or accept delivery of the physical commodities

[7] The Dow Jones-UBS Commodity Index was also known as the Dow Jones-AIG Commodity Index before 2009.

[8] See AIA Research Report (2008) for a detailed account of construction methods of various commodity indices.

in the recent years. Furthermore, the joint set of GSCI and DJ-UBS indices also covers almost all of the commodities in other less popular indices.[9]

The energy sector carries a much greater weight than the other sectors in the GSCI and DJ-UBS indices. The four energy commodities listed in Table 1 add up to 58% of the GSCI and 39.6% of the DJ-UBS. WTI crude oil alone accounts for 40.6% of the GSCI. Since the commodities in the energy sector move closely with each other, we will use crude oil as a focal point in our later analysis to study price comovements of non-energy commodities with oil.

II. The Increased Price Comovements of Commodities

In this section, we provide some preliminary analysis of the price comovements of individual commodities. We illustrate the increased return correlations among seemingly unrelated commodities in recent years by plotting one-year rolling return correlations between oil and a selected commodity from each of the four non-energy sectors: soybeans from the grain sector, cotton from the soft sector, live cattle from the livestock sector, and copper from the metal sector. These commodities give a broad representation of non-energy commodities. We then construct the average return correlation among commodities.

Since centralized trading makes futures contracts more liquid than physical commodities, futures prices are available for a larger set of commodities compared with spot prices. Therefore we choose to focus on futures prices of commodities for the most part of our analysis. In Section IV.D, we will also analyze correlations of spot returns, which are available only for a smaller set of commodities.

For each commodity, we follow Gorton and Rouwenhorst (2006) and Erb and Harvey (2006) to construct a return index from rolling the first-month futures contract. More specifically, we construct a hypothetical investment position in the first-month futures contract of the commodity

[9] Besides directly taking long positions in individual commodity futures contracts, investors can use three types of financial instruments to gain exposure to the return of a commodity index: commodity index swaps, exchange traded funds, and exchange traded notes. See the recent report by US Senate Permanent Subcommittee on Investigations (2009) for a detailed description of these instruments. A commodity index swap is, in essence, a financial instrument that pays a return based on the value of a specified index. A swap dealer, such as a bank or broker-dealer, typically offers a qualified investor the opportunity to purchase, for a fixed price, a swap whose value is linked, on any given date, to the value of the specified commodity index on that date. After selling a swap contract, the swap dealer will typically hedge its own exposure to the swap contract by purchasing the corresponding futures contracts in the commodity index. In the past few years, financial institutions have devised another type of instrument, known as exchange traded funds (ETFs), to mirror the performance of specified commodity indices. Unlike commodity index swaps, which are bilateral transactions between investors and swap dealers, ETFs are traded in exchanges like stocks. An ETF is typically structured so that the value of the ETF shares should reflect the value of the specified commodity index. A third commodity-based instrument involves exchange traded notes (ETNs). ETNs are designed and sold by financial institutions to permit retail investors to purchase shares of a debt security whose price is linked to that of a commodity index.

on a fully collateralized basis. We hold the contract until the 7th calendar day of its maturity month before rolling into the next contract.[10] The excess return of this hypothetical investment on a non-rolling day represents the excess futures return to the initial capital (as we can still earn interest on the capital):

$$R_{i,t} = \ln(F_{i,t,T_1}) - \ln(F_{i,t-1,T_1})$$

where F_{i,t,T_1} is the date-t price of the first-month futures contract of commodity i with maturity date T_1. On a rolling day, not only does the return incorporate the futures price change, but also the price ratio between the first-month contract and the second-month contract.

We normalize the daily excess return from investing in the commodity in each one-year rolling window by its average return and return volatility:

$$R_{i,t}^n = [R_{i,t} - mean(R_i)]/std(R_i).$$

We then regress the normalized return $R_{i,t}^n$ onto the normalized oil return $R_{oil,t}^n$:

$$R_{i,t}^n = \alpha + \rho R_{oil,t}^n + \varepsilon_{i,t}.$$

The estimated coefficient ρ is the return correlation between the two commodities.

Figure 2 depicts the one-year rolling return correlations of oil with soybeans, cotton, live cattle, and copper together with the 95% confidence interval.[11] Panel A shows that from 1986 to 2004, the return correlation between soybeans and oil moved around zero inside a narrow range between -0.1 and 0.2. Between 2004 and late 2009, the correlation steadily climbed up from 0.1 to near 0.6, and this trend is significantly different from zero. Similarly, Panels B, C, and D show that oil had small return correlations with cotton, live cattle, and copper before 2004, and that the correlations have gradually risen to 0.5, 0.4, and 0.6, respectively in 2009.[12] We also plot the one-year rolling correlation between daily returns of GSCI energy and non-energy indices in Panel E. These indices track returns of GSCI commodities (which are listed in Table 1) in the energy and non-energy sectors. Their correlation gradually increased from around 0.1 in 2004 to

[10] GSCI index is rolled from the fifth to ninth business day of each maturity month with 20% rolled during each day of the five-day roll period. DJ-UBS index works similarly. For simplicity, we uniformly specify one-day roll strategy on the 7th calendar of each maturity month for all commodities, including those off-index ones.

[11] Panels B, C, and D start in 1986 because trading of oil futures started only in March 1983. We skip the data in 1983-1984 to avoid potential liquidity problems at the beginning and use returns after 1985 to measure correlations. With the one-year rolling window, our correlation measures start in 1986. Panel D starts in 1990 as trading of copper futures started only in January 1989. Panel E starts in 1983 because GSCI energy index is available only after 1982.

[12] Forbes and Rigobon (2002) point out that when volatility increases, return correlation can be a biased measure of the economic link between assets. We have also adopted the procedure proposed by them to adjust for such biases. The adjustment does not create any significant change to the return correlation plots. More importantly, we will directly test for changes in the links between non-energy commodities and oil by using formal regression analysis. In computing t-stats for testing the changes, we adjust for heteroskedasticity.

over 0.7 in 2009. Taken together, these plots show that return correlations of a broad set of non-energy commodities with oil were small before 2004, which is consistent with the finding of Erb and Harvey (2006), but have been steadily increasing after 2004.

To have a holistic view of return correlations among non-energy commodities and for the period back to 1970s, we construct an average return correlation for all commodities with futures contracts traded at a given time. As commodities in the same sector tend to have greater return correlations with each other than with commodities in other sectors, we need to avoid the potential bias caused by changes of commodity distribution across different sectors. We deal with this issue using the following method: For each sector, we construct an index which tracks the equal-weighted return of all available commodities. Then we compute the return correlations between these indices for all sector pairs, and take the equal-weighted average. To highlight the difference between commodities in and off the two popular commodity indices, we construct two return indices in each sector and calculate the average correlations separately for indexed and off-index commodities. We call a commodity "indexed" if it is in either the GSCI or DJ-UBS index, and "off-index" otherwise.

Figure 3 depicts the average one-year rolling correlations of indexed and off-index commodities from 1973 to 2009. The plot illustrates several interesting features. The average correlation among indexed commodities stayed at a stable level below 0.1 throughout 1990s and early 2000s and was indistinguishable from that among off-index commodities. The mild increase in average correlation among off-index commodities to a level of 0.2 in 2009 is in sharp contrast to that among indexed commodities, which has climbed up to an unprecedented level of 0.5. This difference in the increase in correlations between indexed and off-index commodities allows us to identify the effects of index investment later in our analysis.

Figure 3 also shows that the average correlations of indexed and off-index commodities had been as high as 0.3 in 1970s. As we will discuss in Section III.D, this coincided with the wild inflation and inflation volatility during that period. The average correlations gradually declined below 0.1 in late 1980s as inflation and inflation volatility were eventually tamed. Interestingly, there were no pronounced differences between indexed and off-index commodities despite the high correlation levels in the 1970s. Furthermore, inflation and inflation volatility remained subdued even to date. The contrast between the high return correlations in 1970s and 2000s indicates that they were driven by different mechanisms. Our analysis focuses on understanding the latter period.

III. Economic Mechanisms

What caused the increases of return correlations among seemingly unrelated commodities in recent years? In this section, we discuss several possible economic mechanisms including growing commodity demands from emerging economies and the financialization process of commodities markets precipitated by the rapid growth of commodity index investment.

A. Rapid Growth of Emerging Economies

The rapid growth of China, India, and other emerging economies is a popular explanation for the recent commodity price boom (e.g., Krugman (2008), Hamilton (2009), and Kilian (2009)). The economic development of these emerging economies in 2000s stimulated unprecedented demands for a broad range of commodities in different sectors, such as energy and metals, and thus might have led to a joint price boom of these commodities.

The commodity demands from the emerging economies depend positively on the strength of their economic growth and negatively on the price of the US dollar, which is widely used to settle commodity transactions. We use the Morgan Stanley emerging market equity index to proxy for the economic growth of emerging economies. This index tracks equity market performance of the global emerging markets. As of May 2005, this index consists of 26 emerging economies: Argentina, Brazil, Chile, China, Colombia, Czech Republic, Egypt, Hungary, India, Indonesia, Israel, Jordan, Korea, Malaysia, Mexico, Morocco, Pakistan, Peru, Philippines, Poland, Russia, South Africa, Taiwan, Thailand, Turkey and Venezuela. This broad representation makes this index a good proxy for the economic growth of the global emerging economies. We use return of the US dollar index futures traded on ICE to track price fluctuations of the US dollar. The underlying of this futures contract is an index that weighs dollar exchange rates with six component currencies (euro, Japanese yen, British pound, Canadian dollar, Swedish krona and Swiss franc). We obtain data on these two indices from Bloomberg.

Figure 4 depicts the one-year rolling correlation between daily returns of GSCI index and Morgan Stanley emerging market equity index. Before 2004, the correlation fluctuated mostly around zero, except that it dropped to a negative level of -0.4 during the Gulf war in 1990-1992. The war caused stock prices to fall and oil price to soar. Interestingly, after 2004 the correlation rose gradually from around 0 to above 0.5 in 2009. This increasing trend confirms an increasingly important effect of emerging economies on commodity prices in recent years.

Figure 4 also shows a clear decreasing trend in return correlation between the GSCI index and US dollar index. Before 2004, this correlation fluctuated inside a narrow band between -0.2 and 0.2. After 2004, it dropped steadily from around 0 to -0.4 in 2009. This trend is consistent with growing commodity demands from emerging economies. As we will discuss later, this trend is also consistent with increasing index investment flow into commodities markets from outside US. In our regression analysis later, we will formally examine the links of the GSCI index to the emerging market index and the US dollar index. We will also use the emerging market index to control for the effects of commodity demands from emerging economies in our analysis of price comovements of non-energy commodities with oil.

Despite the important effects of emerging economies on commodity prices, it remains unclear whether they were the driver of the synchronized price boom and bust across the broad range of commodities in 2006-2008. To address this question, we collect futures prices of commodities traded in China, the growth engine of emerging economies in the 2000s, from Wind (a widely used vendor of financial data in China). China gradually introduced futures contracts on a small set of commodities since late 1990s. Table 1 lists these commodities and the starting dates of futures trading in China. Figure 5 depicts front-month futures prices for six commodities in China and the US.[13] Panels A, B and C show that futures prices of heating oil, copper and soybeans in China had boom-and-bust cycles closely matched with the corresponding cycles in the US. These closely matched price dynamics are consistent with the heavy imports of these commodities by China. More interestingly, Panels D, E, and F show that the price dynamics of wheat, corn, and cotton in China are very different from those in the US.. In the US, these commodities experienced boom-and-bust cycles well synchronized with other commodities with peaks in early 2008. In contrast, their prices in China did not display any pronounced cycle. As China was not a major importer or exporter of wheat, corn, and cotton, the large (explicit or implicit) cost of transporting these commodities across the Pacific prevents effective arbitrage of price deviations between China and the US. However, the lack of price cycles for these commodities in China indicates that the synchronized price boom and bust in the US were not driven by demands from China.

To compare commodity return correlations in China and the US, we pool together a sample of 8 commodities with futures contracts simultaneously traded in China and the US. These commodities include heating oil in the energy sector; corn, wheat and soybeans in the grain sector; cotton and sugar in the soft sector; and copper and gold in the metal sector. We match the front-month futures returns of these commodities with the corresponding ones in the US. We use the same procedure we used before to first construct an equal-weighted return index for each commodity sector in China and in the US based on all commodities available in China. We then compute an equal-weighted average of the one-year rolling correlations for all sector pairs in each of the countries. Figure 6 depicts the average commodity return correlations in China and the US from 2000 to 2009. These two correlations were roughly at the same levels around 0.1 in early 2000s. Interestingly, the average correlation in the US had increased steadily to a level above 0.5 in late 2000s, while the average correlation in China did not grow much and stayed

[13] Commodity prices in China are settled in Renminbi. We normalize the price of each commodity in both China and US to be 100 at the beginning of its sample period. Renminbi had a steady appreciation of about 20% against dollar from 2005 to 2009. Adjusting the exchange rate fluctuation does not affect the price boom-and-bust cycles in the plots. The exchange rate has no effect on commodity price comovements in China either.

below 0.2 throughout the same period. This contrast again refutes commodity demands from China as the driver of the large increase of commodity price comovements in the US.

B. Financialization of Commodities

The focus of our analysis is the new development in commodities markets – the large inflow of index investment in recent years. When equity market collapsed in 2000, the widely publicized discovery of a negative correlation between commodity returns and stock returns by Greer (2000), Gorton and Rouwenhorst (2006), and Erb and Harvey (2006) in the investment communities allowed Goldman Sachs and other indexers to successfully promote commodity futures as a new asset class for institutional investors. As a result, commodities markets attracted billions of dollars of investment from financial institutions, insurance companies, pension funds, foundations, hedge funds, and wealthy individuals. Figure 7 depicts the rapid growth in the open interest (total number of contracts outstanding with maturities less than one year) of various commodity futures after 2004.

B.1. Index Investment Flow

The Commodity Index Traders (CIT) report, released by the US Commodity Futures Trading Commission (CFTC) on each Friday, allows us to measure how much index investment has flowed into a set of commodities after 2006. The report shows positions of index traders, which include swap dealers, pension funds, and other investment funds that trade commodity indices for 12 agricultural commodities since 1/3/2006.[14] These include corn, soybeans, Chicago wheat, Kansas wheat, and soybean oil from the grain sector; coffee, cotton, sugar, and cocoa from the soft sector; and feeder cattle, lean hogs, and live cattle from the livestock sector. This list coincides with the joint set of GSCI and DJ-UBS indices in these three sectors. The CIT report does not cover any commodities in the energy and metal sectors.

