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Price Non-Convergence in Commodities: A Case Study of the Wheat Conundrum

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Price Non-Convergence in Commodities: A Case Study of the Wheat Conundrum*

Sophie van Huellen**

Abstract

The close relationship between commodity future and cash prices is critical for the effectiveness of risk management and the functioning of price discovery. However, in recent years, commodity futures prices, across the board, have appeared increasingly detached from prices on physical markets. This paper argues that while various factors, identified in previous literature, which introduced limits to arbitrage have facilitated non-convergence, the actual extent of non-convergence in these markets is caused by essential differences in the mechanisms of price formation on physical and derivative markets. With reference to the particular case of the CBOT wheat market, the paper shows that the size of the spread between futures and cash prices can be theoretically and empirically linked to the increasing inflow of financial investment into commodity futures markets.

Keywords: commodity futures, commodity price formation, financialisation, non-convergence

JEL classification: D82, D84, G13, G14, Q11, Q14

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1. Introduction

Commodity futures markets traditionally fulfil two key functions: price discovery and risk management. The orderly performance of these functions critically depends on the close relationship between physical and derivative markets. These are tied together by both common fundamentals and the possibility of arbitrage. However, in recent years, commodity futures prices, across the board, have appeared increasingly detached from prices on physical markets. This effect has been especially pronounced for Chicago Board of Trade [CBOT] Soft Red Winter Wheat (wheat hereafter) contracts. Since the March 2008 contract, the futures price systematically failed to converge to U.S. American cash market prices and convergence was not restored until two years later with the introduction of a variable storage rate.

The law of one price implies that only if there are limitations to the mechanics of arbitrage, non-convergence can emerge. The debate surrounding potential reasons for consecutive non-convergence in the particular case of the CBOT wheat market revolves around three interlinked factors that have limited or discouraged arbitrage. Firstly, the insufficient size of the delivery system which has restrained arbitrage. Secondly, a change in delivery instruments and a high financial carry which has discouraged arbitrage traders. Thirdly, a misalignment between the exchange storage premium and storage rates at commercial facilities which has undermined the execution of arbitrage trades.

While these reasons for non-convergence shall not be challenged here, the paper argues that the extent of non-convergence i.e. the size of the wheat basis since mid-2008 cannot be explained by these same factors. It is argued that, while limits to arbitrage have facilitated non-convergence in wheat and other commodity markets, the actual extent of the basis is caused by essential differences in the mechanisms of price formation on physical and derivative markets. These differences have been precipitated by the increasing inflow of financial investment into commodity futures markets.

In orderly markets, futures and cash prices are aligned by common fundamentals even if arbitrage mechanisms are disturbed. If, however, arbitrage is limited and factors driving price dynamics at the futures market differ from factors underlying the physical market, these divergences will be revealed in a large basis which is then carried from one contract into the next. With this contention, the paper contributes to the non-convergence debate regarding CBOT wheat futures as well as to a wider literature on the so-called “financialisation” of commodity markets.

The remaining of the paper is structured as follows: Section 2 proceeds with a review of economic theories on the relationship between cash and futures markets and potential reasons for non-convergence. Section 3 presents a detailed discussion on the causal factors underlying the occurrence and extent of non-convergence in the particular case of the CBOT wheat market. Section 4 examines a number of hypotheses, which have been derived from theoretical considerations and the CBOT wheat case study, by simple regression analysis. Section 5 considers the significance of the evidence and concludes.

2. Cash and Futures Markets: A Delicate Relationship

The close relationship between cash and futures markets is commonly derived from no-arbitrage conditions. While these imply that the future price has to equal the cash price at the future's maturity date, the basis (difference between cash and future price) throughout a future contract's life-cycle can vary. Sub-Section 2.1 will present conventional theories on the factors underlying the market basis. Sub-Section 2.2 proceeds with an alternative view, informed by market microstructure theories, on forces affecting the relationship between the cash and future market price.

2.1. Conventional Theories of Market Basis

Risk management strategies via commodity derivative markets critically depend on a close relationship between cash and futures markets. If prices on both markets deviate, the difference will either be carried by the short or the long hedger, depending on the futures price being below or above the spot price. A close relationship between price dynamics on the physical and the futures market is ensured by two underlying mechanisms: 1) common market fundamentals, which equally drive the price formation mechanism on both markets and 2) arbitrage opportunities, which arise if prices on these two markets deviate substantially. While the mechanics of arbitrage ensure convergence of futures and cash prices at each futures contract's maturity, futures and cash prices can – despite common fundamentals – deviate substantially over a contract's life-cycle. Two main theories have been put forward in order to explain such deviation, known as the market basis. The theory of storage ascribed to Kaldor (1939) and Working (1949) and later Brennan (1958) and the theory of normal backwardation advanced by Keynes (1930) and Hicks (1939) explicitly describe the relationship between physical (cash) and futures markets.

Kaldor (1939), in a discussion on speculative activity on goods markets, was the first to argue that "net carrying costs" are also determined by a reward ("yield of goods") from owning a commodity, which must be subtracted from the "carrying costs proper" i.e. the costs incurred by holding the commodity.[1] These considerations form the foundation of the theory of storage, which is based on the rationale that the futures price must equal the cash price[2] plus a compensation for the "cost of carry". This compensation comprises of the physical storage cost [$\delta_{t,T}$] paid for holding the commodity over the time period t to T and the foregone risk free interest rate over the same period [$r_{f,t}$] less the "convenience yield" [$y_{t,T}$] received because of the flexibility gained from holding inventories, i.e. a utility based reward

[1] Kaldor (1939) derives the "convenience yield" from Keynes' "own-rate of interest", which he compares to the "money-rate of interest". According to Keynes, a commodity can be measured in its commodity standard or its money standard. If changes in these measurements are not equivalent over time, the value of the one standard appreciates or depreciates against the other (Keynes, 1935 (2007)). Kaldor (1939), however, ascribes the yield of a good to the flexibility gain that accrues to the owner of a stock. This led later authors to interpret the "convenience yield" as a utility based reward (cf. Brennan, 1958).

[2] The 'cash price' is often denoted as 'spot price'. However, in the literature, the spot price is commonly approximated with the closest to maturity futures price. Since the following debate emphasises the distinct dynamics in the physical and derivate market, we will retain the term 'cash price' in order to emphasise the distinction.

1958). The link between futures [$F_{t,T}$] and cash [S_t] prices can then be expressed as (Hull 2011):

$$(1) \qquad F_{t,T} = S_t\left(1 + r_f\right)^{T-t} + (\delta_{t,T} - y_{t,T})$$

Equation (1) must always hold under the law of one price.[3] The relationship implies that the convenience yield should be high if the basis is strongly positive and is positively related to the cash price. Furthermore, the net storage cost ($\delta_{t,T} - y_{t,T}$) determines if cash exceed futures prices [$(\delta_{t,T} - y_{t,T}) \ll 0$, strong backwardation and positive basis] or if futures exceed cash prices [$(\delta_{t,T} - y_{t,T}) > 0$, contango and negative basis].[4] While there is no limit to the extent of backwardation, a contango has its maximum in the amount of "carry cost proper" (Lautier, 2005). A negative basis, in theory, cannot exceed $\delta_{t,T}$ (with $y_{t,T} = 0$; physical full carry), while a positive basis depends on the "size" of the convenience yield. Since storage costs, as well as convenience yield, converge towards zero when a futures contract approaches maturity at time T, the no-arbitrage condition implies convergence of cash and futures prices at each contracts' expiration date.

A second approach to commodity futures pricing assumes that prices should be subject to a risk premium, which compensates speculators for taking on commercial traders' risk. This idea is motivated by the theory of normal backwardation advanced by Keynes (1930) and has later been taken up in theories on hedging pressure. Keynes originally argues that speculators, who are taking the counter position to hedgers (assumed by Keynes to be short only, i.e. to be producers who hedge their physical long position), would demand a risk premium, so that the market is in backwardation to favour the long traders. As noted inter alia by Hirshleifer (1990),[5] hedging pressure is not limited to backwardation only, as both producers and consumers can execute hedging demand. While producers go short for hedging, consumer have to go long to protect themselves against price increases. Depending on the relative weight of producers and consumers in the market, futures markets would be in contango (if consumers dominate) or in backwardation (if producers dominate). This reasoning forms the foundation of the hedging pressure hypothesis.

While the theory of storage is not controversial, the theory of hedging pressure has frequently been contested (Fama and French, 1987). This is because the convenience yield can be linked to the concept of utility, which has a well established theoretical foundation in conventional economic theory, while the original argument of Keynes' risk premium is based on the assumption of excess demand, which is not easily made consistent with economic models based on a neoclassical framework. Motivated by the problems associated with incorporating

[3] This can be proved by considering that an investor might hold a commodity over the time period t to $t{+}T$ and shorts a futures contract over the same time period. The stochastic return on physical storage $y_{t,T} + (S_{t+T} - S_t) - \delta_{t,T}$ plus the return on shorting the commodity $F_{t,T} - S_{t+T}$ yields a non-stochastic return, which must equal the risk free rate times the cash outlay $y_{t,T} + F_{t,T} - S_t - \delta_{t,T} = r_{f,T} S_t$.

[4] If the net marginal convenience yield is zero, the spot price equals the discounted futures price $S_t = F_{t,T}/(1 + r_{f,t})$. If the spot price is less than the futures price but greater than the discounted futures price, the market is said to be in weak backwardation.

[5] The fact that hedgers could also be forward buyers was already noted by Kaldor (1939) who incorporated the concept of a risk premium into his work on the convenience yield.

an excess demand framework into conventional theories, various authors have tried to integrate Keynes' original argument into a general equilibrium framework by introducing the assumption of market frictions under which excess demand can affect prices (Hirshleifer, 1988, 1990; Chang, 1985; Bessembinder, 1992).

2.2. Limits to Arbitrage, Financial Demand and the Basis

According to the efficient market hypothesis, first formulated by Fama (1965), a commodity market's basis cannot exceed convenience yield and risk premium (in the non-Keynesian understanding) as expounded above. This assertion is based on certain behavioural assumptions of market participants. In the following, it will be shown that, if these stringent assumptions are eased, the basis can exceed the level suggested by previous theories.

