AGRICULTURAL
ECONOMICS

Agricultural Economics 49 (2018) 171–181

How financial investment distorts food prices: evidence from U.S. grain markets

Sophie van Huellen*

SOAS University of London, Thornhaugh Street, Russell Square, London, WC1H 0XG, UK

Received 15 August 2016; received in revised form 28 September 2017; accepted 13 October 2017

Abstract

Convergence between commodity futures prices and the underlying physical assets at each contract's expiration date is a pivotal condition for the market's functioning. Between 2005 and 2010, convergence failed for several U.S. grain markets. This article presents a price pressure-augmented commodity storage model that links the scale of nonconvergence to financial investment channeled through indices, which are traded in commodity futures markets. The model is empirically tested, using Markov regime-switching regression analysis. Regression results strongly support the model's predicted link between index investment and the extent of nonconvergence for three grains traded at the Chicago Board of Trade: wheat, corn, and soybeans.

JEL classifications: G13, G14, Q14, Q18

Keywords: Commodity futures; Convergence; Speculation; Grain

1. Introduction

Nonconvergence between commodity futures and their underlying physical assets undermines the functioning of commodity markets. Episodes of prolonged convergence failure have occurred across commodities since the early 2000s, but have been especially pronounced in three U.S. grain markets: Chicago Board of Trade (CBT) wheat, corn, and soybeans (Adjemian et al., 2013). These episodes of nonconvergence coincided with two global food crises in 2007–2008 and 2010–2011 and a growing concern over the potentially inflationary price effect of novel trading instruments, such as commodity indices (Ghosh, 2010).

The United States is the single largest exporter of wheat and corn and the third largest exporter of soybeans, globally. High prices, as quoted at the U.S. food commodity exchanges in 2008 and 2010, transmitted into local consumer markets and triggered a panic in governments across the world over domestic food security. These concerns resulted in export bans of key staples—some of which had previously been unaffected by the price spike (Headey, 2011; Timmer, 2009). Increasing and more volatile global food prices caused economic and political instability, hitting hard the livelihoods of the poorest (Dorward, 2011; Harrigan, 2014; Nissanke, 2012; Tadesse et al., 2014).

Empirical evidence for a causal link between financial investment and commodity price dynamics has been mixed; see Irwin (2013) and Cheng and Xiong (2014), for comprehensive literature reviews. Most empirical studies have focused on the impact of commodity indices on price levels and volatilities, such as Ott (2014), Sanders and Irwin (2017), and Algieri (2014, 2016). Few have looked at convergence, market basis, or term structure effects. This article reinvestigates the link between financial investment and commodity price dynamics, by examining episodes of prolonged nonconvergence in U.S. grain markets.

The literature, which investigates these episodes of convergence failure, pinpoints the anomaly as a misalignment between the exchange storage premium and commercial storage rates, paired with a change in delivery instruments (Aulerich et al., 2011; Garcia et al., 2015; Irwin et al., 2011). These factors are thought to have jointly contributed to limits to arbitrage and, hence, facilitated nonconvergence. Although the potential link between financial investment and convergence failure was considered (U.S. Senate, 2009), it has not yet been incorporated formally, and only two studies have empirically tested the hypothesized link (Garcia et al., 2015; Irwin et al., 2011).

The reasons for nonconvergence, identified in the literature, are *not* challenged here. Instead, the article argues that the extent of nonconvergence—the size of the market basis at a

---

*Corresponding author. Tel.: +44(0) 20 7898 4543. *E-mail address*: sv8@soas.ac.uk (S. van Huellen).

DOI: 10.1111/agec.12406

contract's maturity date—cannot be fully explained by these same conditions that caused limits to arbitrage. The article derives a *price pressure-augmented commodity storage model*, showing that, while nonconvergence is facilitated by a mismatch in storage rates that hinders the execution of arbitrage trades, the large scale of nonconvergence is caused by financial investment-induced price pressure effects. This link between financial investment and the extent of nonconvergence has been overlooked by previous studies. The reason for this oversight is that previous studies build on the theory of storage, but ignore theories of price pressure. The model is fitted by Markov regime-switching regressions, which yield strong support for the model's predictions.

Two policy implications arise from this analysis. The variable storage rate (VSR), that has been designed to alleviate the misalignment between storage rates and thereby restore convergence, is only partially effective, unless financial investment is also curbed. In the United States, concerns over the potential link between financial investment and high commodity prices led to the passage of the Dodd–Frank Act in 2010. The Act empowers the Commodity Futures Trading Commission (CFTC) to impose position limits for traders other than commercial hedgers, to curb potentially adverse effects of financial investment on price discovery and effectiveness of risk management. However, it is argued that position limits as introduced by the Act fail to deliver the intended effect and, therefore, cannot complement the VSR.

