



# Commodity Index Traders and Boom/Bust in Commodities Prices

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## ABSTRACT

Since 2005, the public has lived with high and volatile prices for basic energy and agricultural commodities. The public focus on this unprecedented commodity price volatility has been intense, because a large proportion of the cost of living borne by individuals and families in the U.S. (and around the globe) is represented by commodities-based costs, notably food, fuel, and clothing. Interestingly, as commodity prices have shown more price volatility, there has been an accompanying significant increase in the volume of commodities futures and swaps transactions, as well as commodities markets open interest. Moreover, Commodity Index Traders (“CITs”), a relatively new type of participant, now collectively make up the single largest group of non-commercial participants in commodities futures markets. These CITs, which represent giant institutional pools of capital, have at times been the single largest class of participant, outweighing *bona fide* hedgers (producers and consumers of commodities) and traditional “speculators,” who take short-term bi-directional bets and provide liquidity. Given both the size and the specific and largely homogeneous investment strategy of the CITs, many market observers have concluded that this group is most likely responsible for greatly disrupting price formation in commodities futures markets. Further, it has been posited that this distortion has directly led to recent unprecedented price volatility and higher absolute price levels for numerous food and energy commodities in markets around the world.

Using a new set of analytic approaches, the authors seek to test whether the behavior of CITs has impacted commodities prices in a manner independent of fundamental supply and

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demand forces. Specifically, we examine the behavior of futures price spreads before, during, and after the monthly CIT “Roll” period, a set period from the 5<sup>th</sup> to 9<sup>th</sup> business day of each month, during which funds tracking the most popular commodity index, the Standard & Poor’s Goldman Sachs Commodity Index (GSCI) must roll forward their expiring futures contracts. We find strong evidence that the CIT Roll Cycle systematically distorts forward commodities futures price curves towards a contango state, which may contribute to speculative “boom/bust” cycles by changing the incentives of producers and consumers of storable commodities, and also by sending misleading and non-fundamental, price signals to the market.

## INTRODUCTION

Since 2005, the public has experienced prices for basic energy and agricultural commodities that have gone through numerous periods of significant volatility and also higher absolute levels. The public focus on this unprecedented commodity price volatility has been intense, because a large proportion of the cost of living borne by individuals and families in the U.S. (and around the globe) is represented by commodities-based costs, notably food, fuel, and clothing.<sup>2</sup> Moreover, this situation has been magnified as incomes have suffered from declining employment and other economic damage caused by the recent financial crisis and associated recession.

Interestingly, during the time that commodity prices have become more volatile, the volume of commodities futures and swaps transactions, as well as open interest, has increased sharply.<sup>3,4</sup> In fact, “the ratio of the notional amount of commodity derivatives contracts in June 1998 to world GDP rose from 1.5 percent in 1998 to 21.6 percent in 2008.”<sup>5</sup> Unsurprisingly, much discussion in political, financial, and academic circles has revolved around the question whether the increased trading activity/open interest and the more erratic behavior of commodities prices are causally related, as well as how such a causal relationship might function.<sup>6</sup>

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<sup>2</sup> According to the U.S. Bureau of Labor Statistics, Comparison of Consumer Price Index for All Urban Consumers: U.S. City Average, All Items and All Items Less Food and Energy, 2001-2011, *available at* [http://data.bls.gov/pdq/SurveyOutputServlet?request\\_action=wh&graph\\_name=CU\\_cpibrief](http://data.bls.gov/pdq/SurveyOutputServlet?request_action=wh&graph_name=CU_cpibrief).

<sup>3</sup> The Commodity Futures Trading Commission (“CFTC”) defines open interest as “The total number of futures contracts long or short in a delivery month or market that has been entered into and not yet liquidated by an offsetting transaction or fulfilled by delivery.” CFTC, *CFTC Glossary: A Guide to the Language of the Futures Industry*, p40, *available at* [http://www.google.com/url?sa=t&source=web&cd=2&ved=0CCMQFjAB&url=http%3A%2F%2Fwww.cftc.gov%2Fucm%2Fgroups%2Fpublic%2F%40educationcenter%2Fdocuments%2Ffile%2Fcftcglossary.pdf&rc=j&q=open%20interest%20definition%20cftc&ei=IkuTTpXTMcStsALA7e2uAQ&usg=AFQjCNHWJIsj\\_DJp6d9RTakzYuvGxSyZGQ&cad=rja](http://www.google.com/url?sa=t&source=web&cd=2&ved=0CCMQFjAB&url=http%3A%2F%2Fwww.cftc.gov%2Fucm%2Fgroups%2Fpublic%2F%40educationcenter%2Fdocuments%2Ffile%2Fcftcglossary.pdf&rc=j&q=open%20interest%20definition%20cftc&ei=IkuTTpXTMcStsALA7e2uAQ&usg=AFQjCNHWJIsj_DJp6d9RTakzYuvGxSyZGQ&cad=rja)

<sup>4</sup> See Crude Oil West Texas Intermediate (WTI) – Cushing, OK., St. Louis Federal Reserve, FRED Database, *available at* <http://research.stlouisfed.org/fred2/series/DCOILWTICO?cid=32355>.

<sup>5</sup> Basu and Gavin, “What Explains the Growth in Commodity Derivatives,” Federal Reserve Bank of St. Louis Review, January/February 2011, *available at* <http://research.stlouisfed.org/publications/review/11/01/37-48Basu.pdf>.

<sup>6</sup> See Appendix A: Review of Academic Literature, *in* Better Markets, Inc., Comment Letter to the Commodity Futures Trading Commission, “Position Limits for Derivatives,” March 28, 2011, (“Position Limits Comment Letter”) *available at* <http://comments.cftc.gov/PublicComments/ViewComment.aspx?id=34010&SearchText=better%20markets>

Because the discussion of these issues is so intense, it is often distorted by hyperbolae and illogic. It is critically important that the question is posed accurately. It would be unreasonable to suggest that commodities prices are a purely financial construct. On the other hand, it appears absurd to claim that commodity futures markets, with their enormous relative size and trading volume, have no impact at all on prices for physical commodities, especially given their leading role as both a hedging vehicle and a direct price benchmark for physical transactions.<sup>7</sup> The real question is the relative strengths and interactions of these two sets of forces. Because of the relatively inelastic nature of commodities, global supply and demand conditions evolve over a long cycle.<sup>8</sup> However, financial market trends and behaviors typically involve a much shorter cycle.<sup>9</sup> The two phenomena are related, but often can display significant independence.

One of the most-discussed elements of the recent inflow of financial capital into commodities markets is the group known collectively as Commodity Index Traders (“CITs”). Today, the *CITs collectively make up the single largest group of non-commercial participants in commodity markets*, and their size as well as their specific investment strategy has led many market observers to conclude that they are the most likely group to disrupt price formation in commodities markets.<sup>10</sup>

We now briefly recap the analytical approach taken by Better Markets, and summarize the basic conclusions drawn in the present study.<sup>11</sup>

## ANALYTICAL APPROACHES

### *Price Spreads*

Using a new set of analytic approaches, the authors seek to test whether the behavior of one specific set of commodity futures market participants –CITs– has directly impacted commodities futures prices in a manner independent of fundamental supply and demand forces. Specifically, we examine the behavior of futures price spreads before, during, and

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<sup>7</sup> See Platts Methodology and Specification Guide available at <http://www.platts.com/IM.Platts.Content/methodologyreferences/methodologyspecs/usoilproductspecs.pdf>.

<sup>8</sup> See Petrostrategies, Inc., “World Oil Supply and Demand,” available at [http://www.petrostrategies.org/Graphs/World Oil Supply and Demand.htm](http://www.petrostrategies.org/Graphs/World%20Oil%20Supply%20and%20Demand.htm).

<sup>9</sup> See Bloomberg, GSCI Index Spot CME, available at <http://www.bloomberg.com/apps/quote?ticker=SPGSCI:IND>.

<sup>10</sup> United States Senate, Permanent Subcommittee on Investigations (2009): Excessive Speculation in the Wheat Market: “This Report concludes there is significant and persuasive evidence that one of the major reasons for the recent market problems is the unusually high level of speculation in the Chicago wheat futures market due to purchases of futures contracts by index traders offsetting sales of commodity index instruments.”

<sup>11</sup> Better Markets recently submitted a comment letter to the CFTC on the subject of financial participation in commodities markets, and the appropriate use of “speculative position limits,” a key tool by which regulators may restrict the percentage of open interest held by any group or class of trader, such as the group of CITs as a whole. Better Markets, Inc., Comment Letter to the Commodity Futures Trading Commission, “Position Limits for Derivatives,” March 28, 2011, (“Position Limits Comment Letter”) available at <http://comments.cftc.gov/PublicComments/ViewComment.aspx?id=34010&SearchText=better%20markets>. An analytic framework for understanding the role and impact of CITs in commodities markets is laid out in that letter. The analysis in this paper is related to, but significantly different from that set out in the letter.

after the monthly CIT “Roll” period, a set period from the 5<sup>th</sup> to 9<sup>th</sup> business day of each month, during which funds tracking the most popular commodity index, the Standard & Poor’s Goldman Sachs Commodity Index (GSCI) must roll forward their expiring futures contracts.<sup>12</sup> As is discussed in Mou (2011), some CIT rolling also occurs outside of this period, but the vast majority of CIT rolling activity typically occurs during this window every month.<sup>13</sup> We focus initially on Crude Oil and Wheat, the two largest and most prominent U.S. commodity futures markets.<sup>14</sup> We examine the change in price spreads for these commodities before, during, and after the Roll, every month from January 1983 to June 2011.

For both of the primary commodities studied, in this case the agriculture and energy benchmark CBOT Wheat and NYMEX WTI Crude Oil contracts, we find strong evidence that commodities futures price spreads display a consistent bias towards an increasing contango curve during the Roll Period, and also that this bias is not present during the rest of the trading month.<sup>15</sup> Moreover, we find no evidence that this persistent contango bias existed prior to the large growth in commodity index trading from 2004 onwards, strongly suggesting that it is caused by CIT trading, and is not caused by another structural or fundamental phenomenon.<sup>16</sup>

To supplement the primary study, we also examine two other important commodities future’s benchmark contracts, those of Heating Oil and Corn. The results show the same overall pattern (a bias towards increasing contango during the general Roll Period, which is not present during the rest of the trading month, and which did not exist prior to the rise of CIT trading). However, the pattern of results is not identical. Therefore, we include two more benchmark futures contracts, Feeder Cattle and Natural Gas, to obtain an even broader perspective and also to give additional insight into potential reasons for non-identical results.