The CIT report classifies the reportable market participants into three groups: commercial traders, index traders, and non-commercial traders. The CFTC identifies an individual reportable trader as commercial if the trader uses futures contracts in that particular commodity for hedging. The non-commercial traders include all reportable traders who are neither commercial nor index traders. The CIT report provides the aggregate long and short positions of each of the three groups in a particular commodity.[15]

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[14] The CIT report supplements the standard Commitments of Traders (COT) report, which is also released by the CFTC on the breakdown of every Tuesday's positions on all exchange-traded futures and options on US-based exchanges. The COT report only classifies reportable traders to two categories, commercial and non-commercial.

[15] The CIT report also presents the non-commercial traders' aggregate spreading positions, i.e., equal long and short futures position on the same commodity but with different maturities.

Table 2 reports the average position size of each group of traders in each of the commodities based on the weekly CIT report from 1/3/2006 to 10/29/2009. The table shows that index traders' long positions contribute to a substantial fraction of open interest of each of the commodities: an average of 28.4% across all the commodities in the sample, 42.4% of lean hogs and 41.6% of Chicago wheat respectively at the high end. Index traders' short positions are minimal, with an average of 1.6% of open interest across commodities.

We can construct the investment flow by index traders in and out of the 12 commodities in each week by summing up the dollar value of index traders' net position change in each of the commodities:

$$IF_t = \sum_{i=1}^{12}(NL_{i,t} - NL_{i,t-1})P_{i,t-1} \qquad (1)$$

where $NL_{i,t}$ represents the net long position of index traders in commodity i in week t and $P_{i,t-1}$ is the price of the commodity in week t-1. In this calculation, we use prices of first-month futures contracts, and assume that all position changes occur during the previous week. Then we add up the index flow from the first week of 2006, the beginning of the CIT report data, to any week before 10/29/2009 to obtain the accumulated index flow to that week.

Figure 8 depicts the accumulated index flow together with the GSCI agriculture & livestock excess return index. This index follows the performance of the same three sectors – grains, softs, and livestocks – as those covered by the CIT report. The figure shows that since the beginning of 2006, these three sectors had a large net inflow which accumulated to nearly 20 billion dollars in early 2008. Then there was a stream of outflow, which led to an accumulated index flow of negative 5 billion dollars by March 2009. The figure also shows that fluctuations of the GSCI agriculture & livestock excess return index were in striking sync with the index flow.

B.2. Economic Effects

There is evidence suggesting that before early 2000s, commodities markets were partially segmented from outside financial markets and from each other. Erb and Harvey (2006) show that commodities had only small positive return correlations with each other; Gorton and Rouwenhorst (2006) show that commodity returns had negligible correlations with the S&P 500 stock index return, especially at short horizons such as daily and monthly; Bessembinder (1992) and de Roon, Nijman and Veld (2000) find that returns of commodity futures increased with net short positions of commodity hedgers after controlling for systematic risk. These attributes contrast those of typical financial assets such as stocks, where prices carry premium only for systematic risk, and tend to have high return correlations with each other (even if they share little common fundamentals).

The segmentation of commodities markets implies potentially inefficient sharing of commodity price risk, which is also consistent with the longstanding hedging pressure theory of commodity prices dating back to Keynes (1930), Hicks (1939), and more recently Hirshleifer (1988). This influential theory posits that commodity hedgers need to offer positive risk premium to induce speculators to share the idiosyncratic risk of the long positions they are endowed with. Since index investors tend to hold large diversified portfolios across different asset classes, their increasing presence is likely to improve the sharing of commodity price risk. However, as is well known, measuring risk premium requires a long sample period. The 5-year period currently available since 2004(roughly when significant index investment started to flow into commodities) is perhaps too short to identify the resulting change in commodity risk premium, which we will leave for future research.

Trading of diversified index investors can act as a channel to correlate commodity prices with prices of other assets in their portfolios (e.g., Kyle and Xiong (2001)). The exact nature of such spillover effects depends on the index investors' portfolio composition and rebalancing strategies. Since commodity index investors usually invest a large fraction of their portfolios in stocks, commodity prices are exposed to shocks to stocks. When a positive shock increases the weight of stocks in the investors' portfolios, diversification incentives motivate them to move some money into commodities, and thus causing commodity prices to comove positively with stock prices. On the other hand, index investors' strategic asset allocation from stocks to commodities or vice versa can also cause commodity prices to comove negatively with stock prices. Furthermore, the rapid growth of commodity index investment is a global phenomenon and a significant fraction of the investment flow comes from international investors who are exposed to shocks to the US dollar exchange rate. When the US dollar appreciates, the same commodity with prices in dollars becomes more expensive to international investors. As a result, their demands decrease and cause commodity prices to comove negatively with the US dollar exchange rate. We will further discuss these spillover effects in Section V.

Our main identification strategy of the increasing presence of commodity index investors builds on the return correlations among different commodities. Index investors are not particularly sensitive to prices of individual commodities since they tend to move in and out of all commodities in their index at the same time based on the strategic allocation of their capital to commodities versus other asset classes such as stocks and bonds. As a result, any shocks to their strategic allocation to the commodity class can cause commodities in the index to move together (e.g., Barberis and Shleifer (2003)). In other words, we expect price comovements of commodities in the GSCI and DJ-UBS indices to be greater than those off the indices. Consistent with this theory, Barberis, Shleifer, and Wurgler (2005) find that in stock markets, addition to the S&P 500 index can significantly increase a stock's return correlation with the index. Motivated by these studies, we focus on the difference between return correlations of indexed and off-index commodities with oil. We choose oil as a focal point because of its dominant weight in the two popular aforementioned commodity indices. In particular, we examine the following empirical hypothesis on the change in this difference after 2004:

- After 2004, non-energy commodities in the GSCI and DJ-UBS indices had greater increases of return correlations with oil than those off the indices.

An implicit assumption in this hypothesis is that other participants of commodities markets, such as traditional speculators, commodity producers, and commercial users only have a limited capacity to absorb trades of index investors. As a result, the increasing presence of index investors can affect commodity prices. It is also worth mention that potential substitutions between closely related commodities by consumers and producers can partially transmit the price impact of index investors to off-index commodities.[16] For example, if prices of corn rise far above those of soybean meal, consumers will substitute soybean meal for corn to feed their animals, or vice versa. Similarly, if prices of corn rise far above those of oats, farmers will allocate more farmland to plant corn instead of oats. But these substitution effects are likely to be imperfect and operate at horizons longer than those of futures trading such as the daily horizon we focus on in this paper.

The choice of the year 2004 as the break point is not important because our main results build on trends in return correlations between non-energy commodities and oil. While the data sample after 2004 may be too short for identifying changes in risk premium, the use of daily data allows us to reliably measure changes in return volatility and correlation.

As mentioned before, commodities in the GSCI and DJ-UBS indices are selected based on their world production and trading liquidity in futures markets. Hence, the higher liquidity of indexed commodities works against this hypothesis because it is less likely for prices of more liquid commodities to be affected by trading of index investors. Liquidity might be a concern for off-index commodities because it can cause price fluctuations of off-index commodities to lag behind oil. We will account for this effect by introducing lags in our regression analysis later.

One might argue that trading by index investors has a greater impact on commodities that carry a greater weight in the commodity indices. However, as their index weights, are matched by their greater world production and higher trading liquidity in futures markets by construction, we expect these commodities to be able to absorb more capital inflow and outflow. For this reason, we choose to focus on the difference in return correlations between commodities in and

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[16] See Casassus, Liu and Tang (2009) for a study of multi-commodity systems with production, substitution and complementary relationships.

off the GSCI and DJ-UBS indices, rather than between commodities with greater and smaller weights in the indices.

As the GSCI and DJ-UBS indices are built on rolling front-month futures contracts of individual commodities, most of our analysis focuses on returns from rolling these front-month futures contracts. A subtle issue is whether the growth of index investment has affected spot prices and futures prices of other maturities in the same way. This depends on the effectiveness of arbitrageurs in synchronizing spot prices and futures prices with different maturities. The standard textbook example on commodity carry trades works as follows: If the price of the front-month futures contract of a commodity becomes too expensive relative to its spot price after adjusting for interest cost and storage cost for carrying the commodity from now to the delivery date of the contract, an arbitrage opportunity emerges and the arbitrageur can short the contract while simultaneously carrying the commodity. Mismatches in the relative prices of futures contracts with different maturities can also lead to similar arbitrage opportunities. Thus, we expect arbitrageurs to spread the price impact of index investment from front-month futures contracts to spot prices and futures prices of other maturities if the interest cost and storage cost incurred in such carry trades are independent of growing index investment. In Section IV.D, we will separately examine the correlations of spot returns and slope changes of futures price curves.

C. The World Financial Crisis

It is well known that prices of financial assets tend to move together during financial crises. Could the recent increase of commodity return correlations be a simple reflection of the recent financial crisis?

Figure 9 depicts the VIX index (i.e., Chicago Board Options Exchange Volatility Index), a widely used measure of equity market volatility derived from the implied volatility of S&P 500 index options. The VIX index mostly stayed near its lowest level around 10% from 2004 to 2007. It gradually climbed up but nevertheless remained below 30% (a normal level from its past) in 2007 and the first half of 2008. Only in September 2008, after the failure of Lehman Brothers, the VIX index suddenly shot up from 20% to near 70%. The dramatic rise of the VIX index is widely regarded as the indicator for the disruption of a full-scale crisis in the financial markets across the world. The VIX index declined below 30% in May 2009 as the crisis abated.

The timing of the financial crisis did not coincide with the increase of commodity return correlations, which has already started in 2004 – long before the dramatic jump-up of the VIX index in September 2008. As a result, the financial crisis cannot fully explain the increase of commodity return correlations. In our regression analysis later, we will separately treat the pre-crisis period before September 2008 to isolate the effect of the crisis.

On the other hand, the crisis also provides an extreme episode for us to examine the effects of financialization on commodities markets. If commodities markets were segmented from outside financial markets, we would not expect a crisis outside to have any significant effect on commodities markets. Figure 10 depicts the one-year rolling correlation between the GSCI and S&P 500 stock index. This figure illustrates a widely noted correlation increase: While this correlation stayed in a band between -0.2 and 0.1 for several years before 2008, it quickly climbed up from 0 to over 0.5 during the crisis and remained high even after the crisis abated in early 2009.[17] This largely increased correlation not only shows that commodities markets became more integrated with outside financial markets, but also suggests potential volatility spillover from outside to commodities markets through trading of index investors, which we will examine in Section V.

D. Inflation

Inflation is a common factor that drives prices of different commodities. Could the recent increase in commodity return correlations be driven by the increasingly important effects of inflation on commodity prices?

Figure 11 depicts the annualized monthly CPI core inflation rate (the percentage change of Consumer Price Index excluding food and energy prices) and the one-year rolling volatility of the monthly CPI core inflation rate. We use the CPI core inflation rate to avoid the contamination of inflation measure by commodity prices. This inflation rate hovered near 10% throughout 1970s when the economy was hit by persistent oil supply shocks and stagflation. The inflation rate remained high around 5% during the 1980s. It was eventually tamed in 1990s and remained low at 2 to 3% levels throughout late 1990s and 2000s. The volatility of the inflation rate has a similar pattern as the inflation rate. It was often above 5% in 1970s and early 1980s, and remained above 3% from early 1980s to early 1990s. After mid 1990s, the inflation volatility gradually declined to a level around 1% in early 2000s and remained at this level during 2000s. Interestingly, in 2000s the commodity return correlations depicted in Figures 2 and 3 show time trends opposite to those of the inflation rate and inflation volatility. Thus, it is unlikely that the recent increase in commodity return correlations were driven by inflation.

E. Adoption of Biofuel

Another recent development in commodities markets is the wide adoption of biofuel. To reduce the reliance on oil as the main source of energy, many countries including the US have adopted new energy policies to promote the use of biofuel. The 2005 US energy bill mandated

[17] See also a recent article in the *Wall Street Journal* (August 16, 2010) based on price fluctuations of oil and S&P 500 stock index in 2010: "Oil gets a new dance partner: stocks" by Carolyn Cui.

that 7.5 billion gallons of ethanol be used by 2012. The 2007 energy bill further increased the mandate to 36 billion by 2022. The combination of ethanol subsidies and high oil prices led to a rapid growth of the ethanol industry, which now consumes about one third of the US corn production. The rise of the ethanol industry might have caused prices of corn and other close substitutes such as soybeans and wheat to comove with oil prices. As corn is also a major source of livestock feed, this effect may have also affected prices of livestock commodities.

A recent study by Roberts and Schlenker (2010) provides a quantitative estimate of the impact of the US ethanol mandate on food prices. By directly estimating demand and supply elasticities of agricultural commodities based on crop-yield fluctuations resulted from random weather shocks, this study shows that the growth of ethanol production can cause food prices to increase by 20-30 percent. While this estimate is significant, it is still too small to explain the near quadruple of corn price from about \$2.00 per bushel in 2006 to almost \$8.00 per bushel in 2008. More importantly, the growth of ethanol production can explain neither the synchronized price booms of commodities unrelated to food such as cotton and coffee, nor the greater increase in return correlations among indexed commodities than among off-index commodities.

IV. Regression Analysis

We now use regression analysis to examine the effects of the aforementioned economic mechanisms on commodity prices in recent years. We first analyze the GSCI index return,[18] and then analyze price comovements of non-energy commodities with oil.

A. GSCI Index Return

We first examine links of the GSCI index return with a set of economic variables, which we choose to capture the economic mechanisms discussed in the previous section. We include return of Morgan Stanley emerging market equity index ($R_{EM,t}$) and the global shipping index ($R_{ACT,t}$), which was constructed by Kilian (2009) based on an average of dry cargo single voyage freight rates, to represent effects caused by the rapid growth of emerging economies. We also include returns of the S&P 500 US equity index ($R_{SP,t}$), JP Morgan Treasury bond index ($R_{JPM,t}$), and the US dollar index ($R_{USD,t}$) which capture the key links of commodity prices with equity market, interest rate and dollar exchange rate. As we discussed before, these links are subject to different forces at work. For example, the link with the dollar exchange rate is affected by both demands for physical commodities from emerging economies and demands for index investment from international investors; the links with equity market and interest rate may reflect effects of economic fundamentals, as well as portfolio rebalancing of index investors. Finally, we also

[18] The correlation between returns of GSCI and DJ-UBS indices is over 0.9. As a result, analyzing DJ-UBS return provides very similar results to those from analyzing GSCI return. Thus, we only report results on GSCI return.

examine the link of GSCI return with CPI inflation rate ($R_{CPI,t}$). We will separately treat the link with CPI inflation rate and CPI core inflation rate (which excludes food and energy prices).