The remainder of the article is structured as follows. Based on a review of conventional arbitrage theories, Section 2 derives a price pressure-augmented commodity storage model that links the size of the market basis at a commodity futures contract's maturity date to price pressure effects. Section 3 introduces econometric methods and data used to test the model. Section 4 reports and discusses empirical results. Section 5 highlights the shortcomings of the VSR, in the light of findings presented in the article. Section 6 concludes with some considerations of policy implications.

2. Explaining convergence failure

2.1. Previous explanations for convergence failure

Two arbitrage mechanisms ensure a close relationship between prices in commodity futures and their underlying physical markets: *fundamental* and *spatial* arbitrage. Fundamental arbitrage opportunities arise if the price in either the cash or futures market deviates from its fundamental value. Spatial arbitrage opportunities arise if prices in two markets trading the same product deviate after adjustments for exchange rates and transport costs.

In the absence of tariffs, transaction costs, or other market distortions, the mechanics of arbitrage ensure convergence of futures and cash prices at each futures contract's maturity. However, futures and cash prices can deviate substantially over a contract's life cycle, despite common fundamentals. The cyclical deviations are explained by two complementary theory strands: theories of storage (Brennan, 1958; Kaldor, 1939; Working, 1948, 1949) and of risk premium (Hicks, 1939; Keynes, 1930).

Equation (1) summarizes the arbitrage relationship between cash and futures markets under theories of storage:

$$F_{t,t+1} = S_t \ (1 + r_t) + \delta_t - y(I_t), \tag{1}$$

with $F_{t,t+1}$ being the futures price at time t and with maturity date $t + 1$, S_t the cash price,[1] δ_t storage cost over one period, r_t interest paid on the initial cash outlay over one period, and y_t the convenience yield. The latter is a utility-based reward that accrues to a holder of inventory and is inversely related to the level of inventory available, I_t.

The market basis is defined as $B_t \equiv S_t - F_{t,t+1}$. A negative basis cannot exceed $S_t r_t + \delta_t$ with $y(I_t) = 0$ (physical full carry), since $r_t, \delta_t, y(I_t) \geq 0$ (Lautier, 2005). A positive basis, in contrast, depends on the "size" of the convenience yield.

What distinguished nonconvergence in U.S. grain markets from other such incidence and, hence, attracted attention was that futures contracts traded far above cash market prices (see Figure 1A in the Online Appendix). The rule that a negative basis cannot exceed the carry was, therefore, consecutively violated, which can only be explained by limits to arbitrage under Eq. (1).

Several studies identified three interlinked factors that have contributed to limits to arbitrage: (1) a misalignment between the storage premium paid by the holder of a delivery instrument and the storage cost paid by a holder of the physical commodity (Garcia et al., 2015); (2) a change in delivery instruments, which provided the holder of the instrument with the option but not the obligation to take delivery (Aulerich et al., 2011); and (3) a high carry that fully compensates for the storage cost incurred by those holding inventory (Irwin et al., 2011). These three factors incentivized traders to postpone load-out, postponing the execution of spatial arbitrage.

Although these factors explain limits to spatial arbitrage and, thereby, the incidence of nonconvergence, they do not explain the extent of nonconvergence. The exception here is Garcia et al. (2015)—who proposed a "dynamic rational expectations commodity storage model," in which nonconvergence of the extent observed empirically could arise in equilibrium when the price of physical storage $\delta_t - y(I_t)$ was greater than the cost of holding the delivery instrument γ_t. They showed that the difference, or "wedge," $w_t \equiv \delta_t - y(I_t) - \gamma_t$, between storage costs drives the basis at maturity. The authors argued 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 traders expect persistent convergence failure (Garcia et al., 2015, p. 47).

---

[1] The "cash price," often denoted as "spot price," is commonly approximated with the closest-to-maturity futures price. Since the debate here emphasizes the distinct dynamics in the physical and derivative markets, we retain the term "cash price."

Based on this reasoning, the CBT adjusted its exchange storage premium by introducing the VSR, and, as it successfully restored convergence, the inconsistency of storage costs hypothesis became the consensus explanation for the extent of nonconvergence in U.S. grain markets.

However, the model proposed by Garcia et al. (2015) rests on the implicit, but essential, assumption that the fundamentals differ, by which traders in physical and futures markets evaluate the respective commodity, resulting in $E_t[F_{t+1,t+1}] \neq E_t[S_{t+1}]$. This apparently violates the fundamental arbitrage condition under which $E_t\ [F_{t+1,t+1}] = F_{t,t+1}\ = E_t\ [S_{t+1}] = S_{t+1}$. However, the violation can be retained if risk premium theories are considered, a fact overlooked by Garcia et al. (2015), as their model was built on theories of storage, but ignored theories of risk premium.