One major advantage of this approach, which tests publicly available price spreads during the known Roll Period, is that the validity of the underlying data is generally accepted. The analytical model for several prior studies of CIT activity has involved testing for correlations between CIT flows and prices, which is subject to well-publicized deficiencies in public data relating to CIT flows.<sup>17</sup> In contrast to the relatively uncertain direct investment flows data,

<sup>12</sup> Futures contracts expire at regular periods. Traditional hedgers simply close out their contracts for cash at expiration, or make or take delivery. However, speculative commodity index funds are designed to keep bets on the table for long periods of time. That is what gives rise to the necessity of “rolling” those expiring contracts into new futures contracts every month.

<sup>13</sup> Since the GSCI TR index is calculated *as though* all rolling occurred during this window, any commodity index sponsor (CIT) tracking the index must either conduct all rolling activity at this time, or else take on proprietary risk.

<sup>14</sup> CME Group, “WTI – The Global Benchmark,” *available at* <http://www.cmegroup.com/trading/energy/files/WTI-Global-Benchmark.pdf>

<sup>15</sup> A “contango” curve is one in which prices are higher the further out you go into the future. Its inverse is “backwardation”. In the present study, we look at the slope between the contract that the index fund closes out and the longer-dated contract with which it replaces the expiring one. Hence, “contango” refers to the bought contract displaying a higher price than the sold contract, and “backwardation” to the inverse.

<sup>16</sup> “Fundamentals” are facts relating to actual supply and demand from producers and consumers of a commodity. In a well-functioning market, futures prices reflect expectations of future prices, based on available information about fundamentals.

<sup>17</sup> Much of the analysis to date has sought to identify the effect of index fund inflows and outflows on price. Inflows and out flows are measured by aggregate index-related positions over time. The data available from the CFTC used to measure these positions are problematic. Available data sets (such as the CFTC’s Commitment of Traders CIT supplement) which are granular and represent a long history of activity must be

the Roll Period is well known and structurally determined. Historic daily settlement prices on futures contracts are also widely available.

In fact, the widening and narrowing of futures price spreads is a particularly useful way to measure the impact of index funds because these spreads reflect the essential characteristic peculiar to index fund-related trading activity: the continuous increasing of duration to hedge exposure under a total return swap to replicate a “perpetual index”.<sup>18</sup> Moreover, it provides a key insight into the direct relationship between futures prices and physical prices. Temporal spreads form a price curve which is the primary signal to the market of the direction in which commodities prices are moving. Thus, the price needed to induce supply into the market sooner rather than later is directly related to the *perceived* direction in prices over time.

Historically, price curves in the commodities futures markets have been predominantly “backwardated;” *i.e.*, longer-dated contracts are most often priced *lower* than shorter-dated contracts.<sup>19</sup> This is a logical price curve structure because of physical storage costs, interest costs, and other factors arising from deferred sale of physical commodities. During the observation period, however, the predominance of backwardated price curves gave way to a far greater incidence of price curves which are in “contango;” *i.e.*, curves in which longer-dated contract prices are relatively *higher*.

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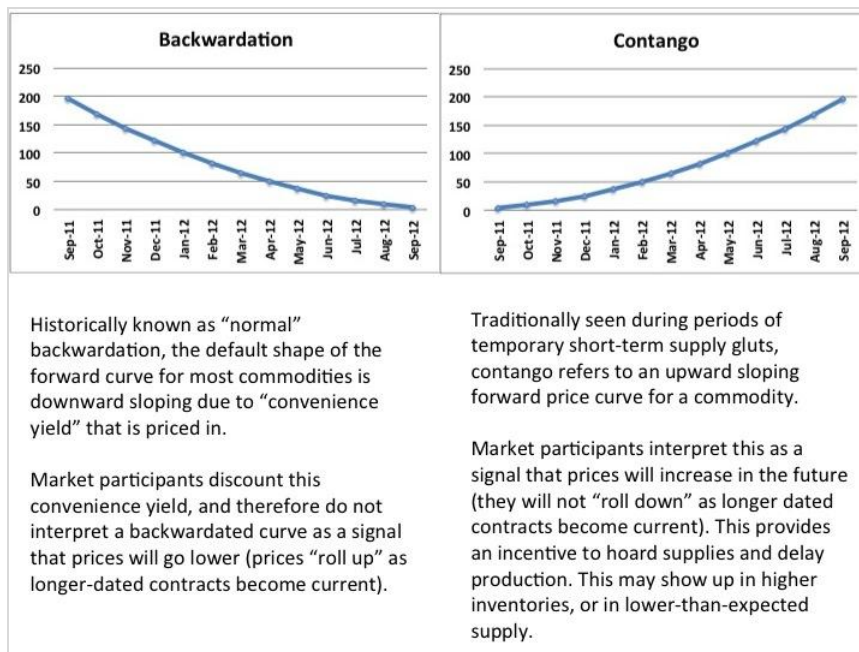
interpolated as they relate to energy derivatives in order to be useful because the categorization is incomplete. The newer swap dealer “survey” data (“Index Investment Data”) have only been available for 3 years, and for 2 of those years data were only gathered quarterly, though monthly reports have been required for the last year. There are also some significant compliance issues that must be considered in using this new survey data. The analysis in this paper is based on data that is not subject to either of those vexing issues.

<sup>18</sup> Buying and holding actual physical commodities would be prohibitively complex and expensive for many institutional investors. Hence, to facilitate and promote commodities transactions, banks and other swap dealers use a derivative of a derivative (a total return swap on the settlement prices of commodity futures contracts), to synthesize the returns of the physical product, so that holding the physical inventory isn’t necessary for the institutional investor. This idea is reminiscent of a similar concept that facilitated institutional investment in derivatives of mortgage derivatives (it allowed institutions to gain exposure to mortgages, without having to actually directly lend people money with which to buy houses), a practice that ended up in the center of the recent financial crisis.

<sup>19</sup> Hotelling, Harold (1929), “Stability in Competition”, *Economic Journal* 39 (153).



Chart 1 – Backwardation vs. Contango



Price curves in contango work to increase physical commodities prices in two important ways:

- The signal given to the market is that prices are going higher, consistent with the upward sloping price curves. Therefore, producers and owners of commodities see a greater advantage in delaying delivery of supplies (as long as the slope of the curve is sufficiently high to offsets storage and other costs). Similarly, consumers are incented to buy product now for use later (again, as long as the contango is steep enough to offset storage costs). Thus, as product is held off the market in the face of inflated demand, spot prices must rise in order to balance the new higher demand and lower supply.
- The role of futures markets as a price benchmark is embedded in many formal pricing structures, such as indexes, standard form contracts and auctions. These structures then become direct transmission conduits for the price signals derived from price curves in contango. As near month futures expire, the next month contracts become the new price benchmark. The spread between the expiring contract and the new contract that replaces it is therefore directly added to the price paid under linked physical contracts that use the prompt month futures price as the benchmark. In fact, this is another key link between commodities futures prices and their spot market counterparts.

Because price signals - unique to the Roll- are generated by CITs acting according to programmed trading activity, *they are not based on fundamentals*. However, there are no observation techniques that allow market participants to transparently discern between what are programmed trading-generated signals vs. what is supply and demand-generated. Inevitably, the artificial nature of these synthetic price signals become apparent (often as the result of the availability of new fundamental based information), *ultimately* returning physical prices to a supply and demand-based level. However, in the meantime, the cycle for this process engenders greater price volatility and also higher than necessary absolute price levels, *which is a direct cost to the public*.

### ***CIT History and Structure***

The commodities index fund concept, dating originally from 1991, has been heavily promoted by swap dealers in the recent past so that “investors” from the much larger capital markets could synthetically own a market basket of physical commodities.<sup>20</sup> Thus the institutional investor synthetically “owns” physical assets for a long duration period without (in theory) having to be concerned about physical possession costs, such as storage and transportation. The presence of commodities index funds in the marketplace increased rapidly since 2004 when a swap-dealer sponsored academic work suggested that these commodity derivative-based products could provide institutional investors with portfolio diversification and other investment benefits.<sup>21</sup> In fact, the size of commodities index fund-related participation in the futures markets is the clear source of a large percentage of the increase in commodities futures volume and open interest in the period since then. (As will be described below, it is very likely that the opportunity to trade opposite commodities index fund sponsors has attracted substantial activity by volatility traders, thus accounting *for almost all of the recent increased speculative volume*). The following chart illustrates this phenomenon for the case of CBOT wheat.<sup>22</sup>

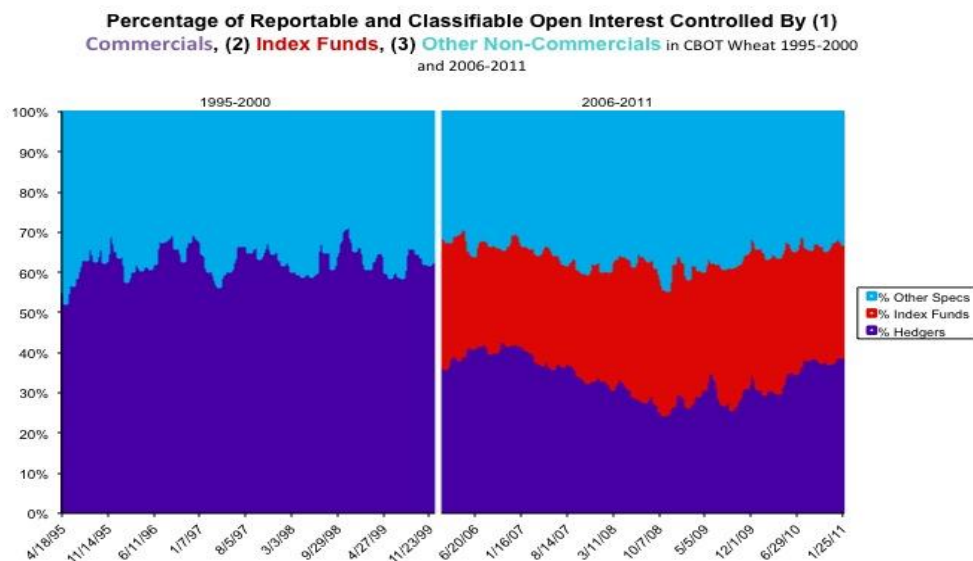
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<sup>20</sup> See note 15, *supra*. Importantly, the concept of an “investor” in commodities is a relatively new one. These participants are technically a form of “speculator” (because they neither produce nor consume commodities). However, they do not provide liquidity in the way that a traditional speculator would. Indeed, because of their monthly need to roll, they are often net liquidity *takers*.

<sup>21</sup> The paper in question was Van Rowenhorst, G., and Gorton, G., *Facts and Fantasies About Commodity Futures*, 2004 (funded by AIG Financial Products). The increase in index fund popularity is detailed in Basu and Gavin at pages 43-44.

<sup>22</sup> Calculated from CFTC CIT Reports. For detailed methodology, see Better Markets, “Position Limits Comment Letter”, *supra* note 4.