The efficient market hypothesis assumes two types of traders in the market: rational arbitrage traders and informed commercial hedgers (commodity consumers and producers).[6] The demand for futures contracts by commercial traders is determined by their hedging needs, while rational arbitrage traders base their investment decisions on expectations of market fundamentals (demand and supply). If prices rise beyond the upper bound of a range within which informed commercial traders would locate the fundamental value,[7] producers try to sell as many inventories as possible in order to take advantage of the high price. In addition, they lock in temporarily high prices via a short position on the futures market. Meanwhile, consumers deplete their inventories in order to postpone buying in the expectation that prices will decline in the future. Thus the demand for short contracts increases along with supply on the physical market, which exerts downward pressure on futures and spot prices. Further, the market contango is weakened or even turned into a backwardation (futures price decrease relative to the cash price) by the risk premium demanded by rational arbitrage traders, which reflects the higher than expected supply on the physical market. The exact opposite applies if prices are temporarily below the expected fundamental value.

The efficient market hypothesis, and hence the validity of such hypothesised market dynamics, critically depends on the assumption that (1) traders do not systematically trade against market fundamentals, (2) there is good knowledge among all traders about market fundamentals, and (3) there is information symmetry among market participants. Although

[6] Many authors employ the notions of "hedgers" and "speculators". However, we eschew this dichotomy because it is both imprecise and politically loaded. If speculation is understood as a trade based on a guess, then even commercial traders would have to be considered as speculators. Since these commonly have a view on the market and chose their hedging positions accordingly, they place their positions strategically based on a guess on future price developments. Further, if hedging is understood as a trade motivated by the intention of risk reduction, index traders would have to be understood as hedgers as their positions are often motivated by portfolio diversification considerations. Instead of juxtaposing "hedgers" and "speculators," we will employ the distinction between "commercial" and "non-commercial" traders throughout this paper. Commercial traders are those whose core business involves trading and/or processing the physical good, while non-commercial traders are those who do not have a particular interest in the physical commodity for their regular business.

[7] It appears realistic to assume that even among informed traders there is some disagreement about the absolute size of the fundamental value, given that economic data gathered rarely correspond exactly to theoretical economic concepts suggested, and that economic theory often does not agree on one single model so that models employed by economic agents vary. Hence, we follow Kilian and Taylor (2003) in their suggestion that there is a range within which expected fundamental values lie.

so-called noise traders, here understood as uninformed traders, might be present in such a market, their positions under these assumptions would be random and hence they do not exert any systematic price impulse.

The recent arrival of index investors in commodity futures markets violates the first assumption. Since index investments are primarily motivated by the intention of portfolio diversification, they are driven by wealth effects rather than considerations of commodity specific fundamentals (Masters and White, 2008; Mayer, 2009). Further, index traders are passive in the sense that they follow a long-only investment strategy, rolling over their positions at each contract’s maturity into a deferred contract. Since the long-orders of index traders have to be successively filled by higher bid orders, these traders induce a systematic positive price impulse which is unrelated to market fundamentals (Tang and Xiong, 2010; Nissanke, 2011; IATP, 2011).

If we assume perfect knowledge about market fundamentals, then there are always enough rational arbitrage traders who will trade against passive investors and hence prevent prices from moving away from their fundamental value. However, if we ease the latter two assumptions of the efficient market hypothesis so that:

(1) There is uncertainty about market fundamentals;

(2) There is informational asymmetry;

traders will interact strategically and not independently of each other. If there is uncertainty about future market fundamentals and awareness about information asymmetry, rational traders have an incentive to follow large market orders as they must assume that these are placed by market makers (mostly dominant commercial traders) with a substantial information advantage. Under such a scenario, additional demand from index traders is likely to enter the expectation formation process of rational non-commercial traders, as they are unable to distinguish between orders placed by informed commercial traders and passive index traders (Tokic, 2011). With the introduction of electronic trading platforms it is even more difficult to identify the agent behind the trade. This development has further encouraged technical and algorithmic traders in commodity futures markets. Such traders display mostly short-term trend following behaviour. Since, under uncertainty, data on past prices and behavioural patterns of other traders contains valuable information, which is systematically exploited (Adam and Marcet, 2010; 2011), long-only index traders paired with technical traders potentially add and augment price impulses which are unrelated to fundamental factors (De Long, Shleifer, Summers, and Waldmann, 1990; Shleifer and Summers, 1990; Nissanke, 2011).

In reality, the distinction between trader types according to their investment behaviour is not as sharp as suggested. Large investment banks, money managers, and hedge funds are known to run a statistical division, watching past price trends and investment positions, as well as an analyst division, conducting research on market fundamentals (Scott, 2011). At the same some commodity trading advisors (CTAs) and commodity hedge funds are known for solely exploiting familiar price patterns by deterministic trade execution (Worthy, 2011). Moreover, as mentioned by Irwin and Sanders (2011), commercial traders also engage in speculative activities or “strategic hedging”. Further, there is a nascent trend of dominant commercial traders setting up associated hedge funds through which they offer their expertise to clients – often smaller commercial traders – and trade in their own right (Oxfam, 2012). Additionally, big financial institutions are more and more involved in physical commodity markets, in that they control an increasing share of exchange registered warehouses and acquire commodity firms through mergers and acquisitions. In addition, while commercial traders can still be considered homogenous in their trading behaviour, traders under the non-commercial trader category are extremely diversified in the trading motivations, frequencies and strategies.

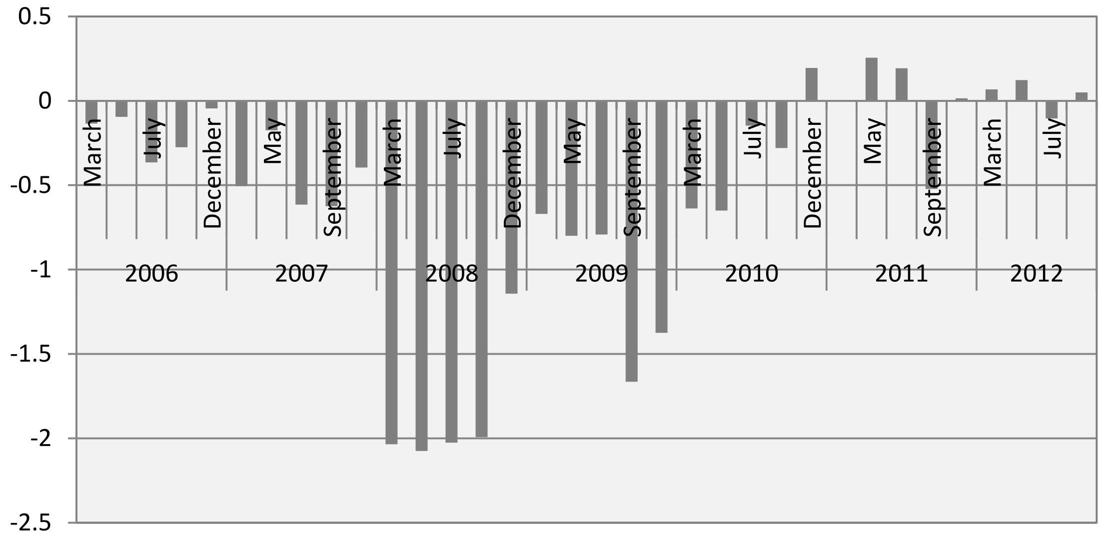
The efficient market hypothesis suggests that the full-information value, i.e. the market clearing price on the futures market under perfect foresight, equals the fundamental value, i.e. the market clearing price in general equilibrium in the spot market. While some non-commercial traders execute trading strategies on the basis of market fundamentals, there is a variety of traders which consider other indicators. These induce price impulses which, depending on their relative market weight, might be dominant on the futures market, but not on the physical market. Considering the differences in trader composition and market structure between physical and derivative markets, the market clearing price of the commodity futures market does not necessarily equal the fundamental value of the commodity underlying the future (O'Hara, 1997, p. 227). Thus, prices might deviate substantially over a contract’s life-cycle; this is reflected in a large and volatile basis. In a market where arbitrage is possible, convergence is nevertheless enforced at each futures contract’s maturity date. If, in contrast, limits to arbitrage exist, the difference in prices on both markets will prevail beyond a contract’s life-cycle and eventually result in an excessive basis even at a contract’s maturity.

The increasing participation of financial investors in commodity derivative markets has potentially caused these differences in price dynamics and has led to the increasing alienation between cash and futures markets. If there are no limits to arbitrage, such a development is not directly observable as the cash and futures prices would be bound by the law of one price and hence price signals would spill over from one market to the other. The extent to which the cash price is affected by speculative demand in the futures market then depends inter alia on the reaction of physical traders to changes in futures prices, the existence of a liquid cash market, and information availability on market fundamentals. However, if arbitrage is limited, the incoherent price dynamics become apparent in the form of a large basis which is carried from one contract to the next.

3. Non-Convergence in the Wheat Market

In reality convergence between futures and spot prices is rarely exact, as arbitrage is not costless. However, historically, large differences between cash and futures prices during a contract’s delivery period have been extremely rare. If they occur, they are one-off events associated with speculation by single actors who tried to corner or squeeze the market Irwin, and Smith, 2011). In this context, the prevailing non-convergence in the Chicago wheat market since March 2008, for 11 consecutive contracts, is puzzling.

Figure 1: CBOT Future and Spot Basis at each Futures Contract's Maturity Day (March 2006 - September 2012 Contract, in USD)



Source: Datastream (author's calculation)

Although convergence was restored after the introduction of a Variable Storage Rate (VSR), various complaints by market participants about inflated storage costs and excessively high wheat cash prices indicate that market order was still not fully achieved (Stebbins 2011).

Various suggestions have been made for the reasons for consecutive non-convergence in the particular case of the CBOT wheat market. Sub-Section 3.1 critically reviews relevant literature. Building on previous arguments, Sub-Section 3.2 presents an interpretation of the literature in the context of market microstructure considerations as discussed in Sub-Section 2.2. Sub-Section 3.3 discusses the effectiveness and consequences of a variable storage rate [VSR], which was introduced by the exchange in order to tackle the problem of non-convergence.