Theories of risk premium suggest that futures prices are subject to a premium, which compensates speculators for taking on hedgers' risk. Futures prices exceed cash prices (*contango*) if consumers dominate, or cash prices exceed futures prices (*backwardation*) if producers dominate the market. This idea is motivated by the theory of "normal backwardation," advanced by Keynes (1930) and later taken up by price pressure theories, which derive the premium from "excess" demand for hedging positions under the assumption of market frictions (Acharya et al., 2013; Bessembinder, 1992; Chang, 1985; Hirshleifer, 1988, 1990). The risk premium, ρ_t, set out in Eq. (2), implies that the futures price is a biased estimator of the future cash price:

$$F_{t,t+1} = E_t\ [S_{t+1}] - \rho_t. \tag{2}$$

The price pressure interpretation of the risk premium provides a foundation for the argument that the arrival of novel trading instruments, foremost commodity indices, has contributed to the increase in commodity futures prices in 2008 and 2010. Index traders are particularly likely to drive a premium due to their unique investment behavior. These traders are "long only" and passive in the market, as they invest in a large basket of commodities by taking buy positions. Therefore, index positions are relatively inelastic, with respect to market fundamentals (Guilleminot et al., 2014; Mayer, 2012; Nissanke, 2012; Tang and Xiong, 2012).

Index traders reduce hedging pressure, acting as counterparty to hedgers (Brunetti and Reiffen, 2014). If, however, net long index positions exceed net short hedging positions, additional short traders are needed to cover the remaining long positions. This arguably results in a positive bias of the futures price over the cash price. This phenomenon is henceforth referred to as *index pressure*.

Index pressure is likely to be reinforced by traders following trends instead of fundamentals. Such trend-following behavior is prevalent in commodity futures markets due to a known information asymmetry between large physical traders and small speculators (Cheng and Xiong, 2014).

This article draws on the model of Garcia et al. (2015) and risk premium theories to derive a price pressure-augmented commodity storage model. The model shows that if limits to spatial arbitrage exist, index and hedging pressure will show in the extent of nonconvergence.

2.2. A price pressure-augmented storage model

Recalling Eq. (1), Eq. (3) must hold under spatial, as well as fundamental arbitrage:

$$S_t = \frac{F_{t,t+1}}{(1+r_t)} - \delta_t + y(I_t). \tag{3}$$

At a futures contract maturity date, the agent who is long in the market faces two choices, of which the maximum payoff must define the futures price at maturity:

$$F_{t,t} = \max \begin{cases} \frac{F_{t,t+1}}{(1+r_t)} - \gamma_t & \text{(i)} \\ S_t & \text{(ii)} \end{cases}. \tag{4}$$

The first strategy in Eq. (4) implies that the long trader holds the delivery instrument until the next contract's maturity at the premium charge γ_t set by the exchange. For the second strategy, the trader takes delivery. Given Eq. (3), the second strategy is equivalent to a trader taking delivery and holding the bulk of grain over one period for future sale at the expected price $F_{t,t+1}$, so that:

$$F_{t,t} = \max \begin{cases} \frac{F_{t,t+1}}{(1+r_t)} - \gamma_t & \text{(i)} \\ \frac{F_{t,t+1}}{(1+r_t)} - \delta_t + y(I_t) & \text{(ii)} \end{cases}. \tag{5}$$

If (i) > (ii), that is, $\gamma_t < \delta_t - y(I_t)$, then a trader gains by holding the delivery instrument and postponing load-out, leading to a lack in spatial arbitrage trade. The increased demand for delivery instruments puts upward pressure on the price for such instruments. This price, however, is fixed by the exchange and, hence, cannot vary, so the size of the basis $B_t \equiv S_t - F_{t,t}$ at maturity t is given by Eq. (6):

$$B_t = \max \begin{cases} \gamma_t - \delta_t + y(I_t) & \text{(i)} \\ 0 & \text{(ii)} \end{cases}. \tag{6}$$

Equation (6) implies that the extent of nonconvergence is related to the difference between the storage exchange premium and storage costs in the physical market, plus convenience yield. This is the "wedge," described by Garcia et al. (2015).

From Eq. (6), implications for the market's term structure can be derived. Given the size of the price spread between the contract maturing next and the one that will mature subsequently to the first, $Z_{2-1} \equiv F_{t,t+1} - F_{t,t}$ is limited by the financial full carry condition, i.e., $F_{t,t} \geq \frac{F_{t,t+1}}{(1+r_t)} - \gamma_t$, and we can define the excess in the spread as $0 \geq \frac{F_{t,t+1}}{(1+r_t)} - \gamma_t - F_{t,t}$, so that:

$$Z_{2-1} = \min \begin{cases} 0 & \text{(i)} \\ -\gamma_t + \delta_t - y(I_t) & \text{(ii)} \end{cases}. \tag{7}$$

Table 1
Size of the "edge" for 2008 CBOT wheat contracts

	May–Jul 2008	Jul–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: Own calculation based on data obtained from Thomson Reuters Datastream, CME Group Registrar, and Irwin et al. (2011).