Chart 2 (CIF/Spec/Hedger Market Shares)



Commodity Index Funds have a unique structure in which large volumes of futures market trading occurs at specific times *without regard to price considerations*. The unique structure and absolute size of these investment vehicles clearly pose the potential to impact the commodities markets over the period of analysis, and this potential is considered.

The indices that these index funds replicate are based on the long futures prices for notional quantities of multiple commodities. The proration of the notional amounts is a function of the specific strategy underlying the index; this balance is adjusted periodically by the index provider.<sup>23</sup> The index is intended to be perpetual to accommodate long duration positions for targeted institutional investors. This poses a structuring challenge to a fund's promoter since futures contracts, by definition, expire. Thus, expiring contracts must be replaced continuously by longer-dated contracts in order for an investor to perpetuate the index. Therefore, the actual index price is based on the assumed liquidation of expiring long futures contracts and simultaneous buying of longer-dated contracts during specified periods of the futures contract cycle. If each contract referenced in the index calculation reflects actual prices experienced for the underlying commodities, then theoretically the index will accurately reflect commodities price movements over time.

The liquidation and replacement periods are colloquially referred to by traders as the Roll. Because the indices must be objectively determinable, the Roll for an index is based on *pre-determined rules* that are made by index providers. Importantly, these rules include the

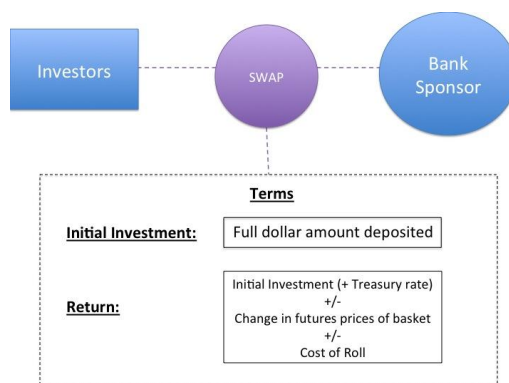
<sup>23</sup> An index provider (such as Standard & Poors) simply calculates and publishes the index. This is distinct from the Index Fund sponsors, who then provide investors with total return swaps and other forms of exposure to the index.



exact time period in the futures contract cycle during which a contract Roll will occur. Often, certain Commodity Index Funds are a large enough presence in the marketplace that the Roll *constitutes the dominant event* each trading month for commodities included in the index.<sup>24</sup>

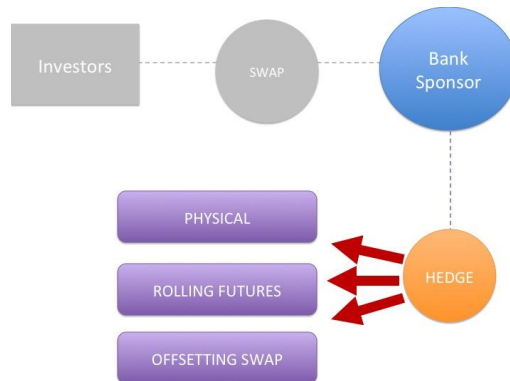
There is an intriguing conceptual issue here. While the use of derivatives is meant to avoid the costs of having to store physical commodities, it is also supposed to avoid impacting their prices (buying and holding the physical inventory would constitute “hoarding”, and would therefore raise prices). Hence, the idea is that investors can “passively” receive the benefits of commodity exposure without facing the costs or creating negative externalities. Such a “free lunch” would indeed be an efficient and impressive achievement. However, as the data analysis below shows, neither of these propositions may be true. If the very act of investing in physical commodities via derivatives impacts prices (as the data suggest it does), then investors may simply end up interpolating the costs of physical storage into their contracts (paying “synthetic” storage). And if investing via derivatives pushes up physical prices over time (as again, the analysis suggests it is likely to), then hoarding by other participants with access to physical storage becomes a low-risk arbitrage strategy. In such a scenario, the price rise would precede the “hoarding,” but the net effect would remain the same: storage costs paid by investors, and negative externalities generated in the form of higher prices and hoarding.

Institutional investors engaging in replicating commodities index-based strategies typically enter into total return swaps with a sponsor (who is a swap dealer).<sup>25</sup> The investment institution begins by transferring funds to the swap dealer equal to the price of a notional quantity of commodities included in the index. The swap dealer sponsor then pays interest at the treasury rate on cash transferred. The institutional investor is then credited with future increases to the index value (and decremented for decreases in value) over time, less any fees due to the swap dealer for managing the swap. Thus, to the extent that the index accurately reflects price changes for the constituent commodities, an investor theoretically experiences the same consequences as one who would have owned the corresponding commodities over the period of investment, and then selling them at the end of the period. Hence the moniker “total return swap”.



<sup>24</sup> E.g., in summer 2008, index funds were greater than 50% of open interest according to the CFTC’s CIT reports (see Better Markets, “Position Limits Comment Letter,” *supra* note 4).

<sup>25</sup> Exchange traded funds or “ETFs” differ from commodities index funds in that the investors receive equity shares instead of the total return swaps. The value of the shares structurally parallels the value of the total return swaps. For purposes of this analysis, the effects on the markets of ETFs and commodities index funds are not materially different.



From the perspective of the institutional investor, the total return swap constitutes a kind of synthetic, long duration ownership of a market-basket of physical commodities, the value of which changes in tandem with price index movements.

The swap dealer facilitating the institutional investor's exposure must offset its client exposure to index movements under the total return swap (except to the extent that it elects to trade speculatively against the exposure under the total return swap, as described below). The swap dealer does so by taking long futures positions and rolling to mimic the index. Gains and losses on the Roll do not affect the sponsor adversely; *rather they are passed on directly to the investor*. Importantly, swap dealer intermediaries holding client commodity index swaps can also offset risk *by owning physical assets corresponding to total return swap notional amounts* or by entering into other swaps.<sup>26</sup> These alternative hedges may be less liquid and potentially expose the swap dealer to cash market basis risk. In fact, these trades can be a significant source of additional proprietary profit or loss for the swap dealer who chooses to speculate on the basis risk. The swap dealer sponsors are classified as "CITs" who engage in market trading associated with Commodity Index Funds. Because Roll trading of futures is consequential to the institutional investor principals, rather than the swap dealer agents, the programmatically required trading volume and direction of CITs during the roll is largely done in a *price insensitive manner* (as long as the swap dealer facilitates the trading in order that it directly mimics the specific commodities index).<sup>27</sup>

Moreover, there is a substantial profit opportunity available to a CIT swap dealer by closely managing its hedge portfolio with respect to the shape of the forward curve. The standard total return swap terms stipulate that the investor must pay (or receive) the cost (yield) of the putative Roll of a number of futures contracts equivalent to the notional value of their investment during a certain pre-defined period of time. So, by holding physical inventory rather than futures contracts in a contango market, not only does the CIT swap dealer

<sup>26</sup> Offsetting swaps are a relatively minor part of the hedging books of most sponsors. See CFTC's *Index Investment Data Reports*, available at <http://www.cftc.gov/MarketReports/IndexInvestmentData/index.htm>

<sup>27</sup> E.g. The GSCI mandates a 5-day period for the Roll to take place each month. On each day, 20% of contracts are assumed to be rolled at the daily closing price. As long as the swap dealer is rolling 20% of contracts per day at or around the daily closing price, he will track the index closely. To the extent he is able to roll at a better price, he retains 100% of the profits generated. Traders have also pointed out that under this arrangement, swap dealers could profit by "banging the close". This practice (technically illegal, though never prosecuted in commodity futures markets) involves placing a large order for the longer-dated contracts right before market close, thus pushing up the price at which the index level is calculated, and creating a wider profit margin for the swap dealer.

sponsor receive the hypothetical cost of the Roll from the investor, but it also captures the corresponding appreciation in the price of its owned physical assets.<sup>28</sup> Thus, by *holding physical commodity inventories directly*, rather than futures contracts that represent physical inventories, a swap dealer receives a paper profit roughly equal to the spread between the two contracts involved in the Roll, less the cost of carry (the investor pays the cost of the “Roll that didn’t happen,” while the dealer receives the value of the appreciation of his physical holdings). In recent years, author calculations show that this strategy would have provided annual equity-like returns on the portion of the portfolio hedged with physicals.<sup>29</sup> It is worth emphasizing that this profit accrues directly to the CIT swap dealer sponsor, and *critically not to the institutional investor*. Indeed, it represents *a direct transfer of wealth* from the institutional investor principal to the swap dealer agent.

Finally, the CIT swap dealer can also position a spread trade ahead of the Roll, benefiting from the market price movements occasioned by the force of the Roll (in which shorter-dated futures are sold and longer-dated futures are bought, in substance for the account of the investor). Other traders can do the same, but in a Roll Period the CIT sponsor has a *superior market information advantage*, by knowing directly client-specific information (this can be individually, at the aggregate level, or both) about the size of the CIT’s swaps with investors and the specific size of rolled futures positions as well as physical and swap hedge positions. Given the information asymmetry enjoyed by the CIT swap dealer vs. other market participants, their agent knowledge offers a significant information-based profit opportunity. Superficially, one could assume that CIT swap dealers’ hedging for clients are a futile effort since after all the CIT swap dealer is in effect front-running its own necessary trading activity; however, *in this case the critical issue is that all the profits and losses of the Roll trades go to the account of the Commodity Index Fund investor, not the CIT swap dealer sponsor*. So the practical effect of institutional investors engaged in commodity indexing strategies is that the CIT swap dealer sponsor, acting as agent, is able to synthetically trade ahead of its counterparty principals on all indexed total return swap products. Therefore, if such market activities affect price spreads in such a way as to *disadvantage* the counterparty (i.e. if spreads are widened by this activity), *then the strategy effectively constitutes another direct transfer of wealth from the index fund investor to the CIT swap dealer*. Given the above, it now becomes all the more important to ascertain precisely when spreads are widened during the Roll Cycle. For this reason, the authors of this paper chose to look not just at the 5-day official “Roll” period (from which index fund investor returns are calculated), but also at the 2 days prior to the Roll, when CIT swap dealer sponsors could theoretically “front-run” their counterparties.<sup>30</sup>

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<sup>28</sup> As has been widely publicized, banks have been buying large quantities of storage capacity over the last few years. While some observers have been puzzled by this large investment in the traditionally low return-on-equity storage business, some of the attraction becomes clearer when it is understood in the context of managing the hedge book on a commodity index total return swap. See, e.g. <http://ftalphaville.ft.com/blog/2011/05/24/576501/the-uk-is-concerned-about-banks-that-warehouse-commodities/>

<sup>29</sup> Author calculations (unpublished).