3.1. The Debate surrounding the Wheat Conundrum

In June 2009 the Permanent Subcommittee on Investigations of the United States Senate published a staff report on the linkages between index based investments and the CBOT wheat basis (U.S. Senate, 2009). The report argues that index traders' passive long positions have successively increased futures prices and hence concludes:

> *"…there is significant and persuasive evidence to conclude that […] commodity index traders, in the aggregate, were one of the major causes of "unwarranted changes"—here, increases—in the price of wheat futures contracts relative to the price of wheat in the cash market. The resulting unusual, persistent, and large disparities between wheat futures and cash prices impaired the ability of participants in the grain market to use the futures market to price their crops and hedge their price risks over time, and therefore constituted an undue burden on interstate commerce." (U.S. Senate, 2009)*

Despite this strong claim, the U.S. Senate (2009) investigation was highly contested as it remained purely descriptive, based on diagrammatic presentation and narrative evidence, which made it incredible to many researchers. Further, although it proposes an explanation for the volatile and large basis throughout futures contracts' life-cycles, it lacks an explanation for non-converge at maturity and prolonged arbitrage opportunities.

Shortly after the introduction of the VSR, the CBOT released a paper entitled "Understanding Wheat Futures Convergence," which declared the issue of non-convergence solved (Seamon 2010). The publication argues that, after a continuous decline in the stock-to-use ratio since 2000 to its lowest value in over 40 years, the exceptionally good harvest in 2008/09 resulted in a shortage in storage space and hence increasing costs for wheat storage. This led to low cash prices relative to futures prices in order to compensate for the increasing storage costs (ibid.). The physical storage charge eventually exceeded the premium fixed by the exchange so that the calendar spread, which is bound to not exceed financial full carry, could not fully reflect the costs incurred by storage in the physical market. These costs were then reflected in the non-convergence of futures and cash markets (ibid.). While the first argument, which explains the large basis by high storage costs and a low marginal convenience yield (i.e. a large $\delta_{t,T}$ and close to zero $y_{t,T}$ in equation one), refers to well established theories, the latter argument's theoretical basis remains unclear in that it provides no explanation for persistent arbitrage opportunities.

Wheat stocks in exchange registered warehouses were certainly high during the second hump of the basis from mid-2009 to mid-2010. This was not the case in the beginning of the non-convergence problem. In fact, stocks were extremely low when the basis reached its first maximum in mid-2008 (Fig.2a).

Figure 2a: Basis and Storage Level at CBOT Exchange Registered Warehouses (Monthly, Jan 2008 – Dec 2012)

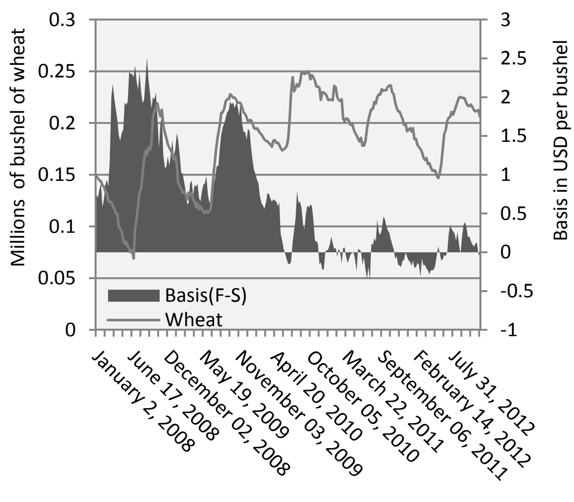
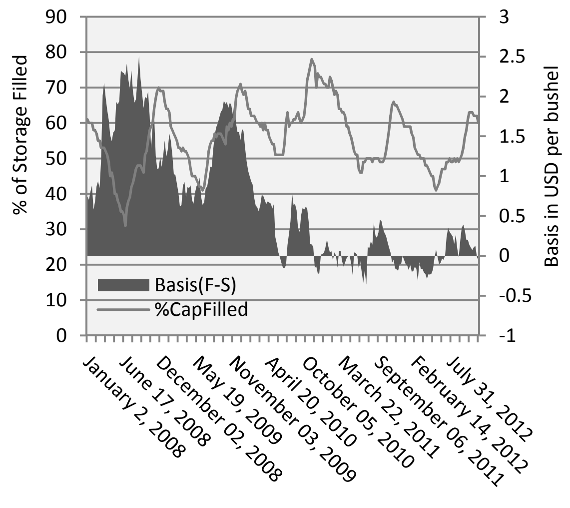


Figure 2b: Basis and Percentage of Storage Filled at CBOT Exchange Registered Warehouses (Monthly, Jan 2008 – Dec 2012)



Source: Datastream & USDA, 2013

However, this might be explained by the time lags with which stocks at exchange registered warehouses reflect new supply, especially in times of previously low inventories. The harvest period for U.S. winter wheat starts in mid-May, which is about the time when the non-convergence problem occurred. Since commercial storage space is filled before stocks in exchange registered warehouses pile up, the excess supply only becomes visible in exchange registered storage facilities in later months. This is a reasonable assumption as exchange inventories commonly reflect the quantity of residual wheat i.e. wheat that is not currently needed for commercial business and hence can be freed for speculative purposes (wheat that is in "speculative storage" rather than in "operational storage" in Kaldor's (1939) words). With commercial storage facilities filling, storage rates were probably rising in March/May 2008 already, which then brought about non-convergence.

It was further argued that issuers of shipping certificates were reluctant to sell those certificates to potential arbitrage traders as the selling would have interfered with their normal merchandise activities (O'Brien, 2010). Every short trader (in the futures market) which seeks to make delivery has to buy a shipping certificate from a regular firm[8] – commonly a large commercial grain merchant – which is eligible to issue such certificates. Hence, unless the short position holder at the exchange is a regular firm they are reliant on the availability of such certificates. Regular firms, however, are not obliged to issue such certificates. Although, according to the CBOT rulebook, shipping certificates allow such firms to issue certificates over more wheat than they actually store in registered warehouses, the factor by which the certificates can exceed the amount stored in registered warehouse is fixed. If they want to issue more certificates, they eventually have to transfer wheat from their own warehouses to the exchange. Further, it has been argued that since storage space at the exchange was already filled with wheat, issuers of shipping certificates were reluctant to take on new wheat arriving due to high opportunity costs incurred by a loss of space that could be used for storing other commodities like soybeans and corn (Garcia, Irwin and Smith 2011).

The first argument might be applicable to the early period of non-convergence when commercial grain traders were still stocking up their previously depleted inventories for regular business. Hence, they might have been reluctant to fill their exchange registered warehouses in order to sell shipping certificates to potential arbitrage traders. The latter hypothesis appears to apply to the second period of non-convergence. However, for the first peak in mid-2008 only 30 per cent of storage capacity at exchange registered warehouses was filled (Fig. 2b). For both claims it remains unclear why the owners of the exchange registered stocks did not execute arbitrage trades to the extent that would have restored convergence.

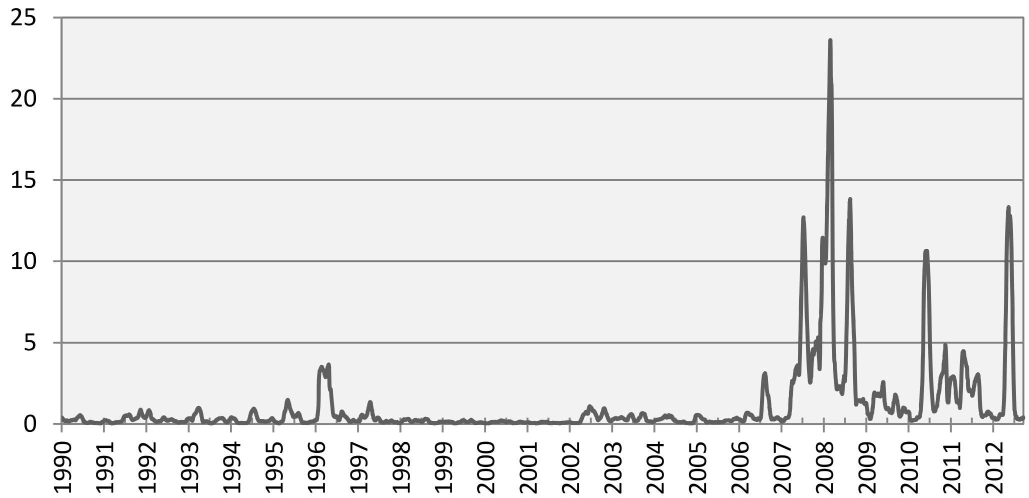
Aulerich, Fishe, and Harris (2011) ascribe the failure of convergence[9] to a change in delivery instruments. Instead of "warehouse receipts," "shipping certificates" were introduced.

[8] Regular firms on the CBOT wheat market are market makers like Andersons, Archer Daniels Midland, Bunge, and Cargill.

[9] The CBOT wheat market was no exception and various other commodity futures markets suffered from consecutive non-convergence. In addition to wheat, Aulerich, Fishe, and Harris (2011) also analysed the CBOT corn and soybean markets, while Kaufman (2011) examined non-convergence in the WTI crude oil market.

Shipping certificates provide the owner with the option to choose if and when to take control of the underlying physical commodity. The owner of the certificates can, instead of executing his right to take physical delivery, sell the certificate into the next futures contract. Since such a shipping certificate can be conceptualised as an "embedded real option," which gains value with an increase in the price volatility of the underlying physical product, owners of the certificate are incentivised to delay load-out when price volatility is high, which might result in convergence failure (ibid.). Indeed, price volatility was, by historical comparison, exceptionally high over the entire non-convergence period. However, price volatility already increased in early 2007 and remained high even after convergence was restored (Fig.3).