Case (i) is given if $F_{t,t} = \frac{F_{t,t+1}}{(1+r_t)} - \gamma_t$, which is case (i) in Eq. (5), with $\gamma_t < \delta_t - y(I_t)$.

Case (ii) is given if $F_{t,t} = \frac{F_{t,t+1}}{(1+r_t)} - \delta_t + y(I_t)$, which is case (ii) in Eq. (5), with $\gamma_t \geq \delta_t - y(I_t)$.

Therefore, the market is either in full carry with nonconvergence, as in case (i) in Eqs. (5)–(7), or below full carry with convergence, as in case (ii) in Eqs. (5)–(7). As in Garcia et al. (2015), the model provides an explanation for the high carry that coincided with nonconvergence.

While the difference in storage costs explains limits to spatial arbitrage and the high carry, the model is yet incomplete, as the difference alone cannot account for the extent of nonconvergence. For example, the storage premium at the CBT wheat market was set at 0.150 cents per bushel per day until July 2008, and raised to 0.165 thereafter, which aggregates to 4.5 and 4.95 cents per bushel per month, respectively. In mid 2008, the CBT conducted a survey of 47 firms, which found an average physical storage rate of 7.1 cents per bushel per month (Irwin et al., 2011).

Table 1 shows the days between two consecutive contracts' maturities, the physical storage rate, and the exchange premium, with the latter two measures in cents (US$) per day per bushel. It further presents an estimate of storage costs and exchange premium costs incurred by holding the physical product and delivery instrument, respectively, from one futures contract maturity to the next futures contract maturity, plus interest (three-month LIBOR rate plus 200 basis points). The "difference" presents case (i) in Eq. (6) under the assumption that convenience yield is negligible in a regime of abundant storage. The basis was 50 times as large as predicted by Eq. (6).

It is clear from Table 1 that the extent of nonconvergence cannot be explained solely by differences in storage cost—an explanation that would be compatible with effective fundamental arbitrage and limits to spatial arbitrage. To explain the excessive market basis, Garcia et al. (2015) implicitly assumed $E_t[F_{t+1,t+1}] \neq E_t[S_{t+1}]$. This assumption is essential to relate the basis size to the continuously discounted difference in the expected prices on both markets, so that Eq. (6) can be extended to Eq. (8):

$$B_t = \max \begin{cases} \frac{E_t[S_{t+1}]-E_t\left[F_{t+1,t+1}\right]}{(1+r_t)} + \gamma_t - \delta_t + y(I_t) & \text{(i)} \\ \gamma_t - \delta_t + y(I_t) & \text{(ii)} \\ 0 & \text{(iii)} \end{cases}. \tag{8}$$

However, rejection of fundamental arbitrage is in fact unnecessary. Since from Eq. (2), $E_t[S_{t+1}] - E_t\ [F_{t+1,t+1}] = \rho_t$, Eq. (8) can be rewritten as:

$$B_t = \max \begin{cases} \frac{\rho_t}{(1+r_t)} + \gamma_t - \delta_t + y(I_t) & \text{(i)} \\ \gamma_t - \delta_t + y(I_t) & \text{(ii)} \\ 0 & \text{(iii)} \end{cases}. \tag{9}$$

If spatial arbitrage is effective, case (iii) prevails and convergence is established. If limits to spatial arbitrage arise and $\rho_t = 0$, case (ii) results, and the basis is linked to the "wedge" only. If $\rho_t \neq 0$, the basis at maturity is driven by the "wedge" plus the discounted risk premium, which, in turn, is driven by hedging and index pressure, giving rise to case (i).

With no limits to spatial arbitrage, cash and futures prices would be bound by the law of one price, and price signals would spill over from one market to the other. In this case, the size of the index pressure effect would be hidden under feedback effects between cash and futures markets. The extent to which the cash price is affected by index and trend-following investment 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 and only if spatial arbitrage is limited, the index premium is directly observable in the form of a large basis.

As can be seen from Eqs. (7) and (9), implications of our model are largely in line with predictions 1–3 and 5 (Garcia et al., 2015, p. 13). However, we differ in prediction 4, which links the growth in the extent of nonconvergence to the size of the "wedge' component." This does not follow from our model, which links dynamics in the extent of nonconvergence to the risk premium, in addition to the wedge component. The former varies with the composition of traders in the futures market.

3. Data and methodology

Based on Eq. (9), we estimate the following regression equation:

$$B_t = \boldsymbol{\beta}'\ \boldsymbol{Z_t}\ + u_t, \tag{10}$$

with B_t being the market basis at maturity and $\boldsymbol{Z_t}$ a vector of explanatory variables. Under effective arbitrage, that is, case (iii) of Eq. (9), $B_t =\ 0$, and under limits to arbitrage, that is, cases (i) and (ii) of Eq. (9), $B_t = \boldsymbol{\beta}'\ \boldsymbol{Z_t}$. To account for the two different market regimes, a regime-switching model is estimated, in addition to the baseline model in Eq. (10).