<sup>30</sup> E.g. suppose a CIT opens a large spread position 2 days before the Roll. This adds 5 cents to the spread, so that by the time the 5-day window opens, spreads are 5 cents higher than they would otherwise be. The CIT then rolls the contracts used to hedge his total return swap exposure. This widens the spread a further 5 cents. The investor pays a Roll yield of 10 cents (plus whatever the base level of the spread was), reflecting not only the price impact of the rolled hedge, but also the price impact of the CIT’s anticipatory spread position. The CIT then profits by the 5 cents that were added to the spread when he rolled the hedge

The analytical work described herein was prompted by a number of observations regarding commodities index funds and trading activity of CIT swap dealers:

- An independent, global concern is that synthetic ownership of commodities might be misinterpreted by other market participants as actual ownership. Specifically, if the hedging activity is similar to the hedging activity that a market participant might employ if he or she actually owned physical commodities, the associated price signals given off to the markets could suggest hoarding activity and attendant rising prices.
- CIT swap dealer hedging activity in the market in response to investment inflows and outflows is *price insensitive* since the timing and amounts are compelled by the actions of the investors and the terms of their swaps, rather than any directional view on individual commodities. It has previously been shown that over certain time periods, the cumulative effect of CIT activities is more closely correlated to commodity price movements than is the effect of fundamental supply and demand changes.<sup>31</sup> The logical implication is that price-insensitive CIT swap dealer hedging activity may influence prices *away* from fundamentals-based levels. These findings also suggest that arbitrageur response to restore fundamental equilibrium is either ineffective or that these artificial and momentum-based price movements create costly and risky volatility which affects prices, or both. CIT activity during Roll Periods is also price-insensitive and is very large. This also strongly suggests that Roll Period trading activity might affect prices.
- Research has shown that a trading strategy in which, just ahead of a Roll, a speculator temporarily takes a long position in the spread between current and next succeeding futures contract prices in products that are constituent elements of the GSCI, and then closing the position over the course of the Roll Period, would have had significant and consistent profitability in recent years.<sup>32</sup> Said another way, betting just before each Roll on a more upward sloping price curve for every product in the GSCI, and then closing the position during the roll, would have paid off consistently. Another significant issue is whether market activities by CITs swap dealers and other speculators trading in anticipation of (or in response to) the roll also affect the price of the next succeeding futures contract relative to the current one. If so, this could be the source of the notional profits identified in the respective research. But importantly, it would indicate a

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contracts (minus the cost of unwinding his position). The investor paid an extra 5 cents in roll yield above what he would have had the CIT not placed the anticipatory spread trade, and the CIT profits by 5 cents.

<sup>31</sup> Singleton, K., "Investor Flows and the 2008 Boom/Bust in Oil Prices, July 22, 2011, available at <http://www.stanford.edu/~kenneths/>

<sup>32</sup> Mou, Y., "Limits to Arbitrage and Commodity Index Investment: Front-Running the Goldman Roll", November 19, 2010, available at [http://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=1716841](http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1716841).

systematic change for the commodities futures price curve based on *causes that are not fundamentals-based*.

### **Methodology**

The present study isolates the Roll Period for 6 commodities contained in the GSCI, the most popular index used for commodity index trading.<sup>33,34</sup> The study isolates the contracts actually used in the roll, in contrast to many previous studies on commodity index funds that only studied near-month futures contracts *despite the fact that these contracts are rarely bought or sold by index funds*.<sup>35</sup> It measures the price impact of the roll, measured by the price spread between the contract sold by the CIT and the longer dated contract bought by the CIT. It then compares this against a benchmark of all other 5-day periods outside of the “Goldman Roll” period and critically also against the equivalent “Goldman Roll” period before index investing became popular (pre-2003).<sup>36</sup>

Because an entire “ecosystem” of speculative traders has sprung up around the CITs, the authors also seek to measure the impact of those traders who aim to “front-run” the roll.<sup>37</sup> These traders tend to position themselves in front of the CITs a day or two prior to the roll, going long the spread – *i.e.*, taking a short position in the near month contract and a long position in the longer-dated contract (seeking to profit from the widening of this spread that they believe the programmed and price insensitive index fund roll will cause),<sup>38</sup> and then closing out any remaining positions over the course of the Roll Period. To measure this, the authors look at the change in spread during the two days prior to the roll, and compare it with the change in spread during the two days following the roll. We interpret the widening of the spread prior to the Roll to indicate the presence of front-running as traders position themselves, and a narrowing of the spread following the roll to indicate the presence of front-running speculative traders closing out long spread positions which have not yet been closed out during the Roll. This trading pattern would be logical for a trader who is disinterested in fundamental causes of a price curve spread, but is simply seeking to profit from the non-fundamental price effects of the roll. Importantly, this activity is not designed to arbitrage out price moves that are not based on fundamentals. The activities of both the CITs hedging activities and the speculative front-running trader activity clearly disregard fundamentals.

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<sup>33</sup> Irwin and Sanders, OECD Food, Agriculture and Fisheries Working Paper No. 27, “The Impact of Index and Swap Funds on Commodity Futures Markets,” 2010, *available at* <http://www.oecd.org/dataoecd/16/59/45534528.pdf>.

<sup>34</sup> Standard & Poor’s, S&P GSCI, *available at* [http://www2.standardandpoors.com/spf/pdf/index/SP\\_GSCI\\_FAQ\\_Web.pdf](http://www2.standardandpoors.com/spf/pdf/index/SP_GSCI_FAQ_Web.pdf)

<sup>35</sup> Irwin and Sanders, *Op. Cit.*

<sup>36</sup> Since the analysis focuses on the Goldman Roll, the prices analyzed are those for contracts directly affected by the Goldman Roll. Contracts affected by other indices, such as the DJ-UBS index, overlap but are different. An analysis which combines all major indices may provide further insights.

<sup>37</sup> See Mou (2010) *Op. Cit.*, in which a repeated front-running strategy was simulated over an extensive period which produced substantial and consistent simulated profits.

<sup>39</sup> OECD, “Commodity Price Variability: Its Nature and Causes,” March 1993, *available at* [http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=OCDE/GD\(93\)71&docLanguage=En](http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=OCDE/GD(93)71&docLanguage=En)



Distributions of commodity price returns are generally considered non-normal.<sup>39</sup> The authors run a K-S normality test on all relevant data sets, and our results confirm the orthodox view. Consequently, when testing for statistically significant increases in spreads a non-parametric Mann-Whitney U-Test is used. Summary statistics can be found in Appendix A. Authors also use a Hodges-Lehman median estimator to give an estimate of the magnitude of the contango bias where it occurs. This is generally considered superior to a simple comparison of median values, though tables 1-6 (below, pp22-24) also include simple median comparisons.<sup>40</sup>

### ***General Analytical Approach***

The authors' approach has been based on several inquiries:

- We have identified new and substantial market practices engaged in by CIT swap dealers and their correlation with changing market price dynamics to determine if causal relationships between such market practices and changing dynamics might exist.
- We have closely examined market structures to better understand how highly correlated market practices and price level and volatility may be structurally related. In particular, we have focused on specific practices – the rolling of futures contracts by CITs – and their impact on futures markets price curves (which signal increasing or decreasing physical prices) and physical prices.

### ***Futures Markets***

The fundamental purpose of commodities futures markets is to allow businesses that are exposed to future commodities price risks (producers, manufacturers and processors and others) to hedge that risk. A short hedger makes the implicit decision that he or she is at least indifferent between the potential gain from higher prices in the future and the potential loss from lower prices, each compared with the synthetically fixed price established by the futures contract, net of transaction costs. A long hedger's decision involves the opposite logic. To fulfill this purpose, the futures markets must provide predictive prices based on understandable and appropriate factors; in other words, future prices should reflect current, commodity-specific supply and demand conditions, and expectations about future changes to those conditions. This describes the theoretical price discovery function that measures how well the futures contract hedging mechanics are achieving their primary purpose.

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<sup>39</sup> OECD, "Commodity Price Variability: Its Nature and Causes," March 1993, *available at* [http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=OCDE/GD\(93\)71&docLanguage=En](http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=OCDE/GD(93)71&docLanguage=En)

<sup>40</sup> Oja, Hannu (2010). *Multivariate nonparametric methods with R: An approach based on spatial signs and ranks*. Lecture notes in Statistics. **199**. New York: Springer. pp.xiv+232.



Working properly, then, the market should effectively process available information to allow participants to price futures contracts based on analysis of the fundamental elements of price: supply, demand, and costs along the production and supply chain (costs of production, transportation and storage). To the extent that futures market pricing deviates from this process, pricing can appropriately be described as distorted. That is to say, at this point futures prices are no longer logically related to available information concerning fundamentals. Thus, the futures market is not then providing reliable price discovery, a kind of market failure.

Classically, in a properly functioning market, market participants with adequate information should be able to eliminate pricing distortions through arbitrage. Arbitrageurs trade so as to force prices back to levels suggested only by information based on current and future fundamentals. However, in reality, there are limits to their ability to act.

- First, price distortions may be so large and frequent that arbitrageurs do not have the capital necessary to sustain arbitraging activity in order to eliminate price distortions. For example, a force that significantly distorts the market may recur often enough so that the arbitrageurs experience intolerable short-term losses or margin calls that reduce cash to levels that pose liquidity risks to their operations.
- Second, the consequences of distorting forces constitute information that must be processed together with *other information*, such as views of perceived fundamentals. Persistent pricing that is not supported by available information suggests to a trader with a different futures price view that his or her information may be inadequate or misleading (since it seems that others in the market are willing to continuously engage in trading destined—according to the original trader’s view—to produce losses). Thus, the trader comes to believe that others with apparently different views must be behaving logically based on different, and likely better, information. This can lead to ongoing price distortions if the persistent trading activity is random (noise trading) or motivated by forces other than profits and losses (e.g. price-insensitive CIT market activity). Other non-rational phenomena like “herding” have been extensively explored in the behavioral finance literature.<sup>41</sup>

Distortions that are not easily susceptible to correction by arbitrage are obvious points of interest to researchers in determining whether a market is functioning properly. CIT activity and the activity of speculative market participants trading ahead of this activity, which is large, recurrent, and motivated primarily by investment mandate, is precisely the type of trading which could minimize the effectiveness of arbitrage forces that are supposed to act to restore the relationship of futures pricing to supply and demand-based fundamentals.<sup>42</sup> Further, CITs can hedge with physicals and swaps as well as futures. Thus, the precise size of the roll is an unknown quantity to all speculators without direct client

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<sup>41</sup> See Shefrin, H, *Beyond Greed and Fear: Finance and the Psychology of Investing*, Oxford (2000) for a good synopsis of the classic behavioral finance theory.

<sup>42</sup> See Frenk, D. and Masters, M. *Anthropic Finance: How Markets Function* (2010)

specific knowledge, which clearly obscures the market source of these price movements. So, arbitrageurs may not be able to perform efficiently because of the size of the activity, the unpredictability of the tactics employed around the roll by swap dealers, and also the difficulty of discerning between the roll effect and fundamentals-based price moves.<sup>43</sup> A thorough analysis of this activity and its relationship to high price volatility and levels by appropriate regulators would likely be very helpful in allowing a better understanding of the full scope of these trading activities, which are propagated before, during, and after Roll Periods.