Figure 3: Three-Month Daily Centred Moving Variance CBOT Wheat Prices (01/01/1990 – 14/12/2012, in Hundred USD per Bushel)



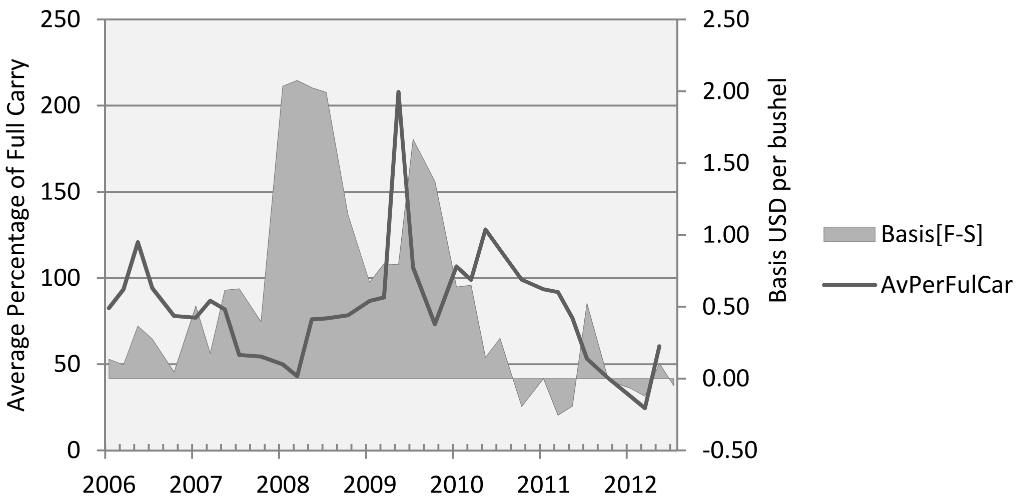
Source: Datastream (author's calculation)

Irwin, et al. (2011) test a related hypothesis. They argue that if the spread between the price of the expiring and the next-to-expire contract is large enough to compensate for the costs of owning the delivery instrument, i.e. the shipping certificate, the owner faces an incentive to postpone load-out. This in turn postpones the purchase of the cash commodity, which holds back convergence mechanisms. Hence, they investigate whether high two-to-one calendar spreads,[10] i.e. a large financial carry, occurred concurrently with non-convergence in recent years. Indeed, the financial carry[11] was exceptionally high before mid-2007 and after mid-2009 (Fig. 4). However, in-between the average percentage of full carry was actually at 50 per cent or below, while consecutive non-convergence occurred.

[10] This is the price spread between first and the second month contract.

[11] The carry usually refers to the "percent of full carry" which is estimated as the percentage of the storage plus interest opportunity costs compensated for by the spread between the nearest to expiration and next nearest to expiration contract price i.e. the return one can earn carrying the physical commodity till the end of the next nearest to expiration contract maturity. This is represented by $Carry_t = \left[\frac{F2_t - F1_t}{C_t^S + I_t}\right] * 100$, with C_t^S being the cost of storage, I_t the foregone interest rate, and $F1_t$ and $F2_t$ the price of the nearest and next-nearest contract to maturity (Irwin, et al., 2011).

Figure 4: Basis and Average Percentage of Full Carry at Each Contract's Maturity



Source: Datastream (author's calculation)

Moreover, Irwin, et al. (2011) were first to explicitly test if the synchronised rolling procedure of index investors has continuously driven up the market carry as was suggested by the U.S. Senate (2009) investigation. Their event study shows a coinciding high carry with the roll-over of index investors. In order to assess the continuity of the impact of index traders on the calendar spread, Granger non-causality tests are employed, which reject the significance of such an impact. Irwin, et al. (2011) conclude that not speculative demand but an increase in the precautionary demand for commodity stocks driven by an increase in uncertainty about market fundamentals were at the root of non-convergence.

While the previously discussed literature suggests cogent arguments for limits to arbitrage, it fails to (formally) explain the extent of non-convergence. Garcia, Irwin, and Smith (2011) fill this gap. They propose a "dynamic rational expectations commodity storage model" in which non-convergence could arise in equilibrium when the market price of physical storage is greater than the cost of holding the delivery instrument, i.e. the premium charge set by the exchange. With the help of some algebraic manipulation, they show that the "wedge," which they define as the difference between market storage costs plus convenience yield and the cost of holding the delivery instrument, drives the basis at maturity (ibid.).

Two independent equations for the cash and the futures markets are assumed in their model. The current cash price is defined as the continuously discounted expected future cash price minus storage costs plus convenience yield, while the futures price is defined as the continuously discounted expected futures price minus the exchange premium. The difference between current cash and futures price (basis) is hence the continuously discounted expected basis plus the "wedge" [$W_T = \delta_T - y(I_T) - \gamma_T$], which is assumed to vary with the level of inventories through the convenience yield and the physical storage costs (as long as the exchange premium remains constant).[12] The authors argue that "a relatively small wedge term in period *t* can have a large effect on the basis if it is expected to persist for an extended period," that is if it enters the expectation on the future basis (ibid.).

However, as will be shown in the following, for Garcia, Irwin, and Smith's (2011) model to be coherent, one has to accept assumptions which violate the no-arbitrage conditions discussed in Sub-Section 2.1. Such violation demands justification, which can be found in market microstructure theory.

3.2. Critical Appraisal of Previous Arguments

Garcia, Irwin, and Smith's (2011) model, and hence their conclusion, is based on the crucial, however, implicit assumption that the cash price is determined independently from the futures price. This assumption enables them to explain the increasing basis in terms of the continuously discounted expected basis. However, recalling equation (1), the theory of storage defines a very precise relationship between cash and futures prices, so that:[13]

$$(2) \qquad S_t = \frac{F_{t,T}}{(1+r_t)^{T-t}} - \delta_{t,T} + y_{t,T}$$

Equation (2) matches Garcia, Irwin, and Smith's (2011) definition of the cash price under the assumption that the expected cash price in time T $[E_t[S_T]]$ equals the price of the futures contract maturing at time T $[F_{t,T}]$. Taking their argument further, at a futures' contract maturity the agent who is long in the market faces two choices, of which the maximum payoff must define the futures price at maturity or else there would be riskless arbitrage opportunities:

$$(3) \qquad F_{T,T} = max \begin{cases} \frac{F_{T,T+1}}{(1+r_t)} - \gamma_{T,T+1} & (i) \\ \frac{F_{T,T+1}}{(1+r_t)} - \delta_{T,T+1} + y_{T,T+1} & (ii) \end{cases}$$

The first strategy implies that the long trader holds the delivery instrument until the next contracts maturity at the premium charge $\gamma_{T,T+1}$ set by the exchange. For the second strategy the trader takes delivery in the physical market and holds the bulk of wheat over one period for future sale at the expected cash price $F_{T,T+1}$ at time period *T*.

If (i) > (ii) i.e. $[\gamma_{T,T+1} < \delta_{T,T+1} + y_{T,T+1}]$ everyone would hold the delivery instrument and postpone load-out, which will then lead to a lack in arbitrage trade. This would result in an increasing demand for delivery instruments, which in turn would put upward pressure on the

[12] The basis is hence defined as: $S_T - F_{T,T} = \left[\frac{E_t[S_{t+1}]}{(1+r_t)} - \delta_t + y(I_t)\right] - \left[\frac{E[F_{T+1,T+1}]}{(1+r_T)} - \gamma_T\right] \Leftrightarrow B_T = \left[\frac{E_t[B_{T+1}]}{(1+r_T)} + W_T\right]$.

[13] This is a simple rearrangement of equation (1) which defines the cash prices as the dependent. Such rearrangement of equation (1) is actually supported by findings which show that in most time periods the futures market is leading the spot price i.e. the futures price serves as a yardstick for what is asked at the cash market (Crain and Lee, 1996; Garbade and Silber, 1983; Hernandez and Torero, 2010).

price [$\gamma_{T,T+1}$] for such instruments. This price, however, is fixed by the exchange and hence cannot vary. This implies for the basis at delivery:

$$(4) \qquad F_{T,T} - S_T = max \begin{cases} -\gamma_{T,T+1} + \delta_{T,T+1} - y_{T,T+1} & (i) \\ 0 & (ii) \end{cases}$$

Like in Garcia, Irwin, and Smith (2011) the equation implies that the degree of non-convergence is related to the difference between the storage exchange premium and storage costs in the physical market. However, previously the size of the basis is further explained by the continuously discounted expected future basis, while in the above specification the basis is determined in a manner that reflects only the cost difference at each and every maturity.

From this, implications for the market's term structure can be derived, including the small changes in the model specification made (cf. Garcia, Irwin, and Smith (2011). Given that the size of the price spread between the contract which is maturing next, and the one which is maturing second next, i.e. the two-to-one term spread [$Z_{2-1} = F_{t,T} - F_{t,t}$], is limited by the financial full carry condition [$F_{t,t} \geq \frac{F_{t,T}}{(1+r_t)^{T-t}} - \gamma_{t,T}$], we can define the excess in the two-to-one spread as [$0 \geq \frac{F_{t,T}}{(1+r_t)^{T-t}} - \gamma_{t,T} - F_{t,t}$], so that:

$$(5) \qquad [Z_{2-1}] = min \begin{cases} 0 & (i) \\ -\gamma_{t,T} + (\delta_{t,T} - y_{t,T}) & (ii) \end{cases}$$

Case (i) is given if:

$F_{t,t} = \frac{F_{t,T}}{(1+r_t)^{T-t}} - \gamma_{t,T}$, which is case (i) in equation (3) under the condition that [$\gamma_{t,T} < \delta_{t,T} - y_{t,T}$].

Case (ii) is given if:

$F_{t,t} = \frac{F_{t,T}}{(1+r_t)^{T-t}} - \delta_{t,T} + y_{t,T}$, which is case (ii) in equation (3) with [$\gamma_{t,T} \geq \delta_{t,T} - y_{t,T}$].

This implies that the market is either in full carry with non-convergence, as in case (i) in equations (3-5), or below full carry with convergence, as in case (ii) in equations (3-5). This provides an explanation for the high carry which was present during the second half of the non-convergence period.

However, the difference in storage costs alone can hardly account for the degree of non-convergence. Until July 2008 the storage premium at the exchange was set at 0.150 cents per bushel per day and was raised to 0.165 thereafter which aggregates to 4.5 and 4.95 cents per bushel per month respectively. In mid-2008 the CBOT conducted a survey of 47 firms which found an average physical storage rate of 7.1 cent per bushel per month (Irwin et al. 2011). The table below shows the days between two consecutive contracts' maturities, the physical storage rate and the exchange premium, both in USD cents per day per bushel. It further presents an estimate of the storage costs and the exchange premium costs incurred by holding the physical product and delivery instrument respectively, from one futures contract maturity to the next futures contract delivery, plus interest (3-month LIBOR rate plus 200 basis The difference presents the size of Garcia, Irwin, and Smith's (2011) "wedge" (assuming that convenience yield is negligible in a regime of abundant storage) compared to the size of the basis which was 50 times as large.