For the regime-switching model, it is assumed that limits to spatial arbitrage introduce a break in the "normal" market behavior, that is, coefficients are assumed to vary between the two regimes (Hamilton, 2008). The regime-switching regression is specified in Eq. (11), with s_t being a random variable that assumes values $s_t = 1$, or $s_t = 2$ to differentiate between converging and nonconverging regimes. The probabilistic model of what causes the change from $s_t = 1$ to $s_t = 2$ is based on a two-state Markov chain with constant regime-switching probabilities:

$$B_t = \boldsymbol{\beta}^{'}_{s_t} \boldsymbol{Z_t} + \varepsilon_t. \tag{11}$$

The set of explanatory variables, $\boldsymbol{Z_t}$ in Eqs. (10) and (11), comprises the exchange storage premium γ_t obtained from the Chicago Mercantile Exchange (CME); convenience yield $y(I_t)$, modeled as a function of inventory, is approximated by beginning stocks and the stock-to-use ratio obtained from the U.S. Department of Agriculture (USDA); and the risk premium ρ_t, approximated by two different measures for hedging and index pressure constructed from CFTC reports. Since the functional form of $y(I_t)$ is unknown, inventory in levels and inventory squared, as well as the stock-to-use ratio, are used. Storage costs, δ_t, are unavailable and approximated with the level of inventories $\delta(I_t)$. Variables and their data sources are listed in Table 1A in the Online Appendix.

The data ranges from January 2006 to August 2015 for soybeans, and March 2006 to July 2015 for wheat and corn.[2] CBT corn and wheat futures contracts are available for the delivery months March, May, July, September, and December, while CBT soybeans futures contracts are available for January, March, May, July, August, September, and November delivery. The five-day price average of the second week into the delivery month is used for the futures price at maturity. Over the same five days, the averages of the respective cash prices are calculated to construct the basis at maturity.

The stock-to-use ratio is calculated as the total disappearance over ending stocks. USDA-observed inventory data is available in quarters of marketing years.[3] Beginning stocks are paired with the months at the beginning of each quarter, and the stock-to-use ratio with the ending months of each quarter.[4] Inventory data for the missing months are interpolated by inverse distance weighting method. By using beginning stocks instead of ending stocks, we control for potential endogeneity between inventory and market basis.[5] As an alternative measure of inventory that does not rely on interpolation, monthly updated USDA projections of the annual crop supply are used.

The CFTC provides a breakdown of each Tuesday's open interest by different trader types for U.S. futures exchanges in three weekly flagship reports. Among these reports, the Commodity Index Trader Supplement (CIT) reflects index positions most accurately and, therefore, is chosen for this study (Irwin and Sanders, 2012). Traders' weight of market, defined as the percentage share of different trader types—commercial hedgers, noncommercial speculators, and index investors—in open interest, is used as an indicator for index and hedging pressure. Traders' net long position, defined as net long position (in absolute values) over total open interest, is considered as an alternative indicator.

All series are in logarithms to adjust for differences in scale. Market basis and carry variables are found stationary, while some of the trader position indicators are first difference stationary (see Table 2A in the Online Appendix). Since some explanatory variables might contain a unit root, Newey and West (1987) heteroscedasticity and autocorrelation consistent standard errors are used to avoid spurious inference in potentially unbalanced regressions (Ventosa-Santaularia, 2012). Also, special attention is paid to parameter instability, indicative of structural breaks with the use of Hansen (1992) parameter instability test.

Given Eq. (9), we expect confirmation of the following relationships:

(a) The market basis increases with convenience yield and decreases with storage costs. Since $y(I_t)$ is a negative function of I_t, but a positive function of the stock-to-use ratio, and $\delta(I_t)$ a positive function of I_t, the basis is inversely related to the level of inventory and positively related to the stock-to-use ratio.
(b) Nonconvergence is curbed with a decrease in the storage costs differential. Therefore, market basis increases with the storage premium γ_t.
(c) The futures price has a positive premium over the cash price if index pressure prevails, and a negative premium if hedging pressure prevails. Therefore, the market basis is inversely related to the weight of portfolio insurance and uninformed traders, and positively related to the weight of hedgers.
(d) At maturity, relationships (i)–(iii) are relevant only if limits to spatial arbitrage are present. Coefficient estimates should be smaller, approaching zero, under effective spatial arbitrage.

4. Empirical results

The CBT wheat market is by far the most affected by index pressure. Index positions outweigh hedging positions in most instances, so that index pressure prevails. For the CBT corn market, index pressure was particularly present from mid 2008 to mid 2010, in early 2012, and from 2013 until early 2016.

---

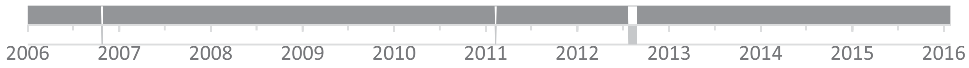
[2] Garcia et al. (2015) had access to nonpublicly available index position data from early 2004.