## ANALYSIS

### *Hypothesis*

The broad hypothesis tested is that, during the Roll Cycle (described below), the activities of CITs and other speculative traders, over and above fundamental considerations, induce contango price curves in traded commodities.<sup>44</sup> This result would be expected because of several factors:

- The volume of trading during the Roll Cycle;
- The fact that CITs trade during the Roll Cycle to fulfill structural requirements rather than to profit based on price fundamentals; and
- The systematic short trades by CITs for the futures contracts that they hold and are expiring and the systematic long trades for the next-maturing futures contracts.

If the hypothesis is confirmed, it must be concluded that the Roll Cycle trading activity constitutes a force that biases the relevant commodities futures price curves in the direction of contango.

More specifically, the analysis tests three formal hypotheses:

- 1) The Roll Cycle displays greater contango bias since the rise of index funds in 2004
- 2) The Roll Cycle displays greater contango bias than non-Roll Periods

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<sup>43</sup> Moreover, the trader(s) in charge of the roll at a given CIT swap dealer sponsor have a strong incentive to keep their activities as opaque as possible (within the parameters allowed), so as to avoid being front-run on the large trades they must necessarily execute.

<sup>44</sup> Other studies have examined different trading activities by CITs, specifically the increase in long positions occasioned by cash inflows into and out of commodities index fund investments. While certain studies (*e.g.*, Irwin and Sanders) have been unable to discover futures price consequences, a more recent study (Singleton) examined the cumulative effect of inflows and outflows on futures prices curve. The structure of the Singleton study better reflects the consequences that are suggested by market structures as the result of actual CIT practices. As a result, the findings of the cash-inflow/outflow studies are best viewed as consistent with each other and suggestive of a strong relationship between inflows and outflows and longer-dated futures contracts prices (significantly stronger than fundamentals). These studies are discussed in detail in Appendix A of the Better Markets Position Limits Letter (*supra*, note 4).

- 3) The 2 days immediately prior to the Roll display greater contango bias than the 2 days immediately following the Roll.

The authors find statistical evidence in favor of all three hypotheses, indicating that CIT activity and related speculative activity is likely to cause distortions in the price curves of traded commodities.

Importantly, unless the market efficiently recognizes that the resulting contango bias is simply a direct function of the Roll Cycle trading activity, this index replication-caused bias will likely be interpreted to mean that market participants now view fundamentals as suggesting higher prices in the future. The greater contango will constitute an artificial price discovery signal that related commodities prices will be increasing. Logically, this can lead to a vicious cycle, in which more financial participants are attracted to invest in commodities markets by the appearance of rising long-term prices, which in turn correspondingly leads to an amplification of *those* price signals. Quite aside from any direct impact of Commodity Index Trader flows on spot prices, therefore, a boom/bust dynamic can theoretically be caused purely by the speculative trading activities inherent in the Roll.

The charts on the next page(s) show the intuitive validity of the approach. They compare the behavior of price spreads for NYMEX WTI Crude Oil futures during 7-day Roll Cycle to other 7-day periods. They show this behavior before the rise of CITs and after the rise of CITs. While there is no discernable difference between the Roll and the non-Roll prior to the CIT era (up to 2004), there is a large difference after this time. Before the appearance of CITs, both Roll and non-Roll alike displayed no bias towards either contango or backwardation. *However, since the rise of CITs, contango events are both more frequent and of greater average magnitude during the Roll, while backwardation events are more frequent and of greater average magnitude during the non-Roll.* The charts show average and count, time series, and density function analysis for NYMEX WTI Crude Oil futures.<sup>45</sup>

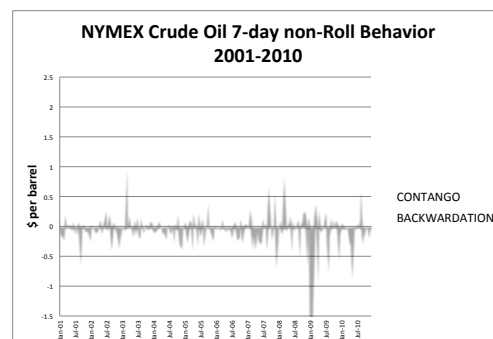
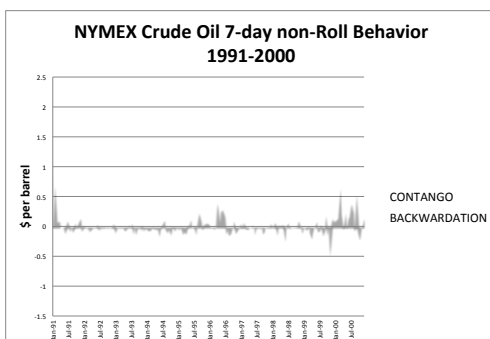
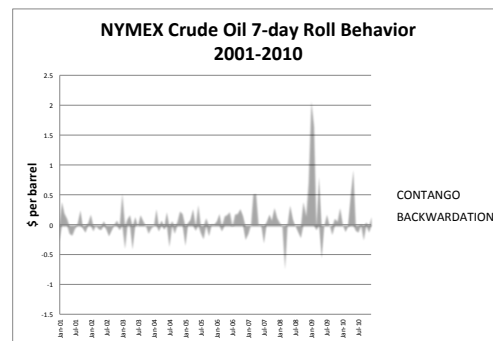
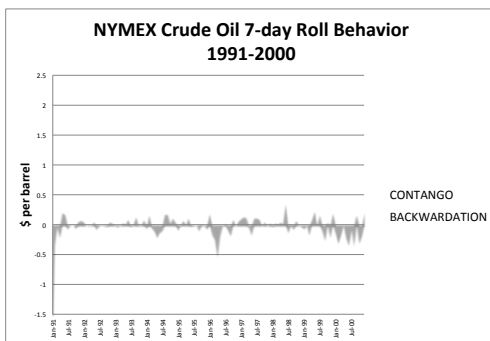
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<sup>45</sup> Density function is calculated as frequency ratio x average magnitude x 10. E.g. in the pre-CIT period (1996-2003), the roll displayed contango effects 40 times out of 84 observations. The average contango magnitude was \$0.12. So, the density function is  $40/84 \times 0.12 \times 10 = 5.71$ .

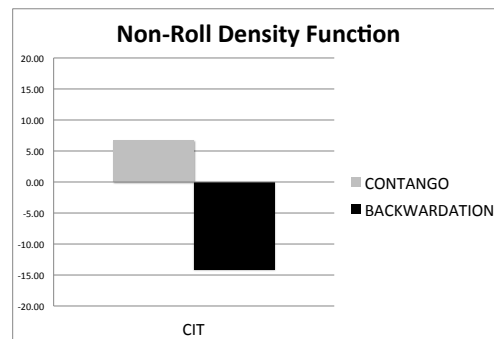
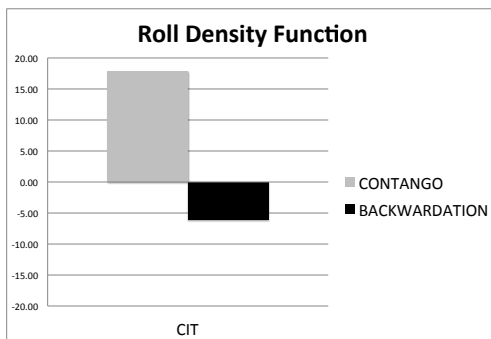
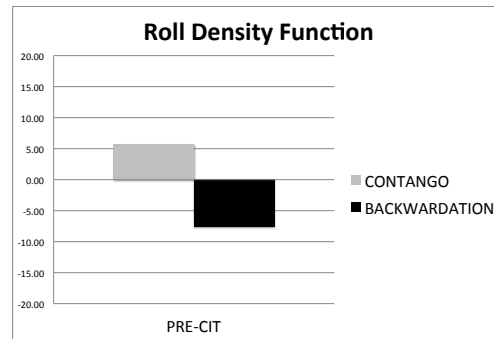
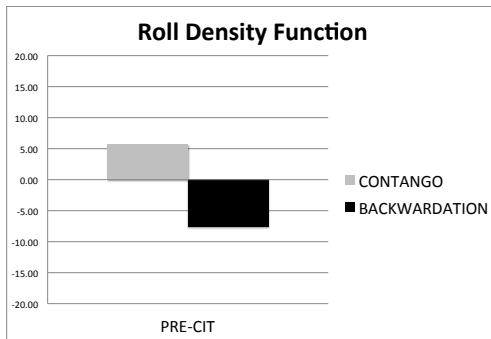
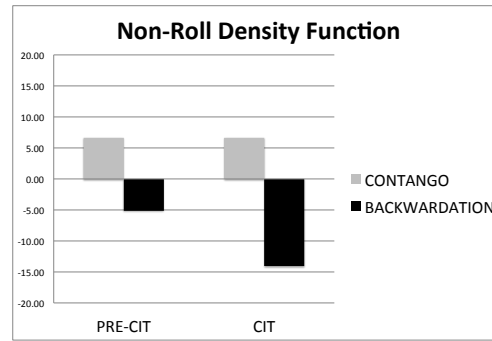
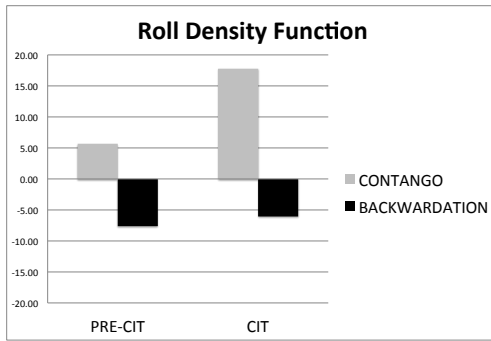
**Summary Tables: 1) Average And Count 2) Time Series 3) Density Function**

		Roll	
		CONTANGO	BACKWARDATION
Jan 1996 - Jan 2003	AVERAGE	0.12	-0.14
	COUNT	40	44
Jan 2004 - Jan 2011	AVERAGE	0.27	-0.18
	COUNT	55	28

		Non-Roll	
		CONTANGO	BACKWARDATION
Jan 1996 - Jan 2003	AVERAGE	0.13	-0.11
	COUNT	65	65
Jan 2004 - Jan 2011	AVERAGE	0.16	-0.26
	COUNT	63	75



The density function is a measure of the typical profile of a Roll or non-Roll event. It is a scaled measure (see note 44 *supra*). Therefore, it allows for an apples-to-apples comparison of different time periods. As is clear from the charts below (for NYMEX WTI Crude Oil), whereas the roll and non-roll were almost indiscernible prior to the rise of the CITs, they have subsequently displayed radically different price behavior. Also apparent from the charts is the fact that the magnitude of the backwardation bias in the non-Roll Period (since the CITs appeared) is insufficient to offset the contango bias in the Roll Period.