Morgan Stanley emerging market equity index, S&P 500 US equity index, JP Morgan Treasury bond index, and the US dollar index are available at daily frequencies, and are obtained from Bloomberg and Datastream. CPI inflation rate and the global shipping index are only available at monthly frequencies and are obtained from the websites of the Bureau of Labor Statistics and Lutz Kilian. Our sample goes from 1/4/1988 to 10/29/2009, the longest period during which all of these variables are available. This sample is sufficient for our focus on analyzing changes in the links of GSCI return with these variables after 2004.[19]

We use the following regression specification:

$$R^n_{GSCI,t} = a_0 + a_1 I_{t\geq 04} + [b_0 + b_1 I_{t\geq 04}(t-2004)]R^n_{EM,t} + [c_0 + c_1 I_{t\geq 04}(t-2004)]R^n_{SP,t} \qquad (2)$$

$$+[d_0 + d_1 I_{t\geq 04}(t-2004)]R^n_{JPM,t} + [e_0 + e_1 I_{t\geq 04}(t-2004)]R^n_{USD,t}$$

$$+[f_0 + f_1 I_{t\geq 04}(t-2004)]R^n_{CPI,t} + [g_0 + g_1 I_{t\geq 04}(t-2004)]R^n_{ACT,t} + \epsilon_t$$

where $I_{t\geq 04}$ is an indicator function which takes a value of 1 if time t is later than 2004 and 0 otherwise. We normalize every variable by its sample mean and standard deviation (as marked by the superscript n on each variable) so that the regression coefficients in a univariate regression can be interpreted as the correlation between the right-hand-side and left-hand-side variables. To highlight the potential changes in the links of GSCI return with the right-hand-side variables after 2004, we impose a linear trend after 2004 in each of the regression coefficients. For example, the coefficient of $R_{EM,t}$ consists of a pre-2004 level b_0 and a linear trend $b_1 I_{t\geq 04}(t-2004)$ with b_1 as the slope of the trend. This linear trend specification is consistent with the gradual increased return correlations of commodities with each other and with other variables that are highlighted in Figures 2, 3, and 4. This specification allows us to conveniently test the changes in the return correlations of GSCI return with the right-hand-side variables after 2004, even though we expect these trends to eventually stabilize.[20]

We analyze this regression in both daily and monthly frequencies. We first examine the pre-crisis period before September 2008 to isolate potential effects of the recent financial crisis, and then we examine the full sample period which extends to the end of October 2009. Table 3 reports the regression results for using the right-hand-side variables individually and jointly, and

[19] We are not particularly interested in an elaborate analysis of these links further back to the past. Instead, we refer readers to other studies, such as Erb and Harvey (2006) and Gorton and Rouwenhorst (2006), for links of commodity prices with broader sets of economic variables over longer sample periods.

[20] In a previous version of this paper, we have also used specifications that use dummies for individual years after 2004. These specifications give similar results as the linear trend specification, although more cumbersome. For brevity of the presentation, we do not present the results based on year-dummies here.

for the pre-crisis period and the full sample period. Panel A covers regressions of the daily data, while Panel B covers the monthly data.

While there was a negligible link between returns of the GSCI index and the emerging market index before 2004 (i.e., the estimates of b_0 in different regressions are all insignificant), a positive trend appeared after 2004. This trend (i.e., the b_1 coefficient) is highly significant in the daily regressions in both of the pre-crisis period and full sample period. Although the t-stats become insignificant possibly due to the smaller sample size, the magnitudes of the b_1 estimates in the monthly regressions remain similar to those in the daily regressions. This positive trend confirms Figure 4 regarding the increasingly important link between commodity prices and emerging economies in recent years. The estimates of g_0 are positive and significant, indicating that commodity prices are positively correlated with the cost of transporting goods across the world. This is consistent with the finding of Kilian (2009) that global economic activity has an important effect on oil prices. However the estimates of g_1 are insignificant, indicating little changes in this relationship after 2004. Overall, these results confirm the important effects of commodity demands from emerging markets on commodity prices.

Table 3 also shows small but significant negative return correlations of the GSCI index with S&P 500 equity index and JP Morgan Treasury bond index before 2004 as reflected by estimates of c_0 and d_0 in the daily and monthly regressions. These negative correlations are consistent with the findings of Greer (2000), Gorton and Rouwenhorst (2006) and Erb and Harvey (2006). There were negligible changes in these return correlations between 2004 and September 2008 because the estimates of c_1 and d_1 are all insignificant in the pre-crisis period. These estimates become highly significant in the full sample period, suggesting significant changes after the financial crisis in September 2008. In particular, return correlation of GSCI with S&P equity index has increased, while with JP Morgan bond index has decreased. These changes are consistent with index investors flying away from risky stocks and commodities and invest in riskless Treasury bonds during the crisis (e.g., Kyle and Xiong (2001)). These results also confirm the findings of Buyuksahin, Haigh and Robe (2009) and Silvennoinen and Thorp (2010) that return correlation between GSCI and S&P indices went up during the crisis, but not before the crisis.

While there was an insignificant link between the GSCI return and the US dollar return before 2004 (as reflected by the insignificant estimates of e_0), a negative trend appeared after 2004 (as reflected by the estimates of e_1). This trend is negative and significant in the daily and monthly regressions and in both of the pre-crisis period and full sample period. This trend, as we discussed before, is consistent with the hypotheses based on the rapid growth of emerging economies and the increase in commodity index investment, and confirms the illustration in Figure 4.

It is well known that commodity prices comove positively with inflation rate, albeit pronounced only at long horizons such as 1-year and 5-year horizons, e.g., Greer (2000), Gorton and Rouwenhorst (2006) and Erb and Harvey (2006). In Panel B of Table 3, the estimates of f_0 and f_1 for the monthly CPI inflation rate and CPI core inflation rate are all insignificant, indicating insignificant correlations between GSCI return and inflation rate in 1990s and 2000s. This is consistent with our earlier discussion that inflation does not appear to have an important effect on commodity prices during this period, especially on commodity price fluctuations at daily and monthly horizons.

B. Price Comovements of Non-energy Commodities with Oil

We now examine whether the increasing presence of index investors contributed to the increase in return correlations of non-energy commodities with oil. To identify this effect, we focus on the difference between the increased correlations of indexed and off-index commodities after 2004. We pool together daily returns of first-month futures contracts of all non-energy commodities from 1/2/1998 to 10/29/2009. We choose this sample period so that there are six years before 1/1/2004 and roughly six years afterwards. As we discussed before, there is not much difference between the return correlations of indexed and off-index commodities in the earlier period. Extending the sample period further back does not affect our result.

We specify the following panel regression of the normalized commodity returns $R_{i,t}^n$ on the normalized return of oil $R_{oil,t}^n$, and a set of control variables including the normalized returns of the Morgan Stanley emerging market equity index $R_{EM,t}^n$, S&P 500 US equity index $R_{SP,t}^n$ JP Morgan Treasury bond index $R_{JMP,t}^n$, and US dollar index $R_{USD,t}^n$:

$$\begin{aligned} R_{i,t}^n = \alpha &+ [\beta_{0i} + \beta_1(t-2004)I_{t\geq 2004} + \beta_2(t-2004)I_{t\geq 2004}I_{index}]R_{oil,t}^n \qquad (3) \\ &+ [\kappa_{0i} + \kappa_1(t-2004)I_{t\geq 2004} + \kappa_2(t-2004)I_{t\geq 2004}I_{index}]R_{EM,t}^n \\ &+ [\gamma_{0i} + \gamma_1(t-2004)I_{t\geq 2004} + \gamma_2(t-2004)I_{t\geq 2004}I_{index}]R_{SP,t}^n \\ &+ [\theta_{0i} + \theta_1(t-2004)I_{t\geq 2004} + \theta_2(t-2004)I_{t\geq 2004}I_{index}]R_{JMP,t}^n \\ &+ [\eta_{0i} + \eta_1(t-2004)I_{t\geq 2004} + \eta_2(t-2004)I_{t\geq 2004}I_{index}]R_{USD,t}^n + \varepsilon_{i,t} \end{aligned}$$

I_{index} is an indicator function with a value of 1 if the commodity is in either the GSCI or DJ-UBS index, and 0 otherwise. We include returns of the Morgan Stanley emerging market equity index and the US dollar index to control for the effect of commodity demands from emerging economies. As we discussed before, the dollar return might also pick up effects by international index investors. Thus, this control might be excessive. We also include returns of the S&P stock index and the JP Morgan Treasury bond index to control for the effects of the recent financial crisis. Again, these controls might be excessive because the spillover of the financial crisis to commodities markets may be caused by trading of index investors.

Motivated by our earlier analysis, we specify a linear trend after 2004 in the regression coefficient of each independent variable. Specifically, we decompose each regression coefficient into three components. Figure 12 provides a graphical account of this decomposition. For example, in the coefficient of oil return, the first component β_{0i} measures the baseline coefficient (specific to the individual commodity i) before 2004; the second component $\beta_1(t-2004)I_{t\geq 2004}$ captures a common trend in the coefficient after 2004 with β_1 as the slope of the trend; and the third component $\beta_2(t-2004)I_{t\geq 2004}I_{index}$ measures the additional trend after 2004 with β_2 as the slope of the trend if the commodity is in at least one of the GSCI and DJ-UBS indices. The last component captures the difference in the changes after 2004 between the return correlations of indexed and off-index commodities with oil. Our key hypothesis is that β_2 is significantly positive, which implies that the increasing presence of index investors has led to a greater increase in return correlations of indexed commodities with oil than that of off-index commodities. We also decompose the regression coefficient on each of the control variables in the same way to control for possible trends driven by other economic mechanisms.

We analyze this regression in the full sample with all non-energy commodities, as well as in several sub-samples including the soybean complex (which includes soybeans, soybean meal, and soybean oil), the grain sector, the soft sector, the livestock sector, and the metal sector. We separately examine the pre-crisis period from 1/2/1998 to 8/31/2008 and the full sample period from 1/2/1998 to 10/29/2009 in order to isolate the crisis effect. For each of the periods, we first analyze the regression with only oil return and then together with the control variables. Table 4 reports the regression results.

Panel A reports the results from the full sample with all non-energy commodities. The estimates of coefficients β_{0i} show that most of the non-energy commodities had a small and positive return correlation with oil before 2004, with gold having the highest estimate of 0.15. Several commodities from the soft and livestock sectors had a small negative return correlation with oil; these commodities include live cattle, feeder cattle, coffee, cocoa, lumber, orange juice, and pork bellies. These small return correlations are consistent with the finding of Erb and Harvey (2006).

The estimates of β_1 and β_2 in both of the pre-crisis and full sample periods are positive and significant. These estimates suggest that there was a significant and increasing trend in return correlations of non-energy commodities with oil after 2004. More importantly, this increasing trend is significantly stronger for indexed commodities than for off-index commodities. This pattern is robust to including the control variables in the regressions and thus supports the hypothesis that the increasing presence of index investors led prices of indexed commodities to comove more with oil. Furthermore, this effect was present before the disruption of the financial crisis in September 2008.

In the pre-crisis period with the control variables, the estimates of β_1 and β_2 are 0.04 and 0.02 respectively. These values imply that the return correlation between an off-index non-energy commodity and oil increased by 0.04 each year. At this rate, the correlation had an accumulative increase of 0.2 between 2004 and 2009. The return correlation between an indexed non-energy commodity and oil had an extra increase of 0.02 each year. Thus its accumulative increase between 2004 and 2009 was 0.3, which is substantial in economic terms.

Panel B of Table 4 also reports the estimates of β_1 and β_2 in each commodity sub-sample in both of the pre-crisis and full sample periods after including the control variables in the regressions. The estimates are consistently positive and significant across the sub-samples except in the livestock sector, in which the estimate of β_1 is zero and the estimate of β_2 is positive but significant only for the full sample period. Taken together, the increased price comovements between indexed non-energy commodities and oil were not driven by a few commodities concentrated in one sector; instead, our result about the increased price comovements is robust across different sub-samples of commodities.

We have also examined the regression in (3) based on weekly commodity returns. The estimates of β_1 and β_2 are positive with similar magnitudes as those reported in Table 4. However, their t-stats are less significant. This is consistent with our earlier discussion that we need to use daily data to measure return correlation in order to compensate for the relatively short sample period after 2004.

Panel A of Table 4 reveals several interesting observations about the return correlations of non-energy commodities with the control variables. First, there is a significant and positive trend in their return correlations with the emerging market index after 2004 in both of the pre-crisis and full sample periods, as reflected by the positive and significant estimates of coefficient κ_1. This is consistent with the increasing return correlation between the GSCI index and the emerging market index after 2004. However, there is a negligible difference between indexed and off-index commodities in the increase of their return correlations with the emerging market index, as reflected by the insignificant estimates of κ_2. This lack of difference is consistent with the fact that the effects of commodity demands from emerging economies are independent of the commodity indices. It also indirectly confirms the discriminating power of our identification strategy based on the difference-in-difference effect.

Furthermore, the estimates of coefficient η_1 are negative, with a significant t-stat in the full sample period although an insignificant one in the pre-crisis period. These estimates suggest a negative trend in the return correlations of non-energy commodities with the US dollar after 2004, which is consistent with the decreasing trend in the return correlation between the GSCI index and the US dollar index. More interestingly, the estimates of coefficient η_2 are also negative, with a significant t-stat in the pre-crisis period although an insignificant one in the full sample period. These estimates indicate that the decreasing trend is stronger for indexed commodities than for off-index commodities. This difference-in-difference result suggests that the decreasing trend in return correlations of non-energy commodities with the US dollar was not all driven by commodity demands from emerging economies and was at least partially related to trading by international index investors in commodities markets.