[3] For soft red winter wheat: Jun–Aug (Q1), Sep–Nov (Q2), Dec–Feb (Q3), and Mar–May (Q4). For corn and soybeans: Sep–Nov (Q1), Dec–Feb (Q2), Mar–May (Q3), and Jun–Aug (Q4).

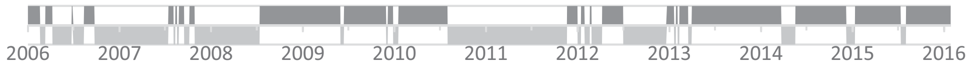
[4] For example, June with Q1 for wheat beginning stocks and August with Q1 for wheat stock-to-use ratio.

[5] Garcia et al. (2015) used instrumental variable estimation instead to ensure exogeneity of inventory approximated by ending stocks. Since beginning stocks are equivalent to lagged ending stocks, exogeneity is ensured here.

(a) CBT Wheat



(b) CBT Corn



(c) CBT Soybeans

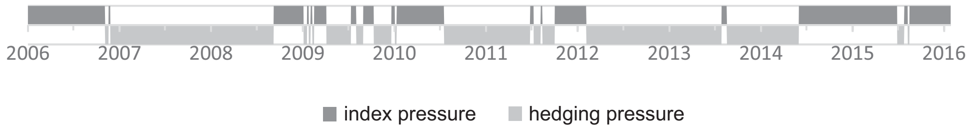


Fig. 1. Hedging and index pressure in U.S. grain markets Jan. 2006–Jan. 2016.
Note: If net long index positions outweigh net short hedging positions, the time period is defined as index pressure. If net short hedging positions outweigh net long index positions, the time period is defined as hedging pressure.
Source: Author's calculation based on CFTC and CIT.

The situation is similar for the CBT soybeans market, with the exception that the last period of index pressure starts instead from mid 2014 (Fig. 1).

Given the prevalence of index pressure in CBT wheat, the premium of futures over cash prices is expected to be largest on average in wheat, compared to the two other grain markets. Table 2 summarizes the estimation results for Eq. (10) with two model specifications, which vary only in risk premium variables. Model I tests jointly for hedging and index pressure effects, while Model II tests for the index pressure-augmenting effect of trend-following speculators, by including the market weight of uninformed traders.

Consistent with relationship (a), the stock-to-use ratio is positively related to the market basis for corn and soybeans. A doubling in the stock-to-use ratio results in a 1.2–1.5% increase in market basis. A direct interpretation of the inventory coefficients is not possible due to the polynomial nature of the convenience yield. Coefficients for level of inventory and level of inventory squared are highly significant for all three markets, supporting the hypothesis that inventory is the main driver of nonconvergence, as suggested by Garcia et al. (2015).[6]

Index pressure effects are found to be significant in all three markets, in support of relationship (c). As expected, the index pressure effect is strongest in the wheat market and weakest in the soybeans market. A 10% increase in the weight of index traders results in a widening of the market basis of around 1.8–2.5% for wheat and 0.2–0.4% for soybeans and corn, respectively. The effect is of similar magnitude when using traders' net long positions instead of traders' market weight (see Table 3A in the Online Appendix). Further, noncommercial speculators have an index pressure-augmenting effect, while commercial hedgers ease index pressure, as can be seen from the slight difference in the size of $\hat{\beta}_{\rho_{w,ind}}$ between Model I and Model II. This observation supports findings by Guilleminot et al. (2014).

To assess the possibility that traders' weight is driven by the size of the basis, we run a reverse regression with index traders' market weight as the dependent variable, and the remaining variables in $\boldsymbol{Z_t}$ and B_t as regressors. Results are available in Table 3A in the Online Appendix. The hypothesis that the market weight of index traders is driven by the basis size is rejected for all three markets. However, there is a positive relationship between the storage premium and the weight of index traders. A possible explanation is that with an increasing storage premium, the futures contracts become less attractive. Index traders are relatively insensitive to market-specific factors and, hence, do not react as strongly as commercial hedgers and speculators to this change. With other traders leaving the market, the relative weight of index traders increases. Controlling for the storage premium is therefore essential.

Diagnostic tests presented in Table 2 detect some autocorrelation and heteroscedasticity in the residuals. These patterns could stem from interpolation of inventory data, structural breaks, or unbalanced regressions. We run two variations of Eq. (10) Model I to test the robustness of our results. Interpolated inventory data is replaced first by USDA monthly projections of annual crop supply, and second, the observed quarterly inventory data, using only four contracts at maturity. Results are available in Table 4A in the Online Appendix. No autocorrelation or heteroscedasticity remains for both variations. When using USDA projections, index pressure coefficients are close

---

[6] If including inventory in levels only, the coefficients are negative, approximating table 2 results in Garcia et al. (2015, p. 18). Results are not reported here, but available upon request.