Table 1: Size of the "Wedge" for 2008 Wheat Contracts

	May-July 2008	July-Sep 2008	Sep-Dec 2008
Days between Maturities	61	60	91
Physical Storage (cents/day/bushel)	0.237	0.237	0.237
Exchange Premium (cents/day/bushel)	0.150	0.165	0.165
Physical Storage costs (cents/bushel)	15.572	15.299	23.092
Exchange Premium costs (cents/bushel)	9.870	10.667	16.010
Difference (cents/bushel)	5.702	4.633	6.993
Basis at maturity (cents/bushel)	202.500	199.300	144.300

Source: Author's calculation

Recalling equation (1), the basis is constrained by physical full carry as long as arbitrage is functioning (and if we ignore the proposition of a risk premium or hedging pressure for now). However, the basis size appears to have exceeded physical storage costs dramatically, which supports the suggestion that limits to arbitrage were present. Under a "normal" market regime we would still expect prices to be aligned by common fundamentals. However, the extent of non-convergence cannot be related to differences in market fundamentals alone, i.e. a difference in storage cost on both markets.

This is precisely the reason why Garcia, Irwin and Smith (2011) have to assume that the expected future cash price at time T is independent from the price of the futures contract maturing at time T. With this implicit assumption they are able to relate the basis size to the continuously discounted difference in the expected prices on both markets plus the difference in the storage costs. Equation (4) then reads as following:

$$(6) \qquad F_{T,T} - S_T = max\begin{cases} \frac{E[F_{T+1}]-E_T[S_{T+1}]}{(1+r_T)} - \gamma_{T,T+1} + \delta_{T,T+1} - y_{T,T+1} & (i) \\ 0 & (ii) \end{cases}$$

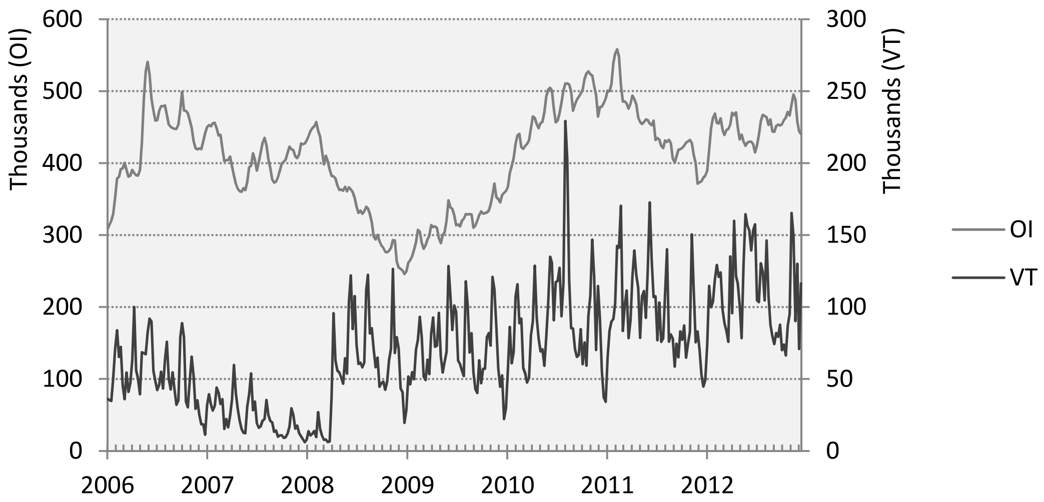
With this model they can conclude that the basis at a futures contract's maturity can be greater than the "wedge".

All these deliberation culminate in the conclusion that for effective arbitrage, and hence convergence, the condition $\gamma_{t,T} \geq \delta_{t,T} - y_{t,T}$ must hold. However, if we do not assume that factors which are driving prices on futures and cash markets are distinct, we cannot attribute the extent of non-convergence to anything but the extent of the deviation between physical storage costs less convenience yield and the exchange premium. Such an assumption is, however, a break with the efficient market hypothesis, which implies that factors driving price discovery on both futures and the underlying cash market are alike at all times.

Such a deviation in the factors which drive the price formation process in the physical and derivative markets can be ascribed to heterogeneity in traders and their interaction. This market microstructure approach was suggested by advocates of the hypothesis that the increasing participation of a diverse set of financial investors in commodity derivative markets has changed the price discovery mechanisms in these markets, which results in an increasing alienation between futures prices and their fundamental value (Nissanke, 2012; UNCTAD, 2008; Mayer, 2009; 2012). If this conjecture is true, the implicit assumption made by Garcia, Irwin, and Smith (2011) might be justified, as shall be discussed in the following.

Indeed, non-convergence in the CBOT wheat market occurred concurrently with a rapid change in trading patterns from long-term (commercial hedge and index positions) to short-term investment (intra-day and high frequency trades). This is reflected in declining open interest, while average daily trading volume doubled during the period of non-convergence (Fig. 5).

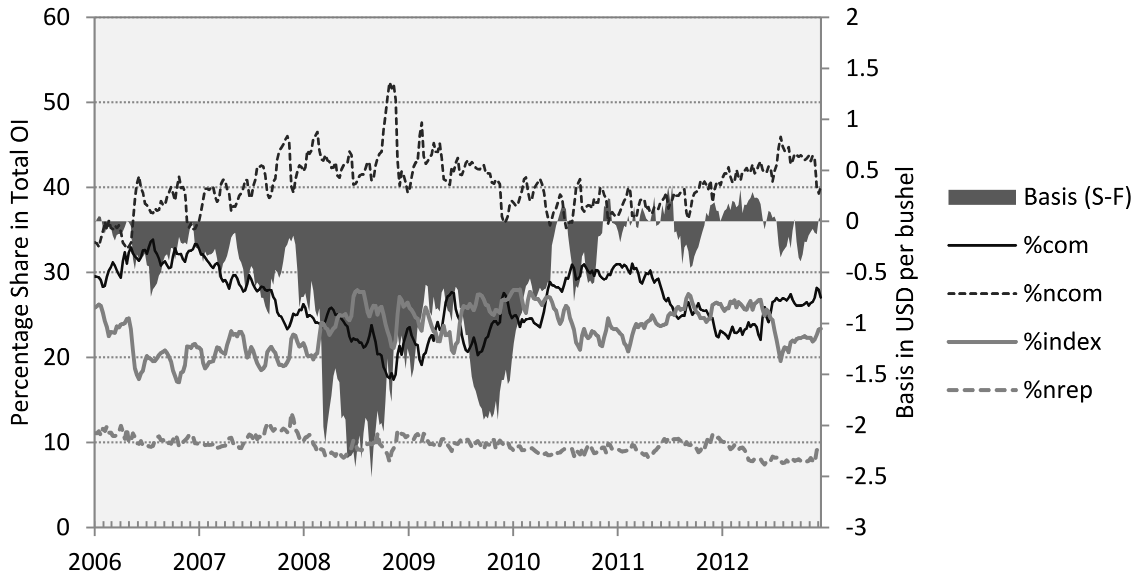
Figure 5: Open Interest and Liquidity (Weekly, Jan 2006 – Dec 2012, in thousands of contracts traded)



Source: Datastream

Further, not only trading strategies but also the composition of traders active in the market changed, in that the percentage share of non-commercial traders (here all traders but commercials) in total open interest increased up to over 80 per cent of open interest when non-convergence was at its height (Fig. 6). This change in traders' relative market weights is probably partly due to commercial traders, who closed out their long hedging positions when margin calls become too costly and hedging became increasingly inefficient.

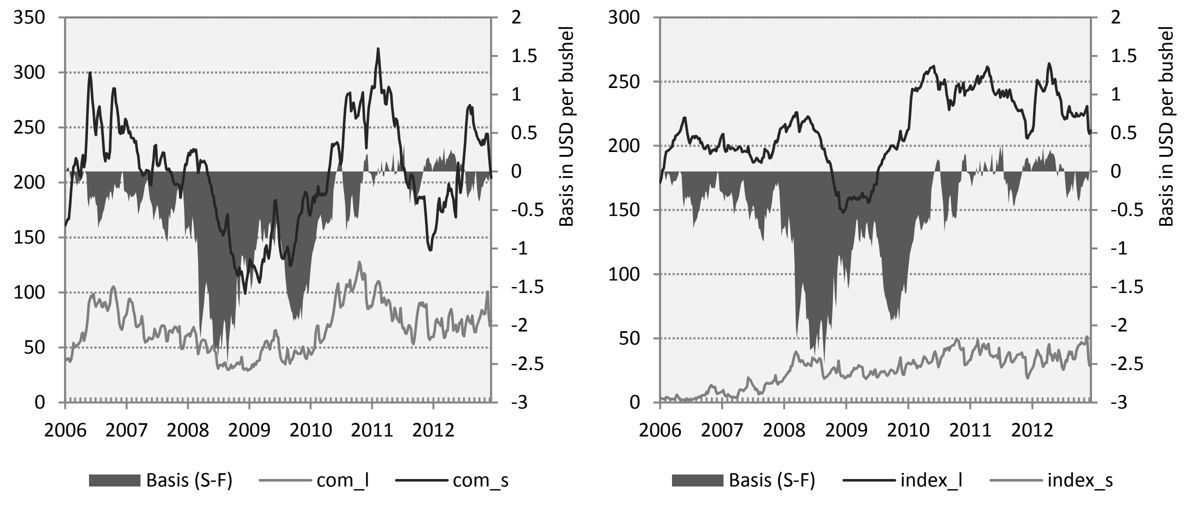
Figure 6: CBOT SRW Wheat Basis and Market Share of Different Trader Types (Weekly, Jan 2006 – Dec 2012, in percentage of total open interest)