C. Controlling for Illiquidity

Because off-index commodities tend to be less liquid, there is a potential concern that their price fluctuations might lag behind that of oil and thus have smaller contemporaneous return correlations with oil than indexed commodities. To ensure that illiquidity is not the reason for the less pronounced trends in return correlations between off-index commodities and oil, we add two lags of oil return in the regression to control for illiquidity:

$$\begin{aligned} R_{i,t}^n = \alpha &+ [\beta_{0i} + \beta_1(t-2004)I_{t\geq 2004} + \beta_2(t-2004)I_{t\geq 2004}I_{index}]R_{oil,t}^n \\ &+ [\beta_{3i} + \beta_4(t-2004)I_{t\geq 2004} + \beta_5(t-2004)I_{t\geq 2004}I_{index}]R_{oil,t-1}^n \\ &+ [\beta_{6i} + \beta_7(t-2004)I_{t\geq 2004} + \beta_8(t-2004)I_{t\geq 2004}I_{index}]R_{oil,t-2}^n \\ &+ [\kappa_{0i} + \kappa_1(t-2004)I_{t\geq 2004} + \kappa_2(t-2004)I_{t\geq 2004}I_{index}]R_{EM,t}^n \\ &+ [\gamma_{0i} + \gamma_1(t-2004)I_{t\geq 2004} + \gamma_2(t-2004)I_{t\geq 2004}I_{index}]R_{SP,t}^n \\ &+ [\theta_{0i} + \theta_1(t-2004)I_{t\geq 2004} + \theta_2(t-2004)I_{t\geq 2004}I_{index}]R_{JMP,t}^n \\ &+ [\eta_{0i} + \eta_1(t-2004)I_{t\geq 2004} + \eta_2(t-2004)I_{t\geq 2004}I_{index}]R_{USD,t}^n + \varepsilon_{i,t} \end{aligned} \quad (4)$$

For the two lagged oil returns $R_{oil,t-1}^n$ and $R_{oil,t-2}^n$, we also use the same trend specification as in the coefficient of the contemporaneous oil return. With the lags, the effective return correlation between a commodity and oil is determined by the sum of the coefficients of $R_{oil,t}^n$, $R_{oil,t-1}^n$, and $R_{oil,t-2}^n$. Then the hypothesis that return correlations of indexed commodities with oil have more pronounced trends after 2004 than off-index commodities is equivalent to that $\beta_2 + \beta_5 + \beta_8$ is significantly positive. We use the F-statistic to test the null hypothesis that $\beta_2 + \beta_5 + \beta_8 \leq 0$.

Table 5 reports the regression results after adding the two lags of oil return. The estimates of the coefficients related to the second lag are all close to zero, suggesting that two lags are sufficient. We have also used more lags and their coefficients are all negligible. Interestingly, the estimates of $\beta_2 + \beta_5 + \beta_8$ are positive in both of the pre-crisis period and full sample period, with or without the control variables. In particular, in the pre-crisis sample period the estimates of the two lagged trends β_5 and β_8 are both close to zero and the F-statistic rejects the null hypothesis that $\beta_2 + \beta_5 + \beta_8 \leq 0$ with 95% confidence. In the full sample period, the estimate of β_5 becomes significantly negative, but the estimate of $\beta_2 + \beta_5 + \beta_8$ remains positive. The F-statistic still rejects the null hypothesis with 95% confidence in the absence of the control variables, although the F-statistic becomes less significant after the control variables are added.[21] Taken together, Table 5 demonstrates that the difference-in-difference result between the return correlations of indexed and off-index commodities with oil is robust to the illiquidity concern about off-index commodities.

We have also examined correlations between trading volume of different commodities. Consistent with the increasing presence of index investors in commodities markets, we find a significant increasing trend in trading volume correlations between indexed non-energy commodities and oil after 2004 even though the existence of such trend is not clear for off-index commodities. To save space, we do not report this set of results in the paper.

D. Spot and Roll Returns

So far, our analysis focuses on returns of rolling front-month futures contracts of different commodities. As highlighted by Erb and Harvey (2006), these returns have two components: spot return (i.e., return from a commodity's spot price) and the so-called roll return (which originates from the commodity's futures price curve). Suppose that the curve is in backwardation (i.e., downward sloping). Then besides the spot return, rolling the front-month futures contract also yields a positive roll return from the increase in the contract price as its maturity shortens. Conversely, the roll return is negative if the curve is in contango (i.e., upward sloping). It is intuitive that the roll return fluctuates with the slope of the futures price curve. Erb and Harvey (2006) show that roll returns contribute to a significant fraction of the historically high average return to GSCI index because many commodities in the index tend to be, although not always, in backwardation. Given the important distinction between these two components, it is interesting to separately examine their roles in driving our result on the increasing return correlations between non-energy commodities and oil.

We first analyze the spot-return correlations of non-energy commodities with oil. Due to the lack of centralized spot markets for commodities, spot prices are often not readily available. We acquired spot prices for a set of commodities from Pinnacle Data Corp., the same data vendor that provided us with the futures price data. The set includes oil and 16 non-energy commodities (8 short of the non-energy commodities with futures listed in Table 1). These non-energy

[21] It is conceivable that during the crisis, market liquidity deteriorated, especially for the off-index commodities. As a result, the crisis effect after September 2008, which is captured by the control variables, dominated the effect of index investment and made it less significant.

commodities include corn, soybeans, wheat, Kansas wheat, soybean oil, Minnesota wheat, and oats from the grain sector; cotton and sugar from the soft sector; live cattle and lean hogs from the livestock sector; and gold, silver, copper, platinum, and palladium from the metal sector. We pool together their daily spot returns and regress them on spot return of oil and the set of control variables based on the regression specified in (3). The estimates of coefficients β_1 and β_2 are reported in Panel A of Table 6. The estimate of β_1 is positive and significant in the pre-crisis period but becomes insignificant in the full sample period. More interestingly, the estimate of β_2 is positive and significant in both of the pre-crisis period and full sample period, confirming the same difference-in-difference result in spot returns as in returns of rolling front-month futures contracts. This result implies that the price effect generated by the growing commodity index investment in recent years is also present in spot prices of commodities.

As fluctuations of roll returns are driven by slope changes of futures price curves, we now examine the slope-change correlations between non-energy commodities and oil. We define the slope of commodity i's futures price curve as the difference between the logarithm of its second-month futures price (with maturity T_2) and the logarithm of its front-month futures price (with maturity T_1) normalized by the difference in the two maturities ($T_2 - T_1$):

$$S_{i,t} = \frac{1}{\mathrm{T}_2 - \mathrm{T}_1} \ln(F_{i,t,T_2} / F_{i,t,T_1}).$$

We compute the slope by the difference between the second and front-month futures prices rather than between the front-month futures price and spot price so that we can employ the larger sample of non-energy commodities with futures contracts listed in Table 1. We pool together daily slope changes of these commodities and regress them on slope change of oil by using the following difference-in-difference specification:

$$\Delta S_{i,t} = \alpha + [\beta_{0i} + \beta_1 (t - 2004) I_{t \geq 2004} + \beta_2 (t - 2004) I_{t \geq 2004} I_{index}] \Delta S_{oil,t} + \varepsilon_{i,t}. \quad (5)$$

As before, coefficient β_1 captures the trend after 2004 in the slope-change correlations of off-index non-energy commodities with oil, and coefficient β_2 captures the additional trend for indexed commodities.

Panel B of Table 6 reports the regression results. The estimates of β_1 and β_2 are small and insignificant in both of the pre-crisis period and full sample period, indicating no evidence of increased slope-change correlations between non-energy commodities and oil after 2004 and no evidence of any difference between indexed and off-index commodities. This result implies that the increasing presence of index investors after 2004 did not systematically affect the slopes of commodity futures curves; this is probably because arbitrageurs were able to effectively spread out the price impact of index investment across the curves. This result also suggests that the increased return correlations between non-energy commodities and oil after 2004 were mostly driven by spot returns rather than roll returns.

V. Volatility Spillover

Our earlier analysis confirms that the rapid growth of commodity index investment after 2004 had a significant impact on commodities markets and caused prices of seemingly unrelated commodities to move together. This effect is a reflection of an ongoing financialization process, through which the previously (partially) segmented commodities markets became more integrated with outside financial markets and with each other. While this process may have led to a more efficient sharing of commodity price risk, it can also act as a channel to spill over volatility from outside financial markets to commodities markets and across different commodities markets.[22] We now discuss this spillover effect.

Figure 13 depicts the annualized daily return volatility of oil, GSCI non-energy excess return index, and Morgan Stanley world equity index estimated from one-year rolling windows. The GSCI non-energy excess return index tracks price fluctuations of GSCI commodities in the four non-energy sectors. Morgan Stanley world equity index tracks the equity market performance of both developed and emerging economies. The figure shows that oil price is always volatile. During most of 1990s and 2000s, its volatility was at least twice as high as the volatility of the world equity index. Oil return volatility shot up from around 30% to near 60% in 2008, a level that had caused great public concerns. However, this is not the first time for oil return volatility to reach this level – it also happened in early 1990s during the Gulf war. More interestingly, while return volatility of non-energy commodities had been very stable at a level around 10% throughout 1990s and early 2000s, it started to rise after 2004 and peaked at an unprecedented level of 27% in 2008. This is concurrent with the hikes in volatility of oil and the world equity index.

Different factors may have contributed to the large volatility increase in oil and non-energy commodities. First, the world economic recession that accompanied the recent financial crisis has made commodity demands more uncertain and thus prices more volatile. Second, the financial crisis which initially disrupted in the markets for mortgage-backed securities eroded balance sheets of many financial institutions and eventually hurt the risk appetite of financial investors for many seemingly unrelated assets in their portfolios including commodities (e.g., Kyle and Xiong (2001)). To identify the latter spillover effect, we analyze the difference between return volatility of indexed and off-index non-energy commodities from 1/2/1998 to 10/29/2009.

[22] See Bekaert and Harvey (1997) for an analysis of volatility spillover after financial liberalization of emerging equity markets.

Specifically, we first normalize the daily return of each commodity (return of rolling its first-month futures contract) by its volatility before 2004 and its whole sample mean. After the normalization, the return series of all non-energy commodities have the same volatility before 2004. We then analyze changes of volatilities after 2004 by regressing the pooled squared normalized returns onto a set of year dummies for each year after 2004 and their interaction terms with an index dummy for whether a given commodity is in at least one of GSCI and DJ-UBS indices:

$$\left(R_{i,t}^{n}\right)^2 = a_{0i} + b_{04}I_{y=04} + b_{05}I_{y=05} + b_{06}I_{y=06} + b_{07}I_{y=07} + b_{08}I_{y=08} \quad (6)$$

$$+b_{09}I_{y=09} + c_{04}I_{index}I_{y=04} + c_{05}I_{index}I_{y=05} + c_{06}I_{index}I_{y=06}$$

$$+c_{07}I_{index}I_{y=07} + c_{08}I_{index}I_{y=08} + c_{09}I_{index}I_{y=09} + \varepsilon_{i,t}$$

The squared return is a widely used proxy for return volatility. The coefficients b_{04}, b_{05}, b_{06}, b_{07}, b_{08}, and b_{09} measure the baseline volatility changes of off-index commodities in each of the years after 2004, while the coefficients c_{04}, c_{05}, c_{06}, c_{07}, c_{08}, and c_{09} measure the additional volatility increase of indexed commodities relative to off-index commodities in each of the years. Table 7 reports the regression results. It shows that the estimates of coefficients b_{08} and b_{09} are positive and significant, indicating significant baseline volatility increase in years 2008 and 2009 across the commodities. Interestingly, the estimates of coefficients c_{04}, c_{06}, c_{07}, c_{08} and c_{09} are all positive and significant, indicating that indexed commodities exhibited larger volatility increases than those off-index commodities in 2004, 2006, 2007, 2008 and 2009. This result is consistent with a spillover effect that the presence of index investors has contributed to the large increase of commodity price volatility in recent years.

The volatility spillover could originate from uncertainty about the economy, turmoil in stock markets and bond markets, or shocks to oil prices. It is difficult to identify the source because the exogenous shocks are unobservable. Following our earlier analysis, we focus on the possible spillover of oil price volatility to non-energy commodities through the largely increased return correlations between non-energy commodities and oil. From non-energy commodity returns, we first filter out the control variables we have used before (i.e., returns of Morgan Stanley emerging market index, S&P 500 stock index, JP Morgan Treasury bond index, and US dollar index, CPI core inflation rate, and change of the global shipping index) and then oil return by using the following regression specification:

$$R_{it} = a_0 + a_1 I_{t\geq 04} + [b_0 + b_1 I_{t\geq 04}(t-2004)]R_{EM,t} + [c_0 + c_1 I_{t\geq 04}(t-2004)]R_{SP,t} \quad (7)$$

$$+[d_0 + d_1 I_{t\geq 04}(t-2004)]R_{JPM,t} + [e_0 + e_1 I_{t\geq 04}(t-2004)]R_{USD,t}$$

$$+[f_0 + f_1 I_{t\geq 04}(t-2004)]R_{CPI,t} + [g_0 + g_1 I_{t\geq 04}(t-2004)]R_{ACT,t}$$

$$+[h_0 + h_1 I_{t\geq 04}(t - 2004)]R_{oil,t} + \epsilon_t$$

We have used a similar specification to analyze GSCI index return. Since we only have monthly observations on CPI inflation rate and the global shipping index, we treat $R_{CPI,t}$ and $R_{ACT,t}$ as constant during a month. Depending on whether we include oil return in the regression, we obtain two sets of residual returns, one after filtering out only the control variables and the other after filtering out the control variables and oil return. As we discussed before, the control variables serve to filter out the potential effects of economic uncertainty, as well as possible spillover of stock market volatility and US dollar volatility to commodities. These controls, while potentially excessive, allow us to highlight spillover of oil price volatility to indexed non-energy commodities.

We then repeat the difference-in-difference analysis of regression (6) using the two sets of residual returns. The results are also reported in Table 7. After filtering out only the control variables from non-energy commodity returns, the estimates of coefficients c_{04}, c_{06}, c_{07}, c_{08} and c_{09} are substantially reduced, although c_{04}, c_{06}, c_{07} and c_{08} are still positive and significant. After further filtering out oil return, the estimates of coefficients c_{04}, c_{06}, c_{07}, c_{08} and c_{09} are further reduced, and the estimates of c_{07} and c_{08} are now insignificant. These reductions indicate that the spillover of oil price volatility through index investment contributed to the greater volatility increase of indexed non-energy commodities in 2007 and 2008.