Table 2
Regression estimation results Eq. (10)

	CBT wheat		CBT corn		CBT soybeans	
	I $i = com$	II $i = ncom$	I $i = com$	II $i = ncom$	I $i = com$	II $i = ncom$
c	-2.670^{***}	-2.720^{***}	2.145^{***}	2.167^{***}	3.077^{***}	3.162^{***}
	(−3.52)	(−3.42)	(7070)	(7.51)	(4.76)	(5.00)
β_{γ}	0.063^{***}	0.065^{***}	0.182^{***}	0.190^{***}	0.166^{***}	0.236^{***}
	(4.25)	(4.32)	(4.15)	(3.87)	(4.75)	(5.24)
β_{y_I}	1.128^{***}	1.116^{***}	-0.266^{***}	-0.265^{***}	-0.302^{***}	-0.269^{***}
	(3.65)	(3.52)	(−3.90)	(−3.87)	(−3.57)	(−3.05)
$\beta_{y_I 2}$	-0.110^{***}	-0.109^{***}	0.017^{***}	0.017^{***}	0.012^{***}	0.010^{***}
	(−3.63)	(−3.51)	(3.89)	(3.87)	(3.61)	(3.08)
$\beta_{y_{su}}$	−0.005	−0.007	0.012^{**}	0.012^{**}	0.015^{***}	0.014^{**}
	(−0.30)	(−0.36)	(2.18)	(2.26)	(2.74)	(2.18)
$\beta_{\rho_{w,i}}$	0.091^{*}	−0.262	0.004	−0.008	0.045^{*}	-0.059^{**}
	(1.89)	(−1.60)	(0.20)	(−0.31)	(1.86)	(−2.30)
$\beta_{\rho_{w,ind}}$	-0.183^{***}	-0.247^{***}	-0.036^{**}	-0.040^{***}	0.005	-0.018^{*}
	(−3.01)	(−3.18)	(−2.69)	(−3.19)	(0.55)	(−1.77)
Diagnostics						
R^2	0.540	0.522	0.566	0.567	0.512	0.512
AR	2.452^{*}	3.000^{*}	2.279	2.295	0.148	0.028
Norm.	10.40^{***}	11.08^{***}	0.457	0.731	15.23^{***}	14.35^{***}
Heter.	1.973^{*}	1.540	0.518	0.508	2.066^{**}	2.202^{**}
Hans.	1.471	1.512	1.719	1.464	2.135^{**}	2.7960^{***}

Notes: Newey and West (1987) robust standard errors used for *t*-statistics in (.). *, **, and *** indicate 10%, 5%, and 1% significance level, respectively. "R^2" is the *R*-square of the regression; "AR" is a test for first and second order autocorrelation in the residuals; "Norm." is a test for normality of residuals; "Heter." is a test for heteroscedasticity in the residuals; and "Hans." is the Hansen (1992) test for parameter stability to test for structural breaks. Models I and II differ only in the definition of the risk premium with *com* for commercial hedgers and *ncom* for noncommercial speculators.

to previous results, but hedging pressure coefficients differ. The seasonality of inventory data, which is missing from the projections of annual supply, seems to be picked up by hedging pressure which is correlated with inventories, suggesting omitted variable bias. When using the observed quarterly inventory data, coefficient estimates are almost identical to results presented in Table 2. These results confirm that patterns in the residuals are, in fact, caused by interpolation alone.

Some care must be exercised in interpreting regression results for the soybeans market, as the Hansen (1992) test detects parameter instability, indicative of a structural break. The Markov switching regressions, presented in Table 3, are better suited in this case. Carry variables have been restricted to be identical over the two regimes, and coefficient estimates mirror what has been reported in Table 2 (see Table 5A in the Online Appendix).[7] The regimes identified for wheat, corn, and soybeans closely track the episodes of convergence and nonconvergence, as seen in Fig. 2. For the soybeans market, the identified nonconvergence regimes are of shorter duration.

Relationship (d) is confirmed for wheat and corn, with trader positions significant in the nonconvergence regime, but insignificant in the convergence regime. For wheat and soybeans markets, price pressure estimates in the nonconvergence regime are almost three times as strong as coefficients obtained without the regime switch, that is, with averaging over both regimes. For instance, a 10% increase in index pressure in the wheat market results in a 5.3–7.5% decrease in the market basis under limits to spatial arbitrage. For corn, the coefficient size in Eq. (11) is similar to Eq. (10), probably due to the prevalence of the nonconvergence regime over the sample period (Fig. 2).