As is clear from the above presentations of the NYMEX WTI Crude Oil data, the market has changed significantly since the appearance of CITs. The remainder of the analysis derives summary statistics for the other commodities surveyed and uses the Mann-Whitney U-Test

and Hodges-Lehmann Estimator to give an estimate of the magnitude and statistical significance of the CIT Roll effect. Histograms of the NYMEX WTI Crude Oil data are also available in Appendix B at the end of this paper.

### ***Structure of Analysis***

The analysis examines each of the commodities futures markets included in the GSCI over a period from January 1983 to June 2011.<sup>46</sup> Trading months are divided into four periods:

- The Roll Cycle is defined to include three periods:
  - The “Roll,” or the five trading day period in which CITs trading with respect to the GSCI must roll out of maturing futures contracts and into longer dated contracts;
  - The “Pre-Roll,” or the two trading days immediately preceding the Roll in each trading month; and
  - The “Post-Roll,” or the two-trading days immediately following the Roll each trading month.
- The “5-Day Control Period” is defined as every other trading day in every trading month apart from the Roll, and is sliced into 5-day units for comparison with the Roll. The “7-Day Control Period” is defined as every other trading day in every trading month apart from the Roll and the Pre-Roll, and is sliced into 7-day units for comparison with the Roll-and-Pre-Roll combined.

The analysis examines five “Measured Periods” for each trading month: the Roll Cycle as a whole; each of the components of the Roll Cycle, the Pre-Roll, the Roll, and the Post-Roll; the 5-Day Control Period, and the 7-Day Control Period.

Bias toward contango or backwardation is measured by the change in the difference between the daily settlement prices for the contract sold during the CIT roll and that for the contract bought during the CIT roll.<sup>47</sup> During each of the Measured Periods, if the difference in prices reflects a relative increase in the longer-dated contract price, a bias toward contango is displayed. And if the difference in prices reflects a relative decrease in the longer-dated contract price, a bias toward backwardation is displayed. Bias toward contango and backwardation does not mean that the price curves displayed those slopes, nor does it necessarily suggest that prices were at any particular absolute level or were more or less volatile. As discussed elsewhere, over the entire period, price curves were persistently in contango and prices were on average more volatile and higher in level, each

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<sup>46</sup> In the case of Heating Oil, data was only available from 1986, when NYMEX began trading the contract.

<sup>47</sup> See Stoll and Whaley (2010) for a breakdown of which contracts are involved in each roll. Price data is taken from Bloomberg.



compared with historical norms.<sup>48</sup> The analysis presented below measures whether the forces biasing the market toward contango were in fact concentrated in the Roll Periods.

The analysis examines each futures market for the commodities that are included in the GSCI. These commodities are set forth below, together with the target weighting to be used by GSCI index sponsors as of January 2011.<sup>49</sup>

	<b>Jan 2011 % Weighting</b>
<b>Wheat (CBOT)</b>	<b>3.00%</b>
<b>Wheat (KBOT)</b>	<b>0.69%</b>
<b>Cocoa</b>	<b>0.39%</b>
<b>Coffee</b>	<b>0.76%</b>
<b>Corn</b>	<b>3.37%</b>
<b>Cotton</b>	<b>1.24%</b>
<b>Soybeans</b>	<b>2.36%</b>
<b>Sugar</b>	<b>2.25%</b>
<b>Feeder Cattle</b>	<b>0.44%</b>
<b>Live Cattle</b>	<b>2.59%</b>
<b>Lean Hogs</b>	<b>1.59%</b>
<b>Natural Gas</b>	<b>4.20%</b>
<b>Brent Crude Oil</b>	<b>15.22%</b>
<b>Gasoil</b>	<b>6.30%</b>
<b>Heating Oil</b>	<b>4.66%</b>
<b>RBOB</b>	<b>4.67%</b>
<b>WTI Crude Oil</b>	<b>34.71%</b>
<b>Copper</b>	<b>3.66%</b>
<b>Aluminum</b>	<b>2.70%</b>
<b>Nickel</b>	<b>0.82%</b>
<b>Zinc</b>	<b>0.72%</b>
<b>Lead</b>	<b>0.51%</b>
<b>Gold</b>	<b>2.80%</b>
<b>Silver</b>	<b>0.36%</b>

<sup>48</sup> Better Markets, "Position Limits Comment Letter," (supra, note 4)

<sup>49</sup> Standard & Poor's, "S&P GSCI Methodology," March 2011, available at [http://www.seemore-indices.com/assets/files/commodities/pdf/Methodology\\_SP\\_GSCI\\_Web.pdf](http://www.seemore-indices.com/assets/files/commodities/pdf/Methodology_SP_GSCI_Web.pdf).

During each of the measured Periods, the relative change in the price curve is assessed and bias toward contango or backwardation is measured. Comparisons are then made between Roll and non-Roll, Pre-Roll and Post-Roll, etc. A detailed description of the methodologies employed is set forth in Appendix A.

## RESULTS

### *General Results*

The analysis of the Control Periods for each of the commodities futures markets analyzed shows that during non-Roll Periods, there is a mild bias toward backwardation in Crude Oil and Corn, no discernable bias in Heating Oil, and a mild contango bias in Wheat. The following table summarizes these results:

**Table 1 - Control Period results**

Commodity	5-day Mean	5-day Median	7-day Mean	7-day Median
Crude Oil	0.00	0.02	-0.10	-0.02
Heating Oil	-0.01	0.04	-0.04	0.03
Wheat	0.12	0.00	0.41	0.00
Corn	-0.02	0.00	0.00	-0.17

*In contrast, the Roll Cycle displays a persistent bias toward contango for all four commodities. The strength of this relationship is extraordinary and is strongly suggestive of causation. The following table summarizes these results.*

**Table 2 - Roll Period results**

Commodity	5-day Roll Mean	5-Day Roll Median	7-day Roll Mean	7-Day Roll Median
Crude Oil	0.05	0.1	0.13	0.07
Heating Oil	0.06	0.06	0.11	0.07
Wheat	0.33	0.5	0.47	0.5
Corn	0.25	0.25	0.33	0.25

*Remarkably, there is not one case in which the Control Period displays more contango (/less backwardation) bias than the Roll Period. The table below summarizes the magnitude of this overall bias (bias during Roll minus bias during Control):*

**Table 3 – Differential Between Roll Period results and Control Period results**

Commodity	5-day Mean	5-Day Median	7-day Mean	7-Day Median
Crude Oil	0.05	0.08	0.23	0.09
Heating Oil	0.07	0.02	0.15	0.04
Wheat	0.21	0.50	0.06	0.50
Corn	0.27	0.25	0.33	0.42

Authors used a Mann-Whitney U-Test to measure the statistical significance of our findings. The results are summarized below. As expected, the results were strongest for Crude Oil and Wheat, and weaker for Heating Oil and Corn:

**Table 4 – Mann-Whitney U-Test and Hodges-Lehmann Statistics**

	5-Day			7-Day		
	p-value	Median Diff	H-L	p-value	Median Diff	H-L
<b>Crude Oil</b>	0.0445**	0.04	0.06	0.00226***	0.09	0.1
<b>Heating Oil</b>	0.57345	0.02	0.04	0.14655	0.04	0.1
<b>Wheat</b>	0.35177	0.5	0.25	0.03627*	0.5	0.5
<b>Corn</b>	0.13343	0.25	0.25	0.12667	0.25	0.25

### ***Pre-Roll vs. Post-Roll***

An examination of the components of the Roll Cycle provides a further and important insight. The trading activity in each of the components of the Roll Cycle is different. By looking at the Pre-Roll, Roll, and Post-Roll separately, information relating to the bias toward contango and also the specific trading activity can be discovered.

During the Pre-Roll, non-CIT traders are preparing to take advantage of the high-volume, price-insensitive, and predictable trading during the Roll. They seek to position themselves to profit from the CITs going short the front month contract and long the next nearby contract in size.

During the Post-Roll, the trading markets experience echo effects from the Roll. Non-CIT traders inevitably will have overshoot or undershot the actual events of the Roll in their preparation during the Pre-Roll.

The following table sets forth the results related to the Pre-Roll and the Post-Roll for each of the futures markets analyzed.

**Table 5 Pre-Roll vs. Post-Roll**

	Pre vs. Post		
	p-value	Median Diff	H-L
<b>Crude Oil</b>	0.0845*	0.02	0.04
<b>Heating Oil</b>	0.10328	0.03	0.08
<b>Wheat</b>	0.0071***	0.5	0.5
<b>Corn</b>	0.00734***	0.25	0.25

*It is remarkable that in every case, price spreads display the exact pattern predicted by the model in which traders position themselves ahead of the roll and thereby generate a contango bias. In Heating Oil, the bias was marginally too small to meet the standards for statistical significance, as measured by the Mann-Whitney U-Test. In all other cases, the bias was statistically significant.*

### ***Historical Comparisons***

Others who have looked at the Roll Cycle have noted that the appearance of systematic price dislocations during this time period coincided with the rise of Commodity Index Trading. We therefore compared the Roll Cycle in the period 2004 onwards against a historical control period beginning when NYMEX WTI Crude Oil futures began trading in 1983 (or the earliest available date for commodities that started trading later, such as Natural Gas), and ending in 2002.<sup>50</sup> The results were broadly consistent with Mou (2010) in that the bias grew rapidly from 2004 onwards, with Crude Oil displaying the most striking increase.

### ***Storability vs. Non-Storability***

Several observers of commodity markets in 2007-8 noticed that non-storable commodities like livestock and natural gas did not experience price bubbles of the same magnitude as storable commodities like energy and grains.<sup>51</sup> Consequently, the authors extended their analysis to Live Cattle and Natural Gas to see if it was also the case that the Roll effects described above were absent from those commodities. The theoretical framework outlined above implies that if the Roll has an effect on prices, it takes place in two ways: first, by creating higher prices in the contracts that are rolled into, which do not subsequently depreciate, given limits to arbitrage; second, by sending a signal to producers and consumers to delay production/bring forward consumption due to the cost/benefit implications of contango price curves. So, given that there was no observed price bubble in livestock or natural gas, two possibilities could be suggested. First, there may have been a contango impact of the Roll, but due to the lack of storability of the commodities in question, this may not have led to higher prices as producers could not delay production. Second, the contango impact may have been absent altogether. In this latter scenario, the implication may be that the contango impact of the Roll is dependent on *interactions between* CITs, other speculators, *and* producers and consumers with storage capacity. Or, alternatively, it could simply be the

<sup>50</sup> 2003 was excluded from either sample, for reasons explained on p36 below.