Overall, we find that non-energy commodities in the GSCI and DJ-UBS indices had significantly greater volatility increase than off-index commodities in 2008. In particular, the greater volatility increase of indexed commodities was related to their greater return correlations with oil. These results suggest that trading of commodity index investors can act as a channel for spilling over price volatility to commodities markets.

VI. Conclusion

This paper finds that concurrent with the rapid growth of index investment to commodities markets, prices of non-energy commodities became increasingly correlated with oil prices and this trend is significantly more pronounced for commodities in the two popular GSCI and DJ-UBS indices. This finding reveals a fundamental process of financialization amongst commodities markets, through which commodity prices became more correlated with prices of financial assets and with each other. This result also helps explain the synchronized price boom and bust of a large set of seemingly unrelated commodities in 2006-2008.

Our analysis suggests that as a result of the financialization process, the price of an individual commodity is no longer simply determined by its supply and demand. Instead, prices are also determined by a whole set of financial factors such as the aggregate risk appetite for financial assets, and investment behavior of diversified commodity index investors. This fundamental change is likely to persist as long as commodity index investment remains popular among financial investors and has profound implications for a wide range of issues from commodity producers' hedging strategies and speculators' investment strategies to many countries' energy and food policies.

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Figure 1: Commodity Prices

This figure depicts price appreciations of five commodities, oil, soybeans, cotton, live cattle, and copper, since January 1991. We normalize price of each commodity in January 1991 to be 100.

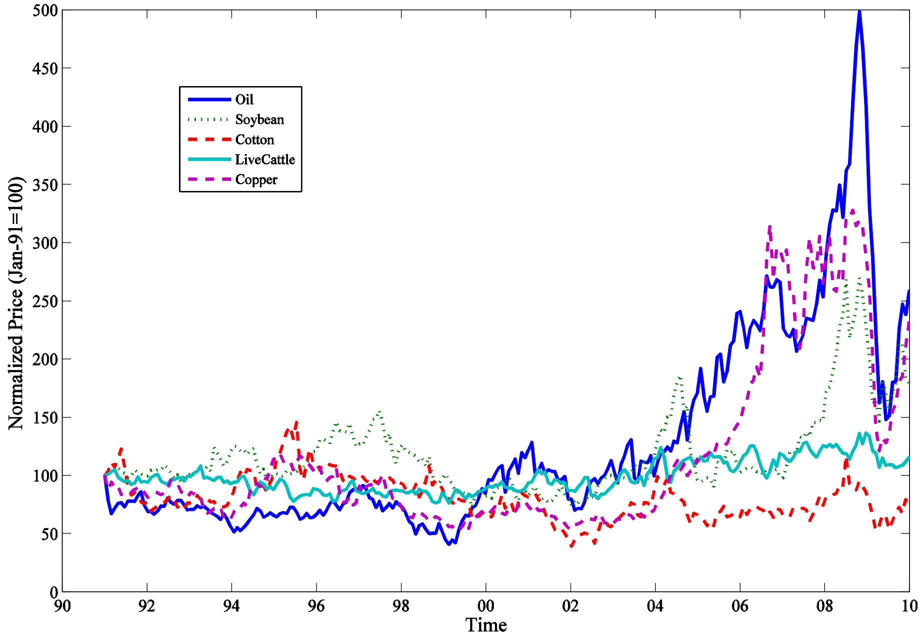

Figure 2: Rolling Return Correlation of Oil with Different Non-energy Commodities

This figure depicts one-year rolling return correlation of oil with soybean, cotton, live cattle, and copper, together with the 95% confidence interval, in Panels A, B, C, and D, respectively. Panel E plots one-year rolling return correlation of the GSCI energy and non-energy indices.

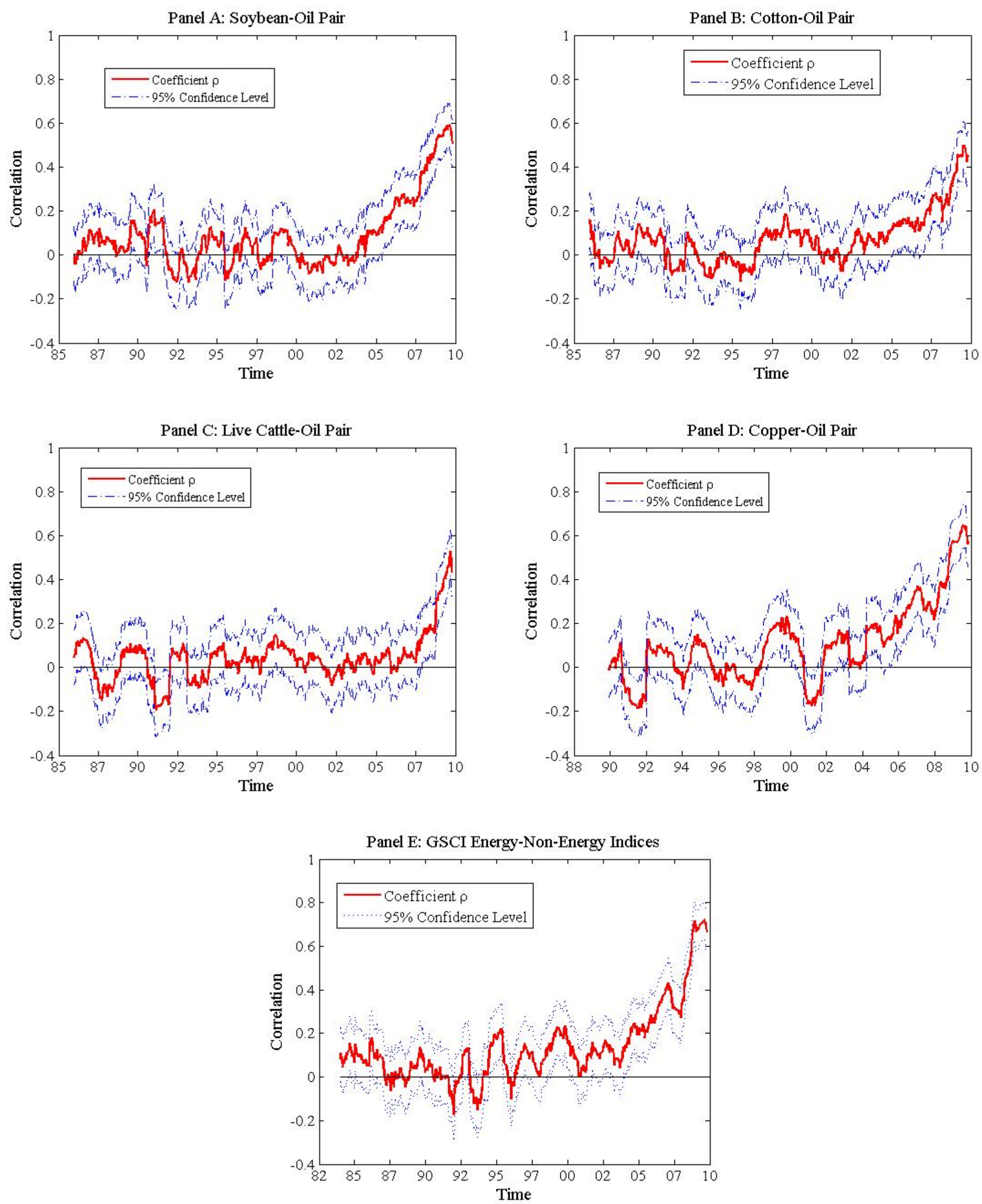

Figure 3: Average Correlations of Indexed and Off-index Commodities

This figure depicts average return correlations of commodities in the GSCI and DJ-UBS indices and commodities off these indices. We separate the samples of indexed and off-index commodities. In each sample, we construct an equal-weighted return index for each commodity sector. A commodity is not included into the index until its average daily futures trading volume in a certain calendar year is larger than 20 million dollars. Then, for both indexed and off-index commodities, we compute equal-weighted average of one-year rolling return correlations of all sector pairs.

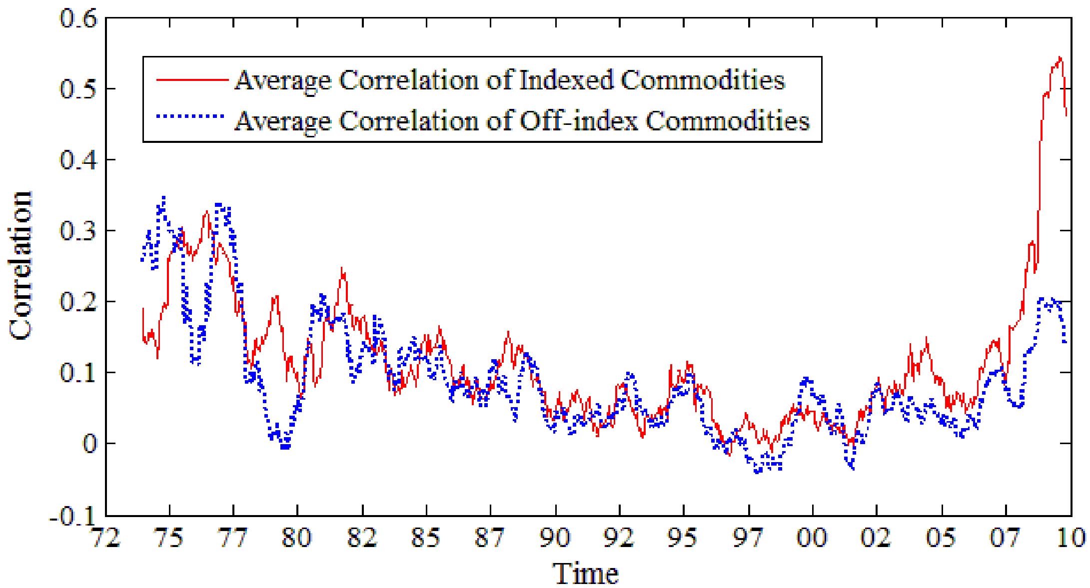

Figure 4: Rolling Return Correlations of GSCI with Emerging Market and US Dollar Indices

This figure depicts one-year rolling return correlation of the GSCI excess return index with the Morgan Stanley emerging market index in Panel A and with the US dollar index in Panel B.

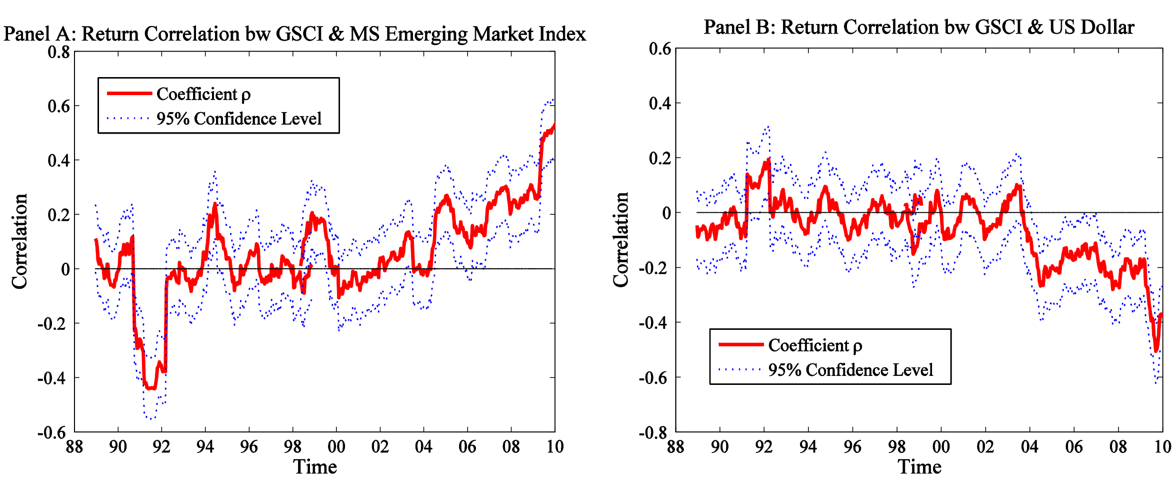

Figure 5: Commodity Prices in China and the US

This figure depicts front-month futures prices of 6 commodities---heating oil, copper, soybeans, wheat, corn, and cotton---in China and the US.

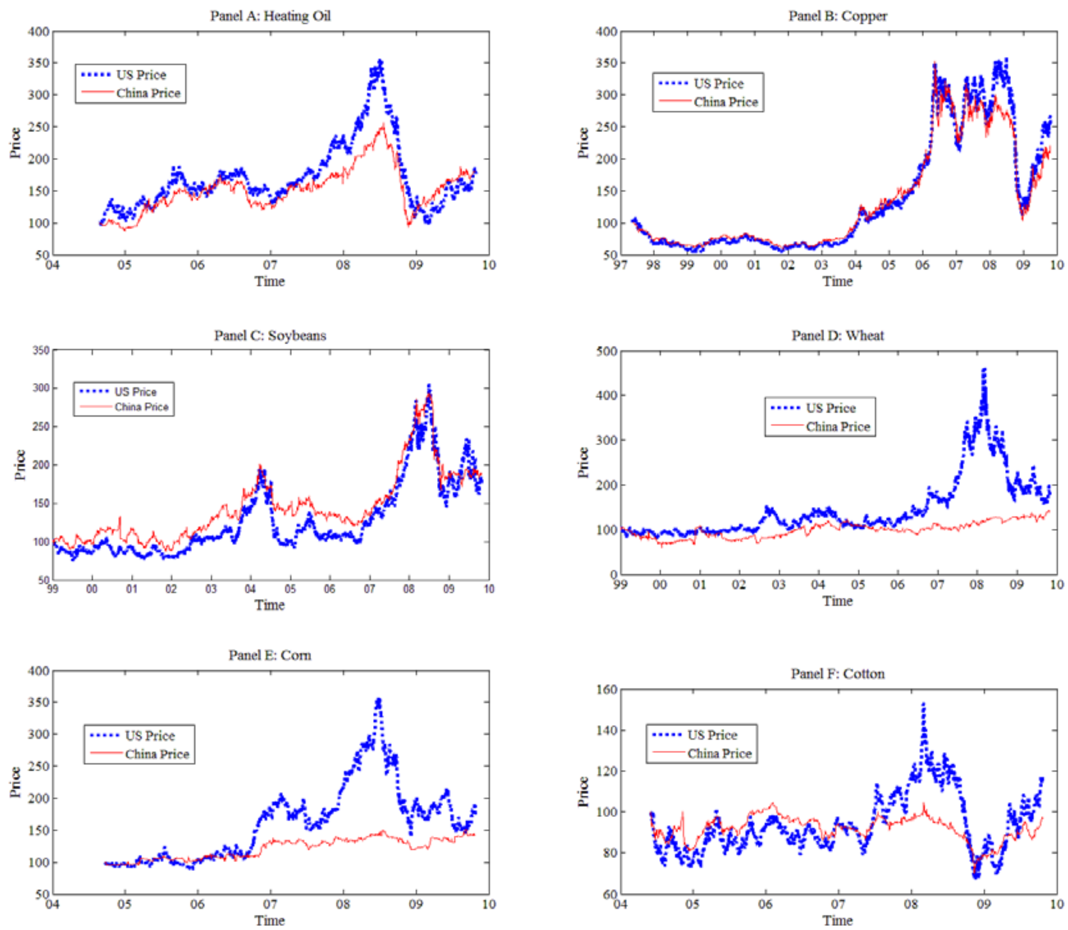

Figure 6: Commodity Return Correlations in China and the US

This figure depicts average commodity return correlations in China and the US based on a sample of 8 commodities, which are listed in Table 1 and which have futures contracts simultaneously traded in both countries.