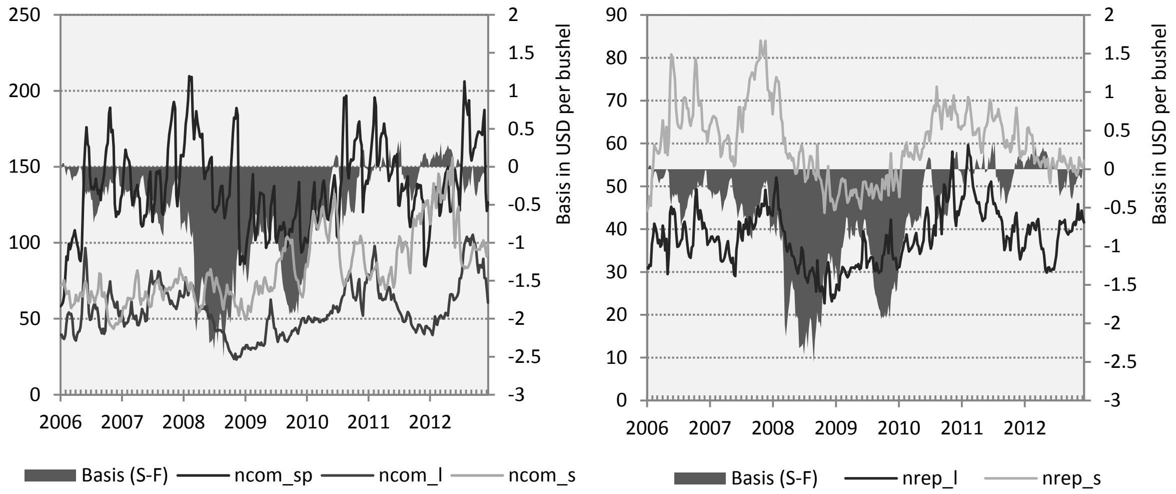


Source: Datastream & CFTC CIT supplement (author's calculation)

Disaggregated traders' position data indeed shows that commercial hedgers' long positions declined sharply after the first appearance of non-convergence and only recovered after the basis shrank again. Index traders long positions did increase throughout the first hump of non-convergence and declined at the same time as the basis started shrinking before the next hump. The decline was probably due to wealth effects in the aftermath of the financial crisis, when investors liquidated positions across markets. However, index investment had already bounced back in mid-2009 coinciding with a widening basis (Fig.7).

Figure 7: CBOT SRW Wheat Basis and Different Trader Type's Long and Short Positions (Weekly Open Interest, Jan 2006 – Dec 2012, number of contracts)





Source: Datastream & CFTC CIT supplement

Non-commercial traders' positions remained almost stable over the period of the first hump of the basis (although they gained a larger market share and hence weight-of-market effects due to decreasing commercial traders' positions), with a minor decline throughout the financial crisis, and increased, in long as well as short positions, over the second basis hump (Fig.7).

3.3. Variable Storage Rate: A Cure and its Consequences

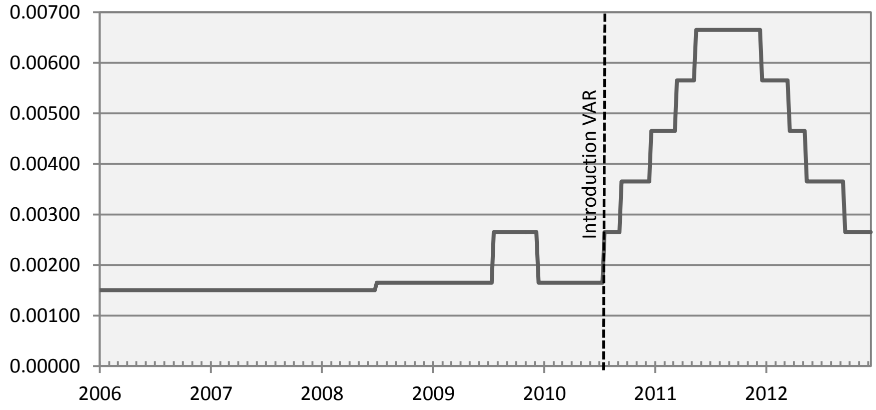
In order to solve the non-convergence problem, the CBOT introduced a variable storage rate [VSR] which was designed to successively narrow the gap between the storage premium at the exchange and the storage rate in the physical market. The VSR, effective since the July 2010 contract's maturity, increases at each contract's maturity as long as financial full carry prevails. On each trading day from the 19th calendar day of the previous delivery month until the nearby contract expiry date, the carry[14] is estimated as an average percentage of full carry over the contract's life-cycle. Should the average percentage of full carry be 80 per cent or more, the daily storage premium increases by $0.001 per bushel (CME Group 2009).

Although convergence was eventually restored, it took another year until the market appeared to work in an orderly manner. Convergence improved substantially right after the introduction of the VSR. This lasted for only a short duration and the basis spread reached more than $0.50 per bushel again in September. During this time period the VSR was heavily criticised by market practitioners and stakeholders in the wheat market for distorting incentives for storage, inflating the cash price, and sending wrong price signals to producers (Stebbins 2011).

[14] The daily carry is estimated by CBT as $D * \left[\left(\frac{i}{360} * F\right) + C\right]$, with D being the number of calendar days from the first delivery day in the nearby contract to the first delivery day in the contract following the nearby contract, i being the 3-month LIBOR rate plus 200 basis points, F being the settlement price for the nearby futures contract, and C being the daily premium charge. The carry is then divided by the two-to-one spread and multiplied by 100 which yields the percentage of full carry (CME Group 2009).

As financial full carry prevailed for a prolonged period of time, the exchange premium successively increased until the end of 2011 (Fig. 8). The storage premium for wheat increased to 20 cents a bushel per month (0.665 cents a bushel a day), while the premium for corn and soybeans remained as low as 5 cent a bushel per month. Storage charges appeared to heavily overshoot, which probably reflected the extent to which futures and physical markets previously departed.

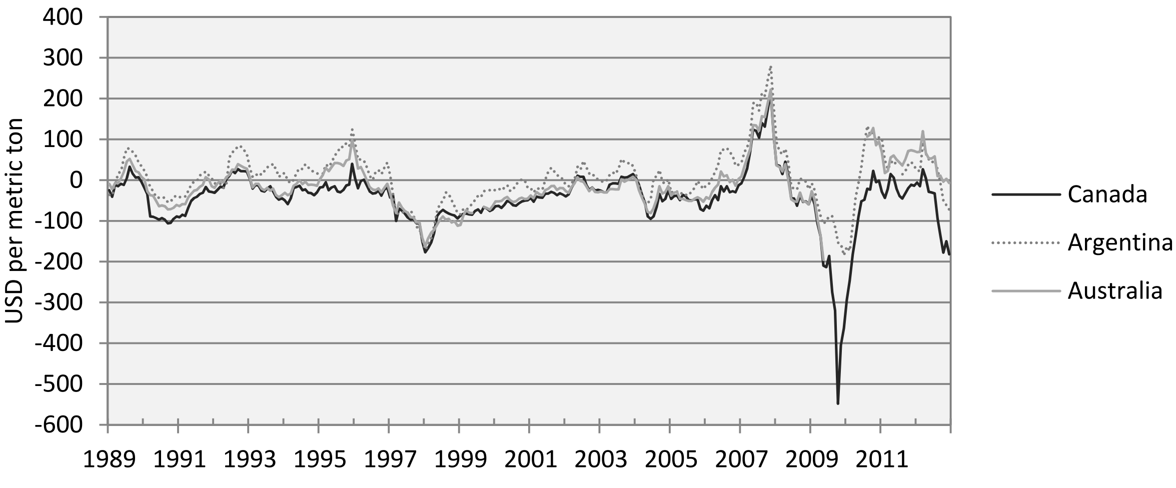
Figure 8: CBOT Exchange Storage charge (Monthly, Jan 2006 – Dec 2012, in USD cents per bushel per month)



Source: CBOT Registrar

Inflated warehouse charges arguably resulted in inflated U.S. wheat cash prices despite abundant supply, and buyers claimed that it became cheaper to source feed wheat from Canada than buying it domestically (Stebbins 2011). Indeed, after the introduction of the VSR, U.S. soft red winter wheat prices increased rapidly relative to Canadian, Argentinean, and Australian prices (Fig.9).

Figure 9: U.S. Soft Red Winter Wheat Cash Prices minus Prices in Canada/ Argentina/ Australia (Monthly, May 1989 – Apr 2013, in USD per metric ton)



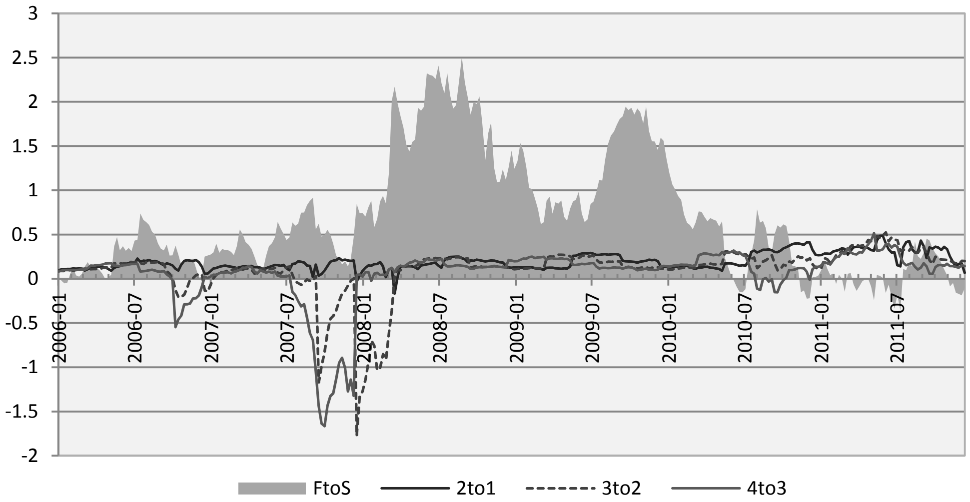
Source: USDA, 2013

The extent to which price changes occurred on the physical market is even more pronounced, as U.S. wheat was, due to the exceptionally good harvest, previously cheaper than elsewhere (Fig.9).

Further, terminal elevators, i.e. exchange registered warehouses, were accused of hording wheat and keeping it away from the market in order to capture the additional storage income, while smaller traders were prohibited from delivering their abundant wheat stocks to the exchange as this right is reserved for regular firms only (ibid.)

Last but not least, with financial fully carry prevailing, the increase in the exchange storage premium was fully reflected in the calendar spread, which increased with the variable storage rate until the end of 2011 (Fig. 10).[15]

Figure 10: CBOT SRW Wheat Inverted Basis and Future Spreads (Weekly, Jan 2001 – Dec 2012, in USD per bushel)



Source: Datastream (author's calculation)

Since such a development implies that deferred futures contracts gained in value relative to closer to maturity contracts, farmers were misled to plant and store additional wheat despite already abundant supply (Stebbins 2011).