<sup>51</sup> E.g. <http://www.voxeu.org/index.php?q=node/5859>

case that, because Index Trading is relatively small in natural gas and livestock as compared to the other commodities surveyed, there may not have been enough index investing to have a large effect, especially net of arbitrage. Further research is required to tease apart these various possibilities. The results of this initial analysis are summarized below:

**Table 6 Live Cattle and Natural Gas**

	Pre vs. Post			Roll vs. Old		
	p-value	Median Diff	H-L	p-value	Median Diff	H-L
<b>Live Cattle</b>	0.10480	0.17	0.15	0.61883	-0.05	0.05
<b>Natural Gas</b>	0.86142	-0.05	0.01	0.85046	-0.01	-0.01

	5-Day			7-Day		
	p-value	Median Diff	H-L	p-value	Median Diff	H-L
<b>Live Cattle</b>	0.07161*	0.13	0.25	0.46613	0.08	0.1
<b>Natural Gas</b>	0.87220	0	0.01	0.29438	-0.14	-0.09

Live Cattle displayed some evidence of contango bias during the Roll Cycle, with a statistically significant contango bias in the 5-day tests. Natural Gas showed no evidence of bias towards either contango or backwardation. These tests therefore proved inconclusive, though they are *prima facie* consistent with the hypothesis that storable commodities behave differently from non-storable commodities when index trading is present.

### ***Boom and Bust***

During the period of observation, commodities prices rapidly increased and decreased in cycles that were reminiscent of other historical speculative “boom and bust” periods. Authors also investigated whether the contango tendencies described above show up differently during periods of “boom” versus during periods of “bust”. We tested this periodicity by identifying a “boom” period for each commodity, starting from the date on which the lowest price occurred in 2007 until the date on which the highest price occurred in 2008, and also a “bust” period that elapsed from the high price point of 2008 until the point in 2009 at which the downward trajectory of price movements stabilized. Different commodities peaked or troughed at roughly different points, but on the whole the “boom” period tended to run from spring 2007 to spring/summer 2008, and the “bust” period from spring/summer 2008 to spring 2009. Therefore this time frame captures the general contours of the commonly recognized “boom and bust” of 2007-8, and is consistent with other quantitative methods of determining the price cycle. Because of the relatively small number of data points (e.g. there were only 5 rolls for wheat during the boom and 6 during the bust), it is harder to draw firm conclusions. However, there was amplification of the identified contango bias effects for various commodities during either the boom or bust periods. In some cases, the amplification was very large (especially during the bust). Since

research into this amplification effect is ongoing, preliminary results are not presented here. Rather, we briefly describe some observations that we believe shed light on the propensity of some commodities to display amplified contango bias during the Roll when the market as a whole is in either a boom or bust scenario.

The effect of the Roll on the price curve, analyzed above, logically might be related to boom and bust market cycles. The bias toward contango is a signal to market participants that prices are more likely to be higher over time than the price levels that are suggested from all other information sources. The price curve is formed by a collective calculation of probabilities, and the non-fundamental Roll signal forces a discounting of the other supply and demand focused data. It is one among many signals, *but it is definitively one that is unrelated to supply and demand forces*. As such, its essential effect is to obscure the reliability of objective fundamental-type data in the price formation process.

Logically, one would expect to find that the obscuring force is strongest at times when the price curve is closer to theoretically “correct” levels, since it is easier to believe that the fundamental forces are expressed more credibly in the price formation process. But the more distortion of the price curve, the weaker the effect until supply and demand forces are simply overcome by the “Roll force.”

This begs the separate but related question: whether the bias is stronger during a boom or a bust cycle. During a bust cycle, the contango bias is working against a general market sentiment that prices are declining, while during a boom cycle, the bias is harmonious with such sentiment. As a result, the bias toward contango associated with the Roll is more likely to stand out in contrast. Furthermore, the relative lack of liquidity in a bust scenario is also likely to amplify (or fail to cushion) the inefficiencies generated by Roll activity.

Some commodities displayed the opposite effect: an amplified contango bias during the Roll Period in the boom. One explanation may be an increase in momentum-strategy capital, which is typically trend-following in nature, deployed during this time.

The differences associated with the various components of the Roll Cycle and the Boom/Bust cycles for each of the components of the GSCI suggests strongly that the specific futures price effects vary among the individual futures markets based on the characteristics of the respective futures and cash markets. For example, grains can be relatively easily and inexpensively stored and value is not as sensitive to delivery time, compared with energy products. As a result, “cash and carry” tactics in response to price signals (which, according to the present analysis are *misleading* signals) are more easily carried out by swap dealers or others. These distinctions suggest that further study into the behavior of specific market participants around the Roll Periods would yield even better information regarding the mechanics behind the correlation of the Roll Cycle with a contango bias. Such an analysis could feasibly be conducted only by the CFTC, given its reliance on sensitive non-public data, which only the CFTC has access to.

The authors also found some evidence to suggest that the magnitude of the impact of the Roll on the curve is related to the number of contracts held (and therefore rolled) by Index Funds. However, the evidence also suggested that in times of stress, market liquidity conditions are the biggest determinant of the magnitude of the roll impact. *Taken as a whole, these results suggest that even in normal times, markets are unable to arbitrage out the impact of Commodity Index Traders, and that in times of stress this inability becomes even more pronounced.* This implies that Commodity Index Traders create volatility in



commodity price curves, especially when markets are already under stress. This raises the question of why CITs should be tolerated in the commodities futures markets by bona fide hedgers, as there seems to be a direct cost borne by hedgers in exchange for CIT participation.

## ***Commodity-Specific Results***

### *Crude Oil*

All the crude oil tests demonstrated statistical significance. All but one (pre-roll vs. post-roll) were significant at the 99% level. Hodges-Lehman median estimator gives a 10 cent contango bias for the roll-and-pre-roll combined versus 7-day periods during which there was not any index fund rolling taking place. The average (mean) contango widening was \$0.27 per roll-and-pre-roll. On three occasions a single roll-and-pre-roll added more than a dollar of contango, and on one occasion it added more than 2 dollars in a single roll (\$2.08 in Jan 2009), followed by another large contango of \$1.66 in Feb 2009. Interestingly, the neighboring non-roll control periods showed the opposite tendency, generating a large backwardation of -\$2.91 and -\$1.22. Patterns like this one suggest there can be a high degree of volatility that is generated by the back-and-forth process between the roll generating contango and the subsequent arbitrage driving the curve back towards normal backwardation. In combination with the fact that for smaller contango events, the subsequent expected offsetting backwardation event *did not* occur, these results further suggest that significant arbitrage may *only* be triggered when the dislocation caused by the Roll is sufficiently large to allow for relatively low-risk profits, while at other times *market participants deem it too risky to engage in arbitrage strategies*. This has obvious implications for broad commodities market liquidity.

The net impact of roll-and-pre-roll days over the entire sample period was a contango of \$11.20. The net impact of non-roll days over the entire sample period was a backwardation of - \$14.00 (spread between the contract sold during the roll and the longer-dated contract bought during the roll). A typical Roll-and-Re-Roll over the observed period would generate a contango roughly 1.7 times the size of the backwardation generated during a non-Roll 7-day period. This has clear and significant implications with respect to efficient pricing. If one assumes a baseline scenario of no change in the shape of the curve (so that all the contango yield added during the Roll Period is a function of artificial index fund activity rather than supply and demand fundamentals), this implies it takes 11.7 trading days to restore the curve to its “true” underlying shape. Therefore, based on this ratio, one could make the observation that for 18.7 trading days per month (out of a total of around 20) the curve remained distorted, *with arbitrage only just reinstating fundamental value in time for it to be distorted anew by the next index fund roll*.

### *Heating Oil*

The tests displayed the same basic shape of results as crude oil, however in all cases the magnitude of the Mann-Whitney U-Test statistic was insufficient to be statistically different from zero. Interestingly, however, the Hodges-Lehman median estimator gave the same high 10 cent value for contango bias for the roll-and-pre-roll combined versus 7-day periods during which no index fund rolling was taking place. When summed, the net impact of roll-and-pre-roll days over the entire sample period was a contango of \$9.69. The sum of the net impact of non-roll days over the entire sample period was only a backwardation of - \$6.56 (the spread between the contract sold during the roll and the longer-dated contract bought during the roll).

### *Wheat*

Wheat also showed strong results, with significance at the 99% level for the pre-roll vs. post-roll test, and significance at the 95% level for the roll-and- pre-roll combined test. The Hodges-Lehman median estimator gave a median value of 50 cents contango bias for the roll-and-pre-roll combined versus 7-day periods during which no index fund rolling was taking place. The average contango spread widening was \$1.09 per roll-and-pre-roll, though this rose to as high as \$1.50 per roll during the “boom” period of Q2 2006 - Q2 2008. Interestingly, much of the contango effect for wheat occurred during the 2-day pre-Roll Period, suggesting the presence of powerful front-running speculative forces. This was reflected in the fact that the 7-day tests showed significance at the 95% level, while the 5-day tests just yielded results that were not significantly different from zero. Consistent with the thesis that speculative forces play a more prominent role in the wheat market, the ratio between a typical roll contango and a typical non-roll backwardation was 0.61 (compared with 1.7 for crude oil). This implies, assuming a baseline scenario of no change to the curve, that it takes only 4.3 trading days for the Wheat curve to return to a fundamentally derived shape, versus 11.7 days for crude oil. Thus, while in crude oil, the roll could be considered to distort the curve for almost the entire calendar month, in Wheat it distorts the curve for roughly half the month (the 7 trading days of the Roll Cycle, and the 4.3 trading days following it).

### *Corn*

Corn showed weaker results than wheat, showing significance at the 99% level for the pre-roll vs. post-roll test, but narrowly failing to meet the 90% threshold for the 5-day and 7-day tests. However, the Hodges-Lehman median estimator did give a median value of 25 cents of contango bias for the roll-and-pre-Roll Periods combined, versus 7-day periods during which index fund rolling was not taking place.

Interestingly, as in the case of wheat, the contango impact of the roll in corn markets since 2004 showed no statistical difference from the contango impact of the roll prior to 2004. This strongly suggests that for these commodities, speculative arbitrage and/or momentum effects before and after the roll may have a larger effect on the shape of the curve than during the actual 5-day Roll Period itself.

## CONCLUSIONS

***Trading activity during the Roll Cycle causes greater contango in commodities price curves than is justified by supply and demand fundamentals.***

There is a strong bias towards contango during the Roll Cycle. This is particularly pronounced in the crude oil market, and can become amplified during periods of extreme price volatility.

This bias is an artifact of the roll itself. It did not exist prior to the rise of CIT trading, and is not present outside of the roll window. The persistence and strength of bias toward contango during the Roll Cycle, together with the absence of such bias during the Control Period, strongly indicate that it is the trading activity during the Roll Cycle that is causing the contango bias.

***During the observation period, futures price curves have reversed historic relationships so that the curves have remained persistently in contango. A significant reason for this has been the CIT-related trading activity during the Roll Cycle.***

The absence of bias toward contango during the Control Period indicates that forces other than those associated with the Roll Cycle generating contango have been weak. The forces generating contango are largely limited to the Roll Cycle, a period that is defined primarily by speculative trading activity rather than typical supply and demand forces.