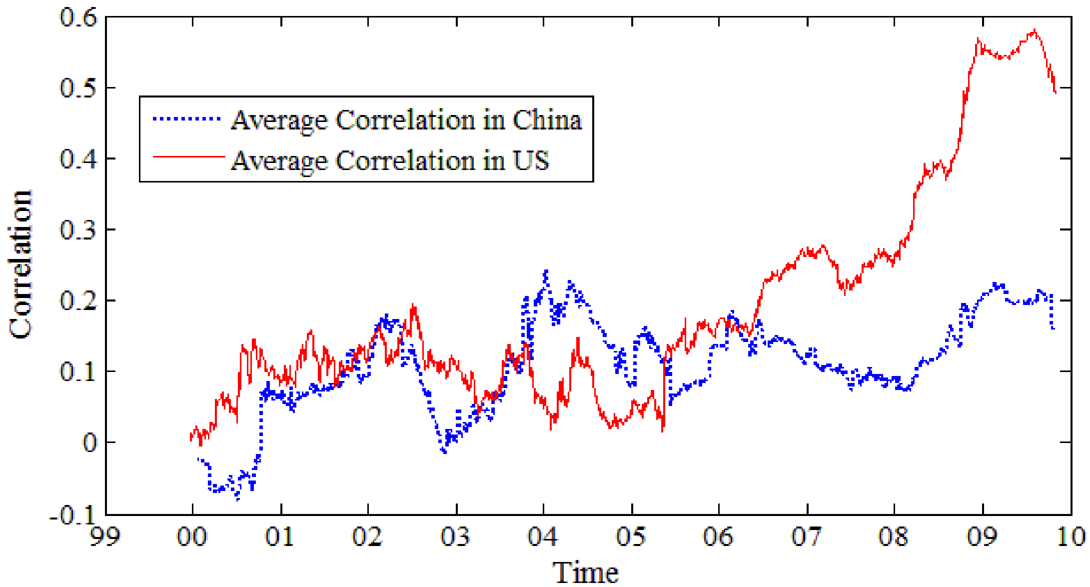

Figure 7: Open Interest of Commodity Futures Contracts

This figure depicts the total open interest of futures contracts with maturities less than one year of five commodities, oil, soybeans, cotton, live cattle, and copper, since January 1991. We normalize the open interest of each commodity in January 1991 to be 100.

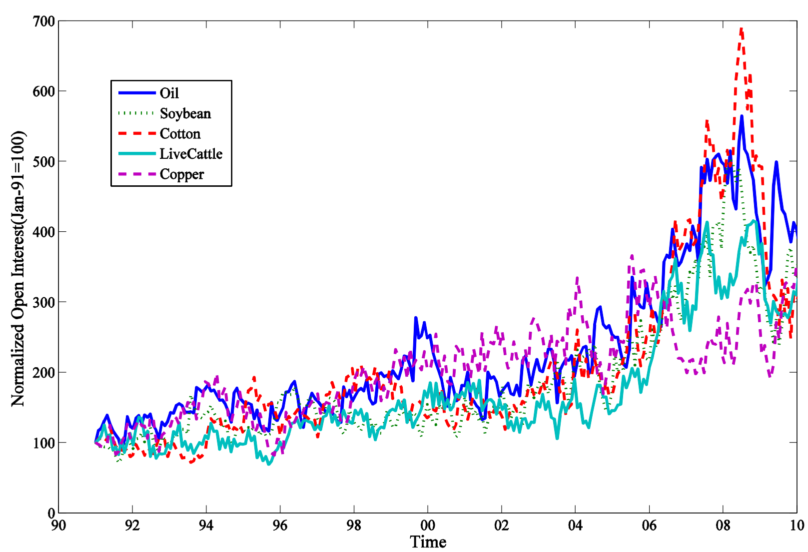

Figure 8: Accumulated Index Flow and GSCI Agriculture & Livestock Excess Return Index

This figure depicts the accumulated index flow to the 12 agricultural and livestock commodities covered by the CIT report of CFTC, together with the GSCI agriculture & livestock excess return index. The weekly flow to each of the commodities is computed according to (1), and the accumulated flow to the commodity is computed by adding up the weekly flow from the first week of 2006 to a given week. By summing up the accumulated flow to the 12 commodities, we obtain the accumulated index flow.

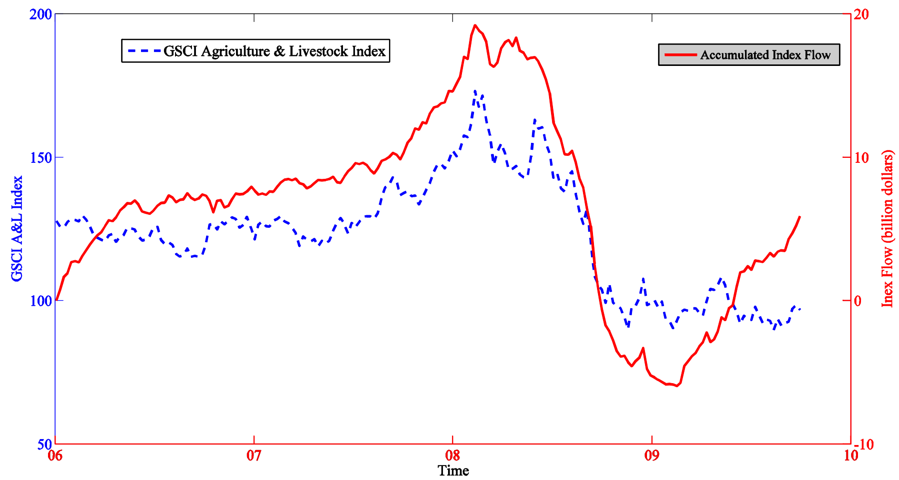

Figure 9: VIX Index

This figure depicts the VIX index (the Chicago Board Options Exchange volatility index), a widely used equity market volatility measure derived from the implied volatility of S&P 500 index options.

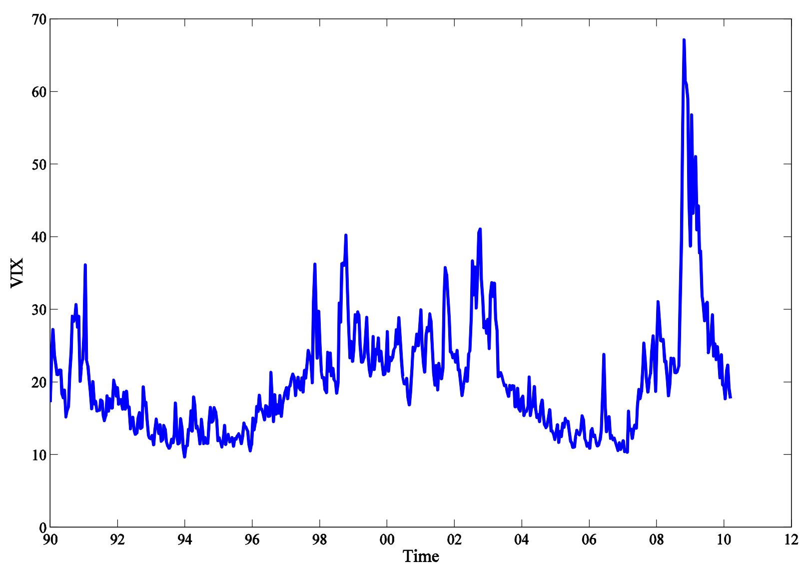

Figure 10: Return Correlation between GSCI and S&P Stock Indices

This figure depicts one-year rolling correlation of daily returns of the GSCI and S&P 500 stock indices.

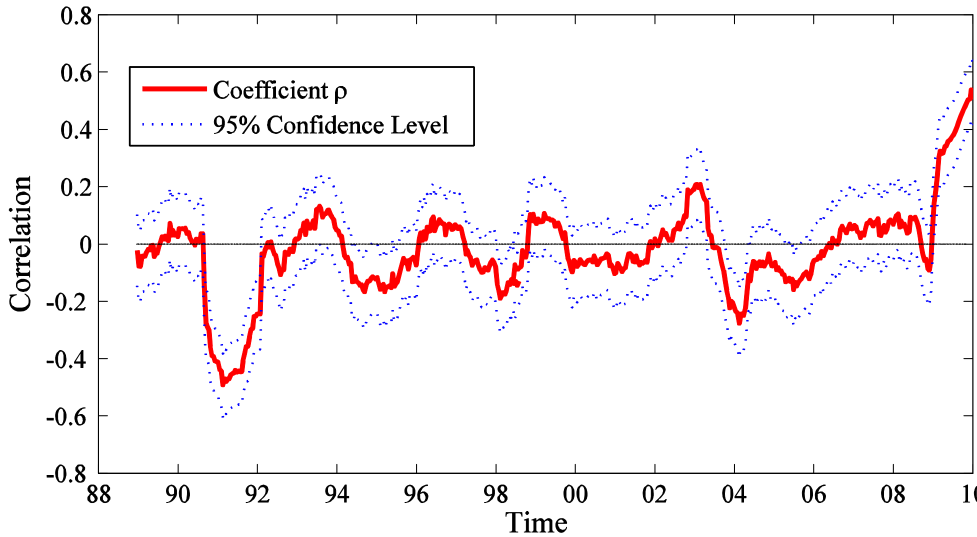

Figure 11: Inflation and Inflation Volatility

This figure depicts the annualized monthly CPI core inflation rate (excluding food and energy prices) and one-year rolling volatility of the monthly CPI core inflation rate.

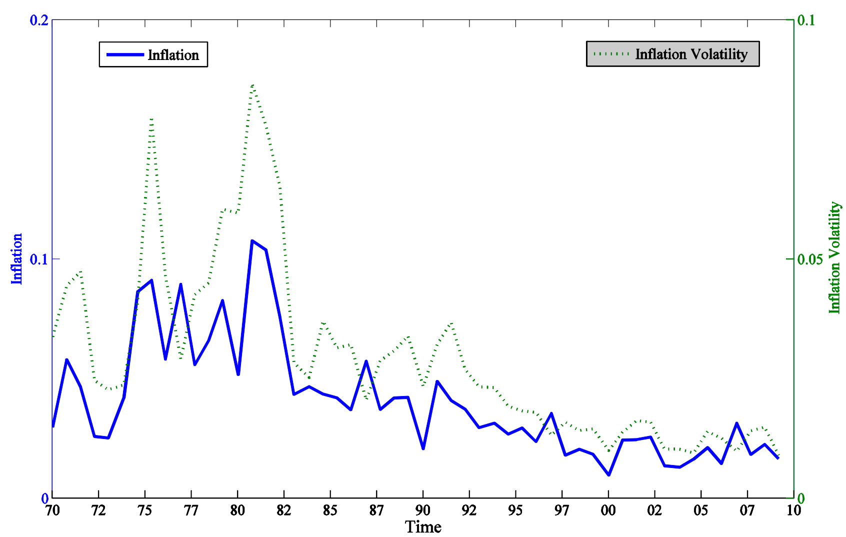

Figure 12: The Difference-in-Difference Specification

This figure illustrates the difference-in-difference specification for individual commodities' regression coefficient of any independent variable in regression (3). For example, the coefficient of oil return is

$$\beta_{0i} + \beta_1 (t - 2004) I_{t \geq 2004} + \beta_2 (t - 2004) I_{t \geq 2004} I_{index}$$

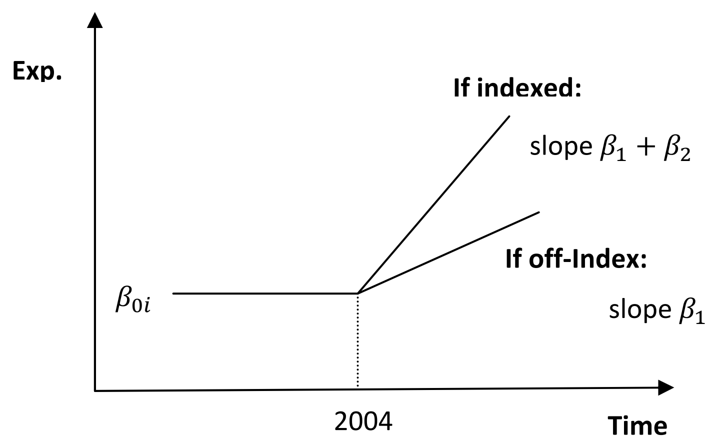

Figure 13: Volatility of Oil, GSCI Non-Energy Index, and Morgan Stanley World Equity Index

This figure depicts one-year rolling volatility of daily returns of oil, the GSCI non-energy excess return index, and the Morgan Stanley world equity index.