4. Empirical Evidence: Non-Convergence and Financial Demand

In an attempt to explain the extent of non-convergence, i.e. the size of the basis at maturity, a simple regression analysis is conducted which relates the basis to various factors which have been advanced in the literature cited above, as well as to financial demand as hypothesised in this paper.

[15] Unlike the relationship between futures and cash prices, the time-wise distance between futures contracts of different maturities never change over a contract's life-cycle. Hence, if financial full carry prevails, the calendar spread only changes at contracts' maturity dates, when the premium charge and the time distance between the different maturities changes. This is reflected in the stepwise movements of the two-to-one spread previous to July 2010.

The basis is defined as the difference between cash and futures prices $S_T - F_{i,T} = B_{i,T}$ at the end of each contract's maturity with i indicating the i^{th} contract (e.g. May 2008 contract) at its maturity date T (e.g. 14th of May 2008). Alternatively, the analysis was conducted taking the average prices of the future price during the delivery month and the corresponding average spot price over the same time period. However, results did not change significantly and hence are not reported here.

Price data for the cash price and the futures price have been obtained from Thomson Reuters Datastream. The futures price is the CBOT No. 2 Soft Red Winter Wheat settlement price at the last day of trading of each contract. The cash price is the No. 2 Soft Red Winter Wheat Spot Price at St. Louis provided by the United States Department of Agriculture (USDA). Open interest differentiated by trader type, with commercial, non-commercial, index, and non reporting traders which hold positions below the reporting level, is obtained from the Commodity Futures Trading Commission (CFTC) Commitment of Traders Report Index Trader Supplement (CIT). The relative market weight of each trader type is calculated as the average percentage share of traders' open interest (long plus short) in total open interest in the last trading days of the contract starting with the first trading day of the expiration month and ending with the contract's expiry day.

The storage premium at the exchange was obtained from CBOT. Storage costs outside the exchange are not available, and hence the exchange premium can only serve as an approximation for the variation in the storage costs difference. In order to capture limits to arbitrage which were related to storage capacity the wheat stock-to-use ratio is used. The estimate for the stock-to-use ratio is based on the USDA Wheat Yearbook Table 5 (USDA 2013) and calculated as the ratio between ending stocks and total disappearance (use) over the same period. As the data is available only quarterly, the ratios are matched with different contracts in the following way: March with Q3 (December to February), May with Q4 (March to May), July with the average of Q4 and Q1 the following year, September with Q1 (June to August), December with Q2 (September to November). The stock-to-use ratio, however, is not an ideal estimator as it does not capture the opportunity costs which might have arisen due to a shortage of storage space. As an alternative estimator, the percentage of storage capacity filled in CBOT exchange registered warehouses is obtained from the USDA Grain Stock Report which is published every Friday. The observation at the last Friday before each contract's final trading day is used. Last but not least, the estimate for the average percentage of full carry follows the CBOT estimation procedure and hence defines the average percentage of full carry as the ratio between the total costs of holding the delivery instrument until a contract's maturity and the two-to-one calendar spread over the life-cycle of each contract from the point where it became the next to maturity contract till its maturity (CME Group 2009). The interest rate used is the three-month LIBOR plus 200 basis points, which is obtained from Thomson Reuters Datastream.

The time period covered starts with the March 2006 contract and ends with the maturity of the September 2012 contract. This time period covers 35 observations in total. Unfortunately, data for the percentage of storage filled in exchange registered warehouses is only available from January 2008 onwards which constrains the sample to 22 observations. The variables used are summarised below:

Variable	Description
B	CBOT Soft Red Winter Wheat basis in USD cents per bushel of wheat.
av%index	Average percentage share of index traders open interest (long plus short).
av%ncom_sp	Average percentage share of non-commercial spread trader's open interest.
av%ncom-sp	Average percentage share of non-commercial traders' open interest (long plus short excluding spread traders).
av%com	Average percentage share of commercial traders' open interest (long plus short).
av%nrep	Average percentage share of non-reporting traders' open interest (long plus short).
StCost	Exchange premium for the currently trading contract in USD cents per bushel per day.
StToUs_1	The previous time period's stock-to-use ratio.
AvFlCar_1	Average of the percentage of financial full carry over the last contract's life-cycle.
%CapFil_1	The percentage of capacity filled in exchange registered warehouses for wheat at the last contract's maturity.

Six different model specifications were run with B as the dependent variable and varying explanatory variables in order to assess the contribution of each factor to the size of the basis at maturity. The models were specified as:

$$B_T = \beta_0 + \sum \beta_i X_{i,T} + u_T$$

$X_{i,T}$ is the ith explanatory variable at the Tth maturity. β_0 is the intercept coefficient and β_i is the slope coefficient of the ith explanatory variable; u_T is the error term. The tables below provide an overview of estimated coefficients, and their standard error and partial r-square, as well as residual diagnostics for each mode.

Table 2: Regression Results and Residual Diagnostics for Model 1 – 3

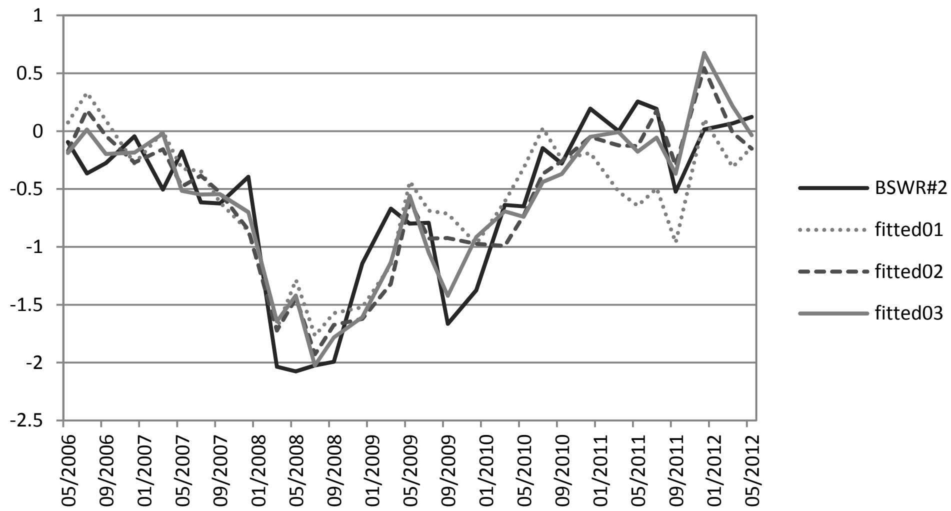
	Model 1			**Model 2**			**Model 3**		
BSRW#2	coeff.	s.d.	part. r^2	coeff.	s.d.	part. r^2	coeff.	s.d.	part. r^2
Constant	1057.59***	200.1	0.5178	947.81***	164.0	0.5439	917.243***	180.4	0.5084
av%index	-25.273***	4.490	0.5221	-24.882***	3.574	0.6339	-24.9211***	3.392	0.6834
av%ncom_sp	-1.36663	2.602	0.0094	-2.77120	2.097	0.0587	-3.85766 *	2.096	0.1284
av%ncom-sp	-16.823***	4.566	0.3189	-14.257***	3.684	0.3485	-14.0097 ***	4.239	0.3040
av%nrep	-18.4642	8.471	0.1408	-10.3022	7.013	0.0716	-7.60530	6.867	0.0468
StCost	-	-	-	17966.***	4259.	0.3886	16188.3***	4132.	0.3804
StToUs_1	-	-	-	-	-	-	0.167315*	0.09663	0.1071
AvFlCar_1	-	-	-	-	-	-	-0.394175*	0.2141	0.1194
Diagnostics	sigma RSS R^2 Adj.R^2 log-likelihood Joint test: F(4,29) Normal: Chi^2(2) Hetero.: F(8,25)	47.3613 65049.7463 0.596734 0.541111 -176.705 10.73 [0.000]** 0.3001 [0.8607] 0.5876 [0.7786]		sigma RSS R^2 Adj.R^2 log-likelihood Joint test: F(5,28) Normal: Chi^2(2) Hetero.: F(10,23)	37.6883 39771.3305 0.753443 0.709416 -168.341 17.1 [0.000]** 1.653 [0.4376] 1.130 [0.3832]		sigma RSS R^2 Adj.R^2 log-likelihood Joint test: F(7,25) Normal.: Chi^2(2) Hetero.: F(14,18)	35.6689 31806.6893 0.80045 0.744576 -160.195 14.3 [0.000]** 2.684 [0.2613] 0.845 [0.6204]	

Note: * indicating significance at 10% level, ** indicating significance at 5% level, and *** indicating significance at 1% level respectively.

The first model specification includes the weight of speculative demand as the percentage share of each trader group in total market open interest. Commercial traders' share was excluded in the first model specification to avoid perfect colinearity between explanatory variables. The coefficient for the market weight of non-commercial non-spread traders and index traders is negative and highly significant. The remaining coefficients are insignificant. The overall fit of the model appears relatively good, with an R-squared of about 0.6. Residual diagnostics suggest normally distributed and spherical residuals. Since the market weight of different trader groups in the derivative market is unlikely to (directly) affect the cash market, the negative coefficients indicate that non-commercial traders' relative demand – especially index traders' demand – results in a significant increase in the futures prices relative to the cash prices. Estimated coefficients suggest that, *ceteris paribus*, if the market weight of index traders increases by one per cent (either due to decreasing positions of non-index traders or increasing open interest by index traders), the futures price increases by about 25 USD cents per bushel of wheat on average relative to the cash price. For non-commercial non-spread traders' this would *ceteris paribus* result in a 17 USD cents per bushel of wheat increase on average in the futures price relative to the cash price.

Since the model seems to underpredict systematically the size of the basis after mid-2010, when the VSR was introduced (Fig. 11), the second model specification includes the exchange storage premium as an additional explanatory variable.

Figure 11: Model 1 to 3 Observed and Fitted Basis at Future Contracts' Maturity (in USD per bushel)



Source: Author's calculation

The additional coefficient is highly significant and the model has a significantly better fit then the previous one. The size of the coefficient indicates that for a 10/100 USD cent per bushel per day increase in the storage premium, the futures price would *ceteris paribus* decrease by almost 1.80 USD on average relative to the cash price.[16] This effect counterbalances the otherwise upward price pressure on the futures prices by non-commercial traders' market weight, and hence adjusts for the under prediction of the basis in the latter half of the sample period.