***CIT trading activity has impaired the price discovery function of futures markets.***

Price curves in contango signal rising prices and thus *de facto* encourage hoarding activity. Commodities index funds are promoted and structured by swap dealers in order to mimic the conditions associated with the condition of owning and storing physical commodities for institutional investors. Therefore, the signals generated are consistent with the synthetic investment. As a result, behavior by other participants in the market is influenced by these practices as to be consistent with hoarding, which then induces *actual* hoarding behavior by other market participants in order to take advantage of perceived rising prices (as reflected in the forward commodities futures price curve).

In fact, there are no transparent mechanisms for other market participants (especially those not privy to customer-specific Roll requirements) to discern that the bias towards contango is only generated by Roll-related trading activity, rather than some supply and demand force. As a result, the futures markets now provide information that is derived from an artificial financial source. Unfortunately, this false signal becomes misinterpreted by many market participants as a sign that higher prices in the forward shape of the curve are due to commodities fundamentals, rather than from the direct activities of the CIT ecosystem.

While market participants undoubtedly sense that the CITs cause price distortion, many strong advocates of the belief in efficient markets, functioning in the context of widely shared information, continuously opine that prices are *only* affected by fundamentals. This falsehood then serves to *reinforce* the artificial and misleading price signals generated around the Roll Cycle.

***Trading activity by CITs causes prices for physical commodities to be higher during periods in which the misleading price signals of contango are seen as credible.***

Several prior works have described how the price level of the next maturing futures contract are transmitted to related physical prices through contracting practices and physical price indices using that futures price as a reference.<sup>52</sup> So long as the signaled rising price in the futures market is seen as credible, these commodities will be priced against the futures reference price (plus basis, which will reflect local delivery-point conditions).

Furthermore, the misleading price signals (again, which really just reflect the synthetic hoarding of physical commodities by institutional investors adhering to the Commodity Index Fund structure) induce a perceived value into the market that encourages more hoarding. In fact, under these conditions, *the price required to induce supplies to meet current demand must be higher than if the misleading price signal did not exist.*

***Trading activity by CITs also causes prices for physical commodities to be higher as a result of increased volatility.***

It is demonstrated that CIT-related trading activity affects futures prices in a persistent manner that is not immediately and fully rectified by arbitrageurs. In this case, the misleading price signals are so strong, and also reinforced by consistent fundamentals-based analysis by market professionals, that the associated price signals also suggest the existence of additional or misunderstood supply and demand information to market participants. This situation is made more acute because the capital required (and attendant liquidity risk) for arbitrageurs to overcome the CIT trading forces is a very high bar, especially during times of market stress.

In fact, CIT-created price volatility makes the affected markets *more* attractive for speculative volatility traders whose strategy focuses on price swings rather than fundamentals. It is also particularly well suited for algorithmic and high frequency speculative trading strategies. Thus the increased participation by more speculators employing such strategies increases the amplitude of price moves, creating a kind of volatility feedback relationship.<sup>53</sup>

As a consequence, the futures markets become less able to function based on fundamentals-based information in a reliable enough manner so that they can achieve maximum practical efficiency and better resource allocation. Prices for affected contracts also vary greatly from levels that would be experienced if information were transparent. These conditions of uncertainty and non-fundamental forces cause prices to vary significantly from a corollary marketplace that does not have these embedded practices.

Moreover, this associated price volatility in effect constitutes a market tax that is borne by hedgers. It is a cost of business, whether expressed in the need for larger sources of liquidity to fund margin or simply the risk of doing business in an environment rendered more uncertain by the opaque impact of non-fundamental forces. As a result, prices

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<sup>52</sup> Position Limits Comment Letter (*see* footnote 4, *supra*); Masters and White, "The Accidental Hunt Brothers," available at [www.accidentalthuntbrothers.com](http://www.accidentalthuntbrothers.com).

<sup>53</sup> When enough traders trade volatility, the very fact of their doing so will tend to increase volatility. *See* De Long, J. Bradford *et al.*, 1990, "Positive Feedback Investment Strategies and Destabilizing Rational Speculation," *Journal of Finance*, American Finance Association, vol. 45(2), pages 379-95, June.

required to induce supply must increase more in a market endemic with CITs, versus a market without them.

***This analysis, viewed in conjunction with Singleton (2011), suggests that increasing volumes rolled during the Roll Period also increase the size of the contango bias, which in turn measurably increases futures prices. The possible interaction of the findings in this analysis combined with the Singleton study warrant further inquiry.***

Singleton (2011)<sup>54</sup> has demonstrated that CIT crude oil trading activity in the form of increased long futures positions in order to hedge risk arising from investment inflows into commodity index funds measured over 13-week periods is strongly correlated to increases in futures contracts prices. He further demonstrated that this correlation is far stronger than the correlation between relevant fundamental factors and such price increases.

These findings are more intriguing when considered in conjunction with the conclusions stated above. Investment inflows affect the size of the Roll on a delayed basis. This is especially true to the extent that the CIT buys the second expiring contract to hedge inflows rather than the contract which expires at the end of the current month, thereby effectively skipping a Roll Cycle rather than hedging for such a brief period. Furthermore, the longer measurement period would also capture building Roll volumes in a directional market during which investment quantities are accreting. Since commodities index funds are almost always long only, this situation may coincide with boom cycles.

All of this could reinforce the authors' conclusion that the Roll Cycle tends to increase price levels and also generate added price volatility. It certainly seems logical to assume that the larger a Roll is (in terms of percentage of total trading or open interest), the greater effect it has on furthering contango. A future research effort which combines the lines of inquiry pursued by Singleton and the present analysis could be greatly illuminating.

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<sup>54</sup> Singleton(2011), see note 20, *supra*.

## APPENDIX A

### Methodology

Data was taken from Bloomberg, except where otherwise noted. All calculations were performed manually in Excel and checked using StatPlus, except for Hodges-Lehmann median estimators, which were simply inspected manually. To identify the Roll Period, an algorithm was developed that calculated the 5<sup>th</sup>-9<sup>th</sup> business day of each month, using a list of non-settlement days (holidays) from each of the exchanges, again taken from Bloomberg. This was checked against the simpler method of simply taking the 5<sup>th</sup> through 9<sup>th</sup> data points for each month of the Bloomberg daily settlement price data.

To identify the Pre-Roll and Post-Roll, an algorithm was developed that calculated the 2<sup>nd</sup>-4<sup>th</sup> business days and 9<sup>th</sup> – 11<sup>th</sup> business days, in similar fashion to the above. This was checked against an analogous simple method to that used to check the Roll Period algorithm.

For the 5-day Control Period, all dates included in the Roll Period were eliminated from the data set, and the remaining dates were arranged into consecutive (non-overlapping) 5-day groups. Similarly for the 7-day Control, all dates included in the Roll Period and Pre-Roll Period were eliminated, and the remaining dates sequenced into 7-day groups. The algorithms were inspected manually.

#### *Robustness*

In drawing historical comparisons, it was not immediately obvious whether to include 2003 as part of the “Index Fund Era” or as part of the “Historical Control”. While there was an appreciable rise in commodity index investment in 2003 versus the other years of the Historical Control, it was not yet close to the elevated levels of 2004 onwards, which we classed as Index Fund Era. Therefore, for our primary analysis we omitted 2003 entirely. Including 2003 in either the Control period or the primary data set did not significantly change the results, though in both cases it tended to slightly weaken them, consistent with



the hypothesis that Index Funds had a small impact in 2003 and a large impact once their presence reached a critical mass in 2004-5

Kolmogorov-Smirnoff tests were applied to all of the data sets to test for normality, with the null hypothesis of normality rejected in all cases. This is consistent with the findings of several other analyses.<sup>55</sup> Consequently, the authors used the non-parametric Mann-Whitney U-Test, which compares distributions non-parametrically, and gives a statistical measure of the degree to which the median price change in the Roll sample differs from the median price change in the Control sample. That test was then supplemented by a Hodges-Lehmann estimator, in order to gauge the size and direction of the difference. Simple median differences of the two samples were also calculated. In general, using the simple median difference did not change the sign, though it generally gave a slightly lower estimate of the magnitude of the difference between Roll and Control. This was supplemented with a simple mean difference, which in almost all cases did not change the sign, and which also tended to give a slightly higher estimate of the magnitude between Roll and Control. We followed other authors in taking the Hodges-Lehmann estimator to be the most reliable indicator of the sign and magnitude of the difference in distribution medians.<sup>56</sup>

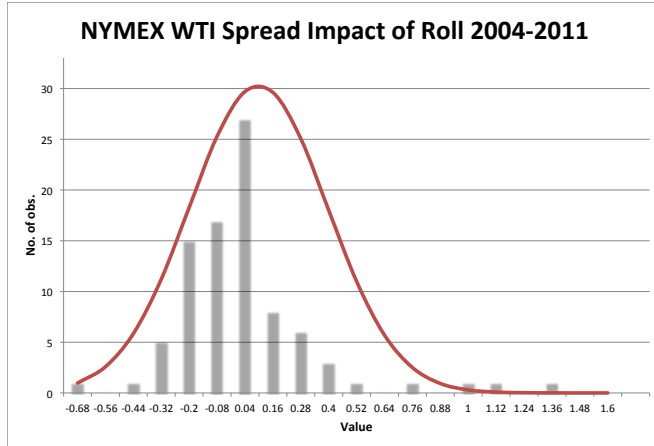
In some commodities, especially grains, a few extreme events dominated the data. In theory, the Mann-Whitney and Hodges-Lehmann non-parametric approach should mitigate this situation. Authors also tested various smoothed data sets, and found that this approach did not change the basic shape of the results, though it strengthened the p-value for both wheat and corn 5-day and 7-day tests, suggesting that occasional extreme contango events outside of the Roll window may distract market observers from the more consistent, but less extreme, contango events that regularly occur during the Roll window. However, since the contango events during the Roll are not arbitrated out, the cumulative effect over time proves to be larger (and potentially far more damaging) than isolated temporary contango effects occurring outside of the Roll (that soon revert to the mean).

We also found some evidence to suggest that the magnitude of the impact of the Roll on the curve is related to the number of contracts held (and therefore rolled) by Index Funds. However, the evidence also suggested that in times of stress, market liquidity conditions are an even bigger determinant of the magnitude of the roll impact. Taken as a whole, these results suggest that even in normal times, markets are unable to arbitrage out the impact of Commodity Index Traders, and moreover, that, in times of stress, this inability becomes even more pronounced. *This implies that Commodity Index Traders create volatility in commodity price curves, especially when markets are already under stress.*

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<sup>55</sup> See note 35 *supra*.

<sup>56</sup> See note 36 *supra*.



**APPENDIX A**  
**Histograms**