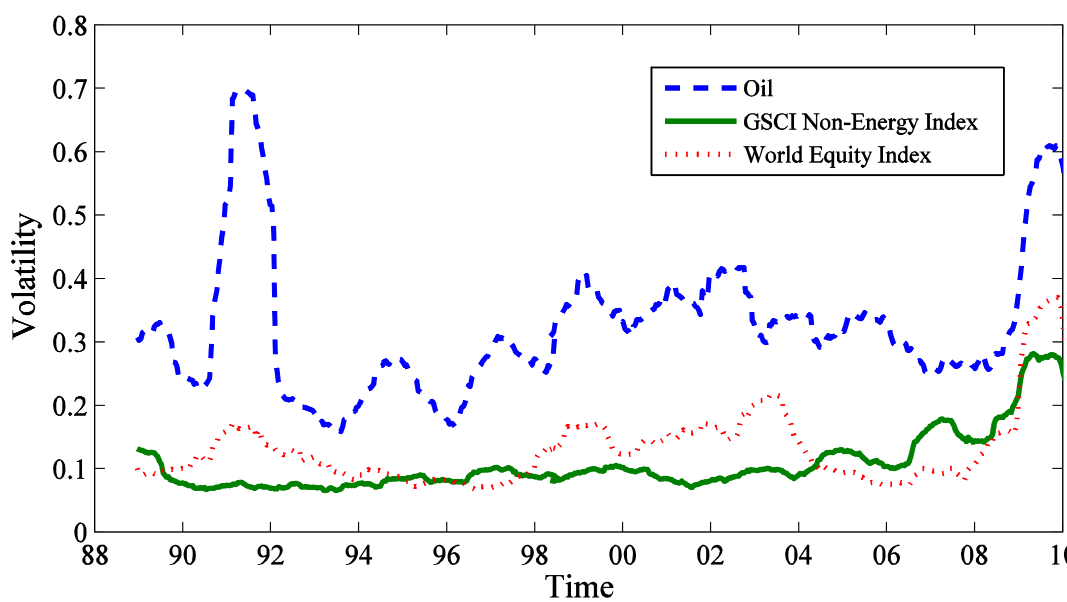

Table 1: Commodity Futures Traded in US and Weights in the GSCI and DJ-UBS Indices

This table lists all of the commodities with futures contracts traded in the U.S. The weights of these commodities in the GSCI and DJ-UBS contracts are taken from 2008.[23]

Commodities	GSCI	DJ-UBS	Exchange	Contracts	Start of futures in US	Start of futures in China
Energy (4 Commodities)						
WTI Crude Oil	40.6	15.0%	NYMEX	Every month	03/30/1983	
Heating Oil	5.3%	4.5%	NYMEX	Every month	11/14/1978	8/25/2004
RBOB Gasoline	4.5%	4.1%	NYMEX	Every month	04/18/2006	
Natural Gas	7.6%	16.0%	NYMEX	Every month	04/04/1990	
Grains (9 commodities)						
Corn	3.6%	6.9%	CME Group	Mar, May , Jul, Sep & Dec	07/01/1959	09/22/2004
Soybeans	0.9%	7.4%	CME Group	Jan, Mar, May , Jul, Aug, Sep, Nov	07/01/1959	01/04/1999
Chicago Wheat	3.0%	3.4%	CME Group	Mar, May , Jul, Sep, Dec	07/01/1959	01/04/1999
Kansas Wheat	0.7%	0	KCBT[24]	Mar, May, Jul, Sep, Dec	01/05/1970	
Soybean Oil	0	2.9%	CME Group	Jan, Mar, May, Jul, Aug, Sep, Oct, Dec	07/01/1959	
Minn. Wheat	0	0	MGE[25]	Mar, May, Jul, Sep, Dec	01/05/1970	
Soybean Meal	0	0	CME Group	Jan, Mar, May, Jul, Aug, Sep, Oct, Dec	07/01/1959	
Rough Rice	0	0	CME Group	Jan, Mar, May, Jul, Sep, Nov	08/20/1986	
Oats	0	0	CME Group	Mar, May, July, Sep, Dec	07/01/1959	
Softs (6 Commodities)						
Coffee	0.5%	2.7%	ICE	Mar, May, Jul, Sep, Dec	08/16/1972	
Cotton	0.7%	2.2%	ICE	Mar, May, Jul, Oct, Dec	07/01/1959	06/01/2004
Sugar	2.1%	2.8%	ICE	Mar, May, Jul, Oct	01/04/1961	01/06/2006
Cocoa	0.2%	0	ICE	Mar , May, Jul, Sep, Dec	07/01/1959	
Lumber	0	0	CME Group	Jan, Mar, May, Jul, Sep, Nov	10/01/1969	
Orange Juice	0	0	ICE	Jan, Mar, May, Jul, Sep, Nov	02/01/1967	
Livestock (4 Commodities)						
Feeder Cattle	0.3%	0.0%	CME Group	Jan, Mar, Apr, May, Aug, Sep, Oct,	11/30/1971	
Lean Hogs[26]	0.8%	2.5%	CME Group	Feb, Apr, May, Jul, Aug, Oct, Dec	02/28/1966	
Live Cattle	1.6%	4.1%	CME Group	Feb, Apr, Jun, Aug, Oct, Dec	11/30/1964	
Pork Bellies	0	0	CME Group	Feb, Mar, May, Jul, Aug	09/18/1961	
Metals (5 Commodities)						
Gold[27]	1.5%	6.1%	NYMEX	Feb, Apr, Jun, Aug, Oct, Dec	12/31/1974	01/01/2008
Silver	0.2%	2.4%	NYMEX	Jan, Mar, May, Jul, Sep, Dec	06/12/1963	
Copper[28]	2.6%	6.7%	NYMEX	Mar, May, Jul, Sep, Dec	01/03/1989	05/12/1997
Platinum	0	0	NYMEX	Jan, Apr, Jul, and Oct	03/04/1968	
Palladium	0	0	NYMEX	Mar, Jun, Sep, and Dec	01/03/1977	

[23] The GSCI and DJ-UBS indices also include commodities traded in London, which are not included in our analysis.

[24] Kansas City Board of Trade.

[25] Minneapolis Grain Exchange.

[26] A June contract has been added to the Lean Hog Futures series since 2002. As this new contract has a low open interest, we omit this contract in our analysis.

[27] For gold, silver, platinum, and palladium, contracts include the current month and the next two consecutive months, plus those contracts listed in the table. However, because the open interest of those short-maturity contracts (with maturities less than 3 months) is typically small, we omit these contracts in our analysis.

[28] The GSCI Index uses the copper contracts traded on LME, while the DJ-UBS Index uses those from NYMEX. We follow the convention of the DJ-UBS index and choose Mar, May, Jul, Sep and Dec for copper contracts in our analysis.

Table 2: The Commodity Index Traders Report

This table summarizes the Commodity Index Traders (CIT) report released by the CFTC, which is reported on each Friday regarding a breakdown of the prior Tuesday's positions for 12 agricultural commodities. The sample period covers from 1/2/2006 to 10/29/2009. We calculate the position of each reported category in each commodity relative to the total open interest, and then calculate the mean across the whole sample period.

	Index Traders		**Non-commercial Traders**			**Commercial Traders**	
	Long	Short	Long	Short	Spread	Long	Short
Chicago Wheat	41.6%	3.6%	10.6%	14.8%	28.2%	12.1%	40.6%
Kansas Wheat	22.7%	0.7%	22.2%	7.8%	13.8%	23.7%	54.5%
Corn	23.4%	1.7%	12.2%	5.9%	29.7%	23.4%	45.4%
Soybean	25.6%	1.7%	13.6%	7.6%	29.1%	20.0%	44.3%
Soybean Oil	23.6%	1.2%	14.3%	8.5%	23.0%	29.2%	60.1%
Cotton	32.2%	1.2%	13.3%	10.8%	27.1%	19.1%	55.8%
Lean Hogs	42.4%	1.1%	12.0%	15.7%	25.0%	8.8%	40.4%
Live Cattle	38.7%	0.7%	16.2%	12.6%	23.1%	12.9%	43.4%
Feeder Cattle	25.0%	1.3%	23.0%	16.3%	17.9%	15.5%	20.9%
Cocoa	12.7%	0.9%	27.7%	13.5%	11.6%	40.5%	69.6%
Sugar	27.7%	4.8%	11.7%	6.2%	22.5%	28.5%	59.4%
Coffee	25.0%	0.8%	17.0%	12.2%	28.7%	22.7%	53.7%
Average	28.4%	1.6%	16.1%	11.0%	23.3%	21.4%	49.0%

Table 3: Regressions of GSCI Index Return

This table reports regressions of return of the GSCI excess return index on returns of the Morgan Stanley emerging market equity index ($R_{EM,t}$), the S&P 500 US stock index ($R_{SP,t}$), the JP Morgan Treasury bond index ($R_{JPM,t}$), and the US dollar index ($R_{USD,t}$), CPI inflation rate ($R_{CPI,t}$), and change of the global shipping index ($R_{ACT,t}$), separately and jointly. We normalize each variable by its sample mean and standard deviation. The data sample goes from 1/4/1988 to 10/29/2009. The regression specification is given in (2). Panel A reports the daily regression results based on the first four independent variables mentioned above, and Panel B reports the monthly results based on all of the six variables. For inflation rate, we separately report results based on CPI inflate rate and CPI core inflation rate (which excludes food and energy prices). Each panel reports results for the pre-crisis period from 1/4/1988 to 8/31/2008 and for the full sample period. The t-statistics are adjusted for heteroskedasticity and serial correlation using the Newey-West method with five lags.

Panel A: Regressions of Daily GSCI Return

		Regression (1)		**Regression (2)**		**Regression (3)**		**Regression (4)**		**Regression (5)**	
		estimate	t-stat	estimate	t-stat	estimate	t-stat	estimate	t-stat	estimate	t-stat
		The Pre-Crisis Period (1/4/1988 to 8/31/2008)									
	a_0	0.00	-0.34	0.00	-0.31	0.00	-0.29	0.00	-0.33	0.00	-0.26
	a_1	0.02	0.60	0.02	0.54	0.02	0.53	0.01	0.41	0.01	0.24
Link to emerging market index	b_0	-0.01	-0.45							0.00	0.14
	b_1	0.07	5.52							0.06	5.00
Link to S&P 500 index	c_0			-0.06	-2.65					-0.06	-2.80
	c_1			0.00	0.07					-0.01	-0.89
Link to bond index	d_0					-0.06	-3.08			-0.06	-3.06
	d_1					0.01	0.76			-0.01	-0.88
Link to US dollar index	e_0							-0.02	-0.74	-0.01	-0.60
	e_1							-0.14	-6.68	-0.13	-6.43
	R^2	1.20%		0.42%		0.30%		1.93%		3.59%	
		The Full Sample Period (1/4/1988 to 10/29/2009)									
	a_0	0.00	0.37	0.01	0.43	0.01	0.41	0.00	0.38	0.01	0.47
	a_1	-0.02	-0.50	-0.01	-0.35	-0.02	-0.60	-0.02	-0.75	-0.02	-0.75
Link to emerging market index	b_0	-0.02	-0.68							0.01	0.21
	b_1	0.10	8.95							0.06	5.63
Link to S&P 500 index	c_0			-0.08	-3.26					-0.07	-3.20
	c_1			0.09	8.29					0.03	3.15
Link to bond index	d_0					-0.05	-2.61			-0.05	-2.70
	d_1					-0.04	-2.47			-0.03	-2.38
Link to US dollar index	e_0							-0.02	-0.90	-0.02	-0.91
	e_1							-0.11	-6.70	-0.07	-4.91
	R^2	7.47%		4.86%		1.09%		5.10%		10.82%	

Panel B: Regressions of Monthly GSCI Return

		Reg (1)		Reg (2)		Reg (3)		Reg (4)		Reg (5)		Reg (6)		Reg (7)			
		est	t-stat	est	t-stat	est	t-stat	est	t-stat	est	t-stat	est	t-stat	est	t-stat	est	t-stat
		The Pre-Crisis Period (1/4/1988 to 8/31/2008)															
	a_0	-0.02	-0.26	-0.01	-0.21	-0.01	-0.13	-0.02	-0.24	-0.02	-0.28	-0.02	-0.22	0.09	1.47	0.12	1.92
	a_1	0.08	0.49	0.06	0.38	0.05	0.31	0.04	0.27	0.08	0.49	0.09	0.56	-0.35	-1.60	-0.52	-2.38
Link to emerging market index	b_0	-0.02	-0.24													0.04	0.57
	b_1	0.07	1.50													0.10	1.37
Link to S&P 500 index	c_0			-0.15	-1.53											-0.18	-1.72
	c_1			-0.02	-0.36											-0.05	-0.68
Link to bond index	d_0					-0.18	-3.09									-0.16	-2.54
	d_1					0.03	0.64									-0.11	-2.82
Link to US dollar index	e_0							-0.06	-0.68							-0.07	-0.88
	e_1							-0.16	-4.80							-0.16	-3.11
Link to inflation rate	f_0									-0.07	-1.20						
	f_1									0.04	0.97						
Link to core inflation rate	f_0											-0.04	-0.75			-0.02	-0.45
	f_1											0.07	1.58			0.05	1.14
Link to global econ activity	g_0													0.25	2.28	0.28	2.71
	g_1													-0.01	-0.24	-0.02	-0.69
	R^2	0.93%		2.94%		2.88%		7.32%		0.6%		0.49%		2.19%		18.11%	
		The Full Sample Period (1/4/1988 to 10/29/2009)															
	a_0	0.03	0.39	0.03	0.52	0.05	0.78	0.04	0.66	0.03	0.40	0.03	0.42	0.15	2.33	0.17	2.94
	a_1	-0.09	-0.53	-0.06	-0.33	-0.20	-0.79	-0.15	-0.79	-0.07	-0.38	-0.07	-0.35	-0.66	-2.22	-0.62	-4.13
Link to emerging market index	b_0	-0.03	-0.35													0.04	0.58
	b_1	0.14	3.97													0.05	0.76
Link to S&P 500 index	c_0			-0.18	-1.76											-0.19	-1.81
	c_1			0.13	3.59											0.06	1.08
Link to bond index	d_0					-0.18	-3.16									-0.16	-2.65
	d_1					0.03	0.85									-0.04	-1.46
Link to US dollar index	e_0							-0.05	-0.70							-0.07	-0.99
	e_1							-0.16	-3.98							-0.12	-2.07
Link to inflation rate	f_0									-0.08	-1.36						
	f_1									0.10	2.97						
Link to core inflation rate	f_0											-0.04	-0.74			-0.02	-0.38
	f_1											0.10	1.84			0.03	0.63
Link to global econ activity	g_0													0.28	2.51	0.29	3.27
	g_1													0.04	1.35	0.01	0.30
	R^2	11.24%		7.99%		2.98%		10.99%		4.77%		1.04%		7.07%		25.92%	

Table 4: Regressions of Daily Futures Returns of Non-energy Commodities

This table reports regression results of daily returns of front-month futures contracts of non-energy commodities on oil return ($R_{oil,t}$), separately and jointly with a set of control variables, including returns of the Morgan Stanley emerging market equity index ($R_{EM,t}$), the S&P equity index ($R_{SP,t}$), the JP Morgan Treasury bond index ($R_{JPM,t}$), and the US dollar index ($R_{USD,t}$):

$$R_{i,t}^{n} = \alpha + [\beta_{0i} + \beta_1(t-2004)I_{t\geq 2004} + \beta_2(t-2004)I_{t\geq 2004}I_{index}]R_{oil,t}^{n}$$

$$+ [\kappa_{0i} + \kappa_1(t-2004)I_{t\geq 2004} + \kappa_2(t-2004)I_{t\geq 2004}I_{index}]R_{EM,t}^{n}$$

$$+ [\gamma_{0i} + \gamma_1(t-2004)I_{t\geq 2004} + \gamma_2(t-2004)I_{t\geq 2004}I_{index}]R_{SP,t}^{n}$$

$$+[\theta_{0i} + \theta_1(t-2004)I_{t\geq 2004} + \theta_2(t-2004)I_{t\geq 2004}I_{index}]R_{JMP,t}^{n}$$

$$+[\eta_{0i} + \eta_1(t-2004)I_{t\geq 2004} + \eta_2(t-2004)I_{t\geq 2004}I_{index}]R_{USD,t}^{n} + \varepsilon_{i,t}$$

We normalize each variable by its sample mean and standard deviation. The data sample goes from 1/2/1998 to 10/29/2009. We report the results of each regression for the pre-crisis period from 1/4/1988 to 8/31/2008 and for the whole sample period. The t-statistics are adjusted for heteroskedasticity and serial correlation using the Newey-West method with five lags. Panel A reports regression results for the full sample with all non-energy commodities. To save space, we skip the estimates for κ_{0i}'s, γ_{0i}'s, θ_{0i}'s, and η_{0i}'s in panel A. Panel B separately reports the estimates of the main variables of interests β_1 and β_2 in different subsamples of commodities, including the soybean complex (which includes soybeans, soybean meal and soybean oil), the grain sector, the soft sector, the livestock sector, and the metal sector, with the control variables.