Besides the storage premium mismatch, two further explanations for successive non-convergence were put forward in the literature; firstly a high market carry which resulted in a reluctance to load out, and secondly insufficiencies in the delivery system. In order to account for these two effects, the average percentage of full carry and the stock-to-use ratio are included. The two variables are backward looking as traders are likely to act on the basis of observed past carry relationships and past consumption-production patterns. Both coefficients are weakly significant. The coefficient on the average full carry is negative, supporting the theory that the compensation for storage costs is related to non-convergence. However, the carry can only explain the existence of limits to arbitrage but not the extent of non-convergence, which probably accounts for its low significance. The coefficient on the stock-to-use ratio is positive, indicating that as stocks increase relative to use, that is as supply becomes relatively abundant, the premium of the futures price relative to the spot price decreases. This is coherent with the theory of storage which predicts that the marginal convenience yield is a negative function of inventories (Pindyck, 2001) and that if inventories become abundant, opportunity costs might cause the marginal convenience yield to approach zero.

However, one might argue that the significance of the market weight of non-commercial traders is actually due to a decreasing market weight of commercial traders resulting from a loss in hedging effectiveness. Hence, the causality would be the reverse, where commercial traders exit the market because of an increasing basis. The counter image of this effect is the increase of the market share of non-commercial traders, which then shows a significant effect falsely suggesting causality. In order to test for this alternative hypothesis we run two additional regressions with the percentage share of commercial traders included.

Indeed, if only including the share of commercial traders in total open interest, the coefficient is significantly positively related to the basis, supporting the above argument (cf. table 3). However, the size of the coefficient is much smaller than the estimated effect of the market share of non-commercial traders on the market basis. Further, comparing adjusted R-squares of model one with model four, as a rough indicator of the relative goodness of fit, the first model specification appears preferable.

In model five non-commercial as well as commercial traders' market weights are included as explanatory variables. Commercial traders and non-commercial spread traders have a high negative correlation and including both results in a variable inflation factor of over 50 for the respective coefficients. Further, the partial r-squares of both coefficients drop significantly

[16] Recall that the storage rate is expressed in USD cents and is increased by 10/100 USD cents each time the average percentage of full carry over the maturing contract exceeded 80 per cent. Hence, it increases stepwise by 0.001 USD cents and not 1 USD cents, which means that the coefficient has to be divided by 100 for a meaningful interpretation.

indicating substitutive effects of multicollinearity. Hence we exclude non-commercial spread traders in the fifth model. The coefficient on the market weight of commercial traders turns insignificant while still positive. Although non-significant, the inclusion of commercial traders' market weight seems to result in a decrease of the effect of index traders, which suggests that these trader groups are not independent. However, the effect of index traders' market weight, as well as that of non-commercial non-spread traders' market weight, remains highly significant even with commercial traders' market weight included. This refutes the pervious hypothesis that non-commercial traders' market weight is only significant on the basis of it being the counter-image of commercial traders' market weight.

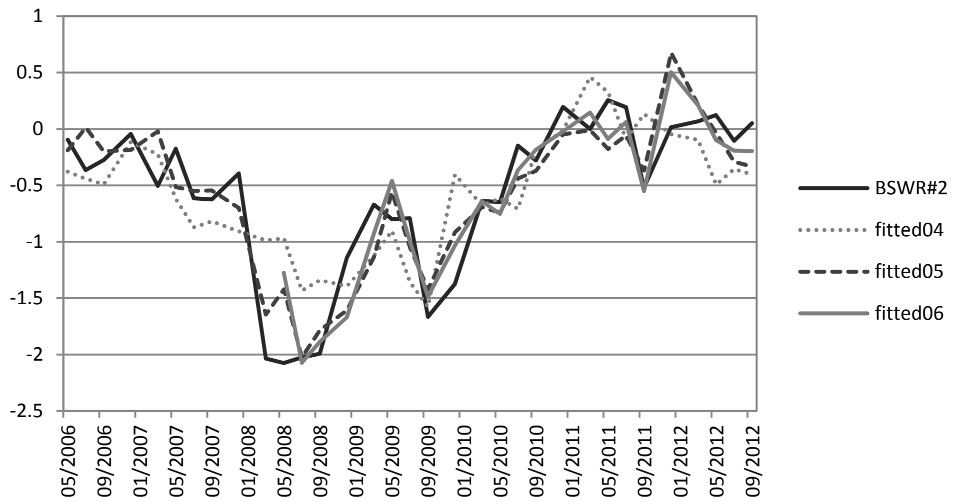
Table 3: Regression Results and Residual Diagnostics for Model 4 – 6

	Model 4			**Model 5**			**Model 6**		
BSRW#2	coeff.	s.d.	part. r^2	coeff.	s.d.	part. r^2	coeff.	s.d.	part. r^2
Constant	-385.16***	68.40	0.5311	631.88***	206.7	0.2722	976.228***	297.3	0.4182
av%com	8.74365***	2.184	0.3640	2.85358	2.071	0.0706	-	-	-
av%index	-	-	-	-22.068***	4.328	0.5098	-29.2057***	5.822	0.6265
av%ncom-sp	-	-	-	-11.156***	3.539	0.2845	-13.9427**	5.845	0.2751
av%nrep	-	-	-	-4.75172	6.850	0.0189	-7.37043	9.342	0.0398
av%ncom_sp	-	-	-	-	-	-	-2.68197	2.725	0.0606
StCost	20030.1***	5424.0	0.3275	16188.***	4132.0	0.3804	13886.5***	4720.	0.3659
StToUs_1	0.225253*	0.1248	0.1043	0.167315*	0.09663	0.1071	-	-	-
AvFlCar_1	-0.267085	0.2826	0.0309	-0.394175*	0.2141	0.1194	-0.419307*	0.2358	0.1741
%CapFil_1	-	-	-	-	-	-	1.81619*	0.9738	0.1882
Diagnostics	sigma RSS R^2 Adj.R^2 log-likelihood Joint test: F(4,28) Normal: Chi^2(2) Hetero.: F(8,19)	50.72 72030.6072 0.548092 0.483534 -173.683 8.49 [0.000]** 10.6 [0.0050]** 0.8321 [0.5857]		sigma RSS R^2 Adj.R^2 log-likelihood Joint test: F(7,25) Normal: Chi^2(2) Hetero.: F(14,10)	35.6689 31806.6893 0.80045 0.744576 -160.195 14.33 [0.000]** 2.6844 [0.2613] 0.4208 [0.9323]		sigma RSS R^2 Adj.R^2 log-likelihood Joint test: F(7,15) Normal: Chi^2(2) Hetero.: F(14,18)	36.0535 19497.8237 0.84928 0.778944 -110.175 12.07 [0.000]** 3.4136 [0.1814] 5.1330 [0.0129]*	

Note: * indicating significance at 10% level, ** indicating significance at 5% level, and *** indicating significance at 1% level respectively.

Further, the variable for the stock-to-use ratio does not fully capture the argument of the insufficiencies in the delivery system, which is related to high opportunity costs of storing additional wheat as storage space becomes scarce. Hence, we substitute the stock-to-use variable [StToUs] with the percentage of storage space at exchange registered warehouses filled [%CapFil] in a sixth model. Unfortunately data for this new variable is only available from January 2008 onwards which reduces the sample size to 22 observations. However, regression results are very similar to the third model specification, which supports the arguments put forward in the literature that non-convergence is due to insufficiencies in the delivery system as well as a high percentage of full carry. Fitted and observed values for the basis for model one to six are presented in figure 11 and 12.

Figure 12: Model 4 to 6 Observed and Fitted Basis at Future Contracts' Maturity (in USD per bushel)



Source: Author's calculation

5. Conclusion

Overall, the empirical analysis conducted here presents evidence in support of the various reasons for non-convergence of CBOT wheat futures contracts which were advanced in the literature. However, as discussed in the paper, while these do explain limits to arbitrage and hence the existence of non-convergence, they fail to explain empirically, as well as theoretically, the extent of non-convergence, i.e. the size of the basis at a futures contract maturity as well as over a futures contract's life-cycle.

Although Garcia, Irwin, and Smith (2011) claim to have finally found a sufficient explanation for the extent of the basis spread, their model is based on the assumption of an independent determination of cash and futures prices. This assumption is an implicit break with the efficient market hypothesis, which demands justification. The paper fills this gap by proposing an alternative hypothesis based on market microstructure analysis and insights provided by the bounded rationality school (Summers and Summers, 1989; Shleifer and Vishny, 1997; Shleifer and Summers, 1990; De Long, et al., 1990) and the financialisation of commodity markets literature (Nissanke, 2011, 2012; UNCTAD, 2008; Mayer, 2009, 2012). The paper suggests that the increasing demand by financial investors in commodity derivative markets since 2002 has alienated cash and futures prices as the factors on which price discovery in both markets rest became detached. If limits to arbitrage exist and factors driving the price formation process on both markets deviate, prices will deviate as well, resulting in an increasing basis size. Hence, the extent of non-convergence can be explained by the relative market weight of financial demand in derivative markets. Since such financial demand is unrelated to market fundamental, it is not reflected in physical markets. Within a simple regression framework, the paper presented convincing evidence for the extent of the basis spread being related to speculative demand. In further controlling for factors posing limits-to-arbitrage, the paper succeeds in almost fully explaining the basis size since the CBOT wheat March 2006 contract's maturity.

Although convergence was restored by the implementation of the VSR, the insights gained from this paper suggest that the problems underlying the extent of non-convergence, which became apparent throughout a time period of persistent limits-to-arbitrage, are everything but resolved. This is especially worrisome as, if the hypothesis put forward here is correct, the two key functions of commodity derivative markets appear at stake. Firstly, if arbitrage mechanisms are effective, then speculative demand driving the futures market price is likely to spill-over to the cash market price, impeding the market's price discovery function. Secondly, if arbitrage is limited, hedging, and hence risk management, becomes ineffective under a volatile and large basis. Further, incoherent price impulses at cash and futures markets are likely to increase market uncertainty and hence price volatility, further burdening producers and consumers in the physical market.

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