Panel A: Full Sample with All Non-Energy Commodities

			The Pre-Crisis Period (1/2/1998 to 8/31/2008)				The Full Sample Period (1/2/1998 to 10/29/2009)			
			est	t-stat	est	t-stat	est	t-stat	est	t-stat
	α		0.00	0.03	0.00	-0.08	0.00	0.75	0.00	0.42
Link of individual commodity with oil before 2004	β_{0i}	Corn	0.07	4.17	0.07	4.39	0.09	4.69	0.09	5.07
		Wheat	0.04	2.36	0.05	2.62	0.06	2.98	0.07	3.48
		Kansas Wheat	0.04	2.43	0.05	2.76	0.06	3.03	0.07	3.70
		Soybean	0.06	3.34	0.06	3.25	0.09	4.55	0.08	4.50
		Soybean Oil	0.05	2.69	0.05	2.54	0.11	5.01	0.09	4.94
		Live Cattle	-0.02	-0.88	-0.01	-0.39	-0.01	-0.54	0.00	0.23
		Lean Hogs	0.00	-0.07	0.01	0.28	-0.05	-2.26	-0.02	-0.88
		Feed Cattle	-0.07	-3.78	-0.06	-3.15	-0.06	-2.87	-0.04	-1.95
		Gold	0.15	7.09	0.12	6.57	0.08	3.34	0.07	3.45
		Silver	0.12	5.93	0.09	5.10	0.10	4.00	0.06	2.96
		Copper	0.10	5.02	0.09	4.78	0.16	6.87	0.12	5.75
		Coffee	-0.03	-1.06	-0.02	-1.02	-0.04	-1.84	-0.04	-1.58
		Cocoa	-0.02	-0.81	-0.02	-0.83	-0.03	-1.17	-0.02	-1.19
		Cotton	0.04	1.90	0.04	2.13	0.04	2.12	0.05	2.61
		Sugar	0.02	1.06	0.03	1.23	0.02	0.90	0.03	1.58
		Rough Rice	0.02	0.81	0.02	0.99	0.02	0.81	0.03	1.38
		Soybean Meal	0.05	2.72	0.05	2.57	0.07	3.35	0.07	3.35
		Oat	0.02	0.76	0.02	0.73	0.04	2.02	0.04	2.00
		Minn Wheat	0.06	3.39	0.06	3.56	0.09	4.46	0.09	4.91
		Orange Juice	-0.02	-1.07	-0.01	-0.53	-0.03	-1.32	0.00	-0.21
		Lumber	-0.02	-1.07	-0.02	-0.89	-0.03	-1.70	-0.03	-1.54
		Platinum	0.09	4.85	0.08	4.16	0.11	4.81	0.08	3.89
		Palladium	0.03	1.60	0.02	1.03	0.04	2.02	0.02	1.09
		Pork Belly	-0.02	-0.90	-0.01	-0.60	-0.06	-2.62	-0.03	-1.38
Trend with oil after 2004	β_1		0.06	10.48	0.04	8.21	0.05	15.14	0.03	8.81
	β_2		0.02	3.55	0.02	2.61	0.02	5.01	0.02	4.26
Trend with emerging market index after 2004	κ_1				0.02	4.41			0.02	5.12
	κ_2				0.00	-0.39			-0.01	-1.88
Trend with S&P 500 index after 2004	γ_1				-0.01	-1.09			-0.01	-3.03
	γ_2				0.00	0.27			0.00	0.99
Trend with bond index after 2004	θ_1				-0.01	-1.48			-0.01	-1.77
	θ_2				-0.01	-0.91			0.00	-0.10
Trend with US dollar after 2004	η_1				-0.01	-1.10			-0.01	-3.67
	η_2				-0.02	-2.47			-0.01	-1.41
	R^2		2.13%		4.64%		5.04%		7.98%	

Panel B: Estimates of β_1 and β_2 in Different Commodity Sectors

	The Pre-Crisis Period (1/2/1998 to 8/31/2008)		The Full Sample Period (1/2/1998 to 10/29/2009)	
	est	t-stat	est	t-stat
Soybean Complex				
β_1	0.07	4.29	0.05	4.51
β_2	0.06	2.90	0.04	3.08
Grain Sector				
β_1	0.06	6.84	0.05	4.51
β_2	0.04	3.21	0.04	3.08
Soft Sector				
β_1	0.02	2.07	0.02	2.71
β_2	0.02	1.56	0.02	2.11
Livestock Sector				
β_1	0.00	0.26	0.00	-0.26
β_2	0.01	0.35	0.03	2.91
Metal Sector				
β_1	0.05	5.42	0.03	4.20
β_2	0.03	2.08	0.02	1.80

Table 5: Regressions of Daily Futures Returns of Non-energy Commodities with Lags

This table reports regression results of daily returns of first-month futures contracts of non-energy commodities on oil return ($R_{oil,t}$), separately and jointly with a set of control variables, including returns of the Morgan Stanley emerging market equity index ($R_{EM,t}$), the S&P equity index ($R_{SP,t}$), the JP Morgan Treasury bond index ($R_{JPM,t}$), and the US dollar index ($R_{USD,t}$). We use two lags of oil return in the regression specification:

$$R_{i,t}^{n} = \alpha + [\beta_{0i} + \beta_1(t-2004)I_{t\geq 2004} + \beta_2(t-2004)I_{t\geq 2004}I_{index}]R_{oil,t}^{n}$$

$$+ [\beta_{3i} + \beta_4(t-2004)I_{t\geq 2004} + \beta_5(t-2004)I_{t\geq 2004}I_{index}]R_{oil,t-1}^{n}$$

$$+ [\beta_{6i} + \beta_7(t-2004)I_{t\geq 2004} + \beta_8(t-2004)I_{t\geq 2004}I_{index}]R_{oil,t-2}^{n}$$

$$+ [\kappa_{0i} + \kappa_1(t-2004)I_{t\geq 2004} + \kappa_2(t-2004)I_{t\geq 2004}I_{index}]R_{EM,t}^{n}$$

$$+ [\gamma_{0i} + \gamma_1(t-2004)I_{t\geq 2004} + \gamma_2(t-2004)I_{t\geq 2004}I_{index}]R_{SP,t}^{n}$$

$$+ [\theta_{0i} + \theta_1(t-2004)I_{t\geq 2004} + \theta_2(t-2004)I_{t\geq 2004}I_{index}]R_{JMP,t}^{n}$$

$$+ [\eta_{0i} + \eta_1(t-2004)I_{t\geq 2004} + \eta_2(t-2004)I_{t\geq 2004}I_{index}]R_{USD,t}^{n} + \varepsilon_{i,t}$$

We normalize each variable by its sample mean and standard deviation. The sample goes from 1/2/1998 to 10/29/2009. We report the results of each regression for the pre-crisis period from 1/4/1988 to 8/31/2008 and for the whole sample period. The t-stats are adjusted for heteroskedasticity and serial correlation using the Newey-West method with five lags. We only report the coefficients related to the trends with oil after 2004. We also report the F-statistic for testing $\beta_2 + \beta_5 + \beta_8 \leq 0$ with 95% significance level as 2.71.

			The Pre-Crisis Period (1/2/1998 to 8/31/2008)				The Full Sample Period (1/2/1998 to 10/29/2009)			
			No Controls		With Controls		No Controls		With Controls	
			est	t-stat	est	t-stat	est	t-stat	est	t-stat
Trend with oil after 2004	Lag0	β_1	0.06	10.35	0.04	7.91	0.05	15.08	0.03	8.80
		β_2	0.02	3.56	0.02	2.58	0.02	5.03	0.02	4.22
	Lag1	β_4	-0.01	-2.38	-0.01	-2.77	0.00	1.03	0.00	-0.70
		β_5	0.00	0.09	0.00	-0.31	-0.01	-2.87	-0.01	-2.99
	Lag2	β_7	-0.01	-1.37	0.00	-0.66	0.00	-0.92	0.00	-0.79
		β_8	0.00	0.63	0.00	0.60	0.00	-0.05	0.00	-0.11
F-test for $\beta_2+\beta_5+\beta_8\leq 0$			8.07		3.43		3.35		1.48	

Table 6: Regression Analysis of Spot Returns and Slope Changes of Futures Curves

This table reports regression results of daily spot returns and slope changes of futures curves. Panel A pools the daily spot returns of 16 non-energy commodities: corn, soybeans, wheat, Kansas wheat, soybean oil, Minnesota wheat, oats, cotton, sugar, live cattle, lean hogs, gold, silver, copper, platinum, and palladium, and regresses them on oil spot return and a set of control variables, including returns of the Morgan Stanley emerging market equity index, the S&P equity index, the JP Morgan Treasury bond index, and the US dollar index based on regression specification (3). Panel B pools together the daily slope changes of all non-energy commodities listed in Table 1 and regresses them on slope change of oil based on regression specification (5). For both Panels A and B, we report the results of each regression for the pre-crisis period from 1/4/1988 to 8/31/2008 and for the whole sample period. We only report the coefficients related to the trends with oil after 2004. The t-statistics are adjusted for heteroskedasticity and serial correlation using the Newey-West method with five lags.

Panel A: Spot Returns

	The Pre-Crisis Period (1/2/1998 to 8/31/2008)		The Full Sample Period (1/2/1998 to 10/29/2009)	
	est	t-stat	est	t-stat
β_1	0.03	2.83	0.00	0.17
β_2	0.03	2.96	0.03	4.43

Panel B: Slope Changes

	The Pre-Crisis Period (1/2/1998 to 8/31/2008)		The Full Sample Period (1/2/1998 to 10/29/2009)	
	est	t-stat	est	t-stat
β_1	0.01	1.30	0.00	0.08
β_2	0.00	-0.65	-0.01	-0.50

Table 7: Regression Analysis of Volatility of Non-energy Commodities

We analyze volatility of daily returns of all non-energy commodities between 1/2/1998 and 10/29/2009. We normalize return of each commodity by its volatility before 2004 and its whole sample mean. We filter out from return of each commodity a set of control variables (including returns of the Morgan Stanley emerging market index, the S&P 500 index, the JP Morgan Treasury bond index, and the US dollar index, the core CPI inflation rate, and change of the global shipping index) and oil return by using regression specification (7). Then, we regress the normalized raw returns, the residual returns after filtering out the set of control variables, and the residual returns after filtering out the set of control variables and oil return onto a set of index and year dummies:

$$\left(R_{i,t}^{n}\right)^2 = a_{0i} + b_{04}I_{y=04} + b_{05}I_{y=05} + b_{06}I_{y=06} + b_{07}I_{y=07} + b_{08}I_{y=08}$$

$$+b_{09}I_{y=09}+c_{05}I_{index}I_{y=04} + c_{05}I_{index}I_{y=05} + c_{06}I_{index}I_{y=06}$$

$$+c_{07}I_{index}I_{y=07} + c_{08}I_{index}I_{y=08} + c_{09}I_{index}I_{y=09} + \varepsilon_{i,t}$$

To save space, we only report estimates of coefficients related to changes of volatility in years after 2004. The t-statistics are adjusted for heteroskedasticity and serial correlation using the Newey-West method with five lags.

		Raw Returns		**Residual Returns after Control Variables**		**Residual Returns after Control Variables and Oil Return**	
		estimate	t-stat	estimate	t-stat	estimate	t-stat
Baseline Effects	b_{04}	0.25	3.52	0.19	2.84	0.19	2.85
	b_{05}	-0.09	-1.62	-0.12	-2.18	-0.13	-2.29
	b_{06}	-0.01	-0.15	-0.08	-1.36	-0.10	-1.58
	b_{07}	-0.07	-1.16	-0.12	-2.09	-0.13	-2.21
	b_{08}	1.45	10.80	1.10	9.40	0.96	8.70
	b_{09}	0.78	8.59	0.55	6.75	0.51	6.54
Diff-in-Diff Effects	c_{04}	0.34	3.55	0.26	2.84	0.25	2.74
	c_{05}	0.09	1.26	0.07	1.07	0.06	0.93
	c_{06}	0.54	4.63	0.45	4.44	0.38	4.06
	c_{07}	0.25	3.35	0.17	2.35	0.14	1.93
	c_{08}	0.68	3.42	0.43	2.55	0.24	1.59
	c_{09}	0.37	2.88	0.22	1.90	0.14	1.29
	R^2	4.5%		3.2%		2.6%	