The VSR was introduced only for the wheat market, not for the corn or soybeans markets. This is potentially why the expected duration of the nonconvergence regime is 10 times longer for corn than for wheat. For soybeans, the Markov model only identifies those periods of convergence failure which show a very large basis at maturity. Thus, episodes of nonconvergence are identified as being of relatively short duration, with the likelihood of a transition from a nonconvergence regime to convergence as high as 70–80%. The fact that the convergence regime identified for the soybeans market is likely to cover some periods of nonconvergence explains the significance of hedging pressure in both the convergence and nonconvergence regimes.

Econometric results presented here highlight the key role of inventory and storage costs in explaining the occurrence of prolonged nonconvergence through limits to arbitrage. However, these factors fail to explain the extent of nonconvergence. Instead, results strongly support the hypothesis that the extent

---

[7] Coefficients of carry variables were not found to vary across regimes and were subsequently fixed. This is probably because carry variables explain limits to arbitrage, but do not explain the extent of nonconvergence.

Table 3
Markov switching regression estimation results of Eq. (11)

	CBT wheat		CBT corn		CBT soybeans	
	I	II	I	II	I	II
	$i = com$	$i = ncom$	$i = com$	$i = ncom$	$i = com$	$i = ncom$
Regime 1						
c	-1.877^{***}	-4.668^{***}	1.439^{***}	1.537^{***}	2.895^{***}	3.068^{***}
	(−5.4055)	(−14.079)	(14.430)	(18.453)	(28.337)	(41.044)
$\beta_{\rho_{w,i}}$	0.337^{**}	-0.450^{**}	−0.012	0.003	0.119^{***}	-0.160^{***}
	(2.4234)	(−2.5687)	(−0.7070)	(0.1734)	(3.8108)	(−4.7568)
$\beta_{\rho_{w,ind}}$	-0.525^{***}	-0.752^{***}	-0.043^{***}	-0.040^{***}	−0.002	-0.062^{***}
	(−4.5118)	(−5.9266)	(−3.9948)	(−4.3093)	(−0.1124)	(−3.9490)
Regime 2						
c	-1.615^{***}	-3.206^{***}	1.480^{***}	1.637^{***}	2.872^{***}	3.312^{***}
	(−6.7520)	(−17.541)	(13.242)	(15.954)	(34.644)	(50.958)
$\beta_{\rho_{w,i}}$	0.003	0.006	−0.032	0.025	0.044^{***}	-0.042^{***}
	(0.0708)	(0.1114)	(−1.2621)	(0.7967)	(2.957)	(−2.6148)
$\beta_{\rho_{w,ind}}$	−0.047	−0.048	−0.017	−0.007	0.010	−0.011
	(−1.3732)	(−1.0753)	(−0.6217)	(−0.2422)	(1.6160)	(−1.6179)
Transition probabilities and expected duration						
P11	0.684193	0.582662	0.972492	0.971676	0.189768	0.266421
P22	0.924274	0.925231	0.899738	0.898475	0.903505	0.885593
P12	0.315807	0.417338	0.027508	0.028324	0.810232	0.733579
P21	0.075726	0.074769	0.100262	0.101525	0.096495	0.114407
Exp1	3.166487	2.396137	36.35285	35.30608	1.234214	1.363180
Exp2	13.20554	13.37449	9.973823	9.849800	10.36328	8.740734

Notes: Constant transition probabilities: $P(i, k) = P(s(t) = k \mid s(t-1) = i)$; Exp1 and Exp2 are expected duration of regime 1 and 2. P11, P12, P22, and P21 are the transition probabilities. Starting value is 0. HAC standard errors are used. (.) z-statistic. *, **, and *** indicate 10%, 5%, and 1% significance level, respectively. Models I and II differ only in the definition of the risk premium with *com* for commercial hedgers and *ncom* for noncommercial speculators.

of nonconvergence is explained better by index and hedging pressure effects.

5. Is a VSR the solution?

The VSR was designed to successively narrow the gap between the storage premium at the exchange and the storage rate in the physical market. Effective since the July 2010 contracts' maturity, the storage rate increases at each contract's maturity, as long as financial full carry prevails (CME Group, 2009). However, even though the VSR effectively eliminates the "wedge," $\gamma_t - \delta_t - y(I_t)$, thereby enforcing convergence, it has no effect on the risk premium, ρ_t.

In the case of the CBT wheat market, feedback mechanisms between the cash and futures markets, resulting from enforced convergence, led to an unwarranted increase in the cash market price despite abundant supply. With forced convergence, it became 5 US$ per bushel less for U.S. consumers to buy feed wheat from Canada than domestically (see Figure 2A in the Online Appendix). As financial full carry prevailed, the exchange premium for wheat successively increased until the end of 2011, to 20 cents (US$) a bushel per month, while the premium for corn and soybeans remained as low as 5 cents (US$) a bushel per month. Storage charges appeared to heavily overshoot, reflecting the extent to which futures and physical markets previously departed. This is because exchange storage charges were compensating not only for δ_t but also ρ_t in Eq. (9).

With financial full carry prevailing, the increase in the exchange storage premium was fully reflected in the CBT wheat calendar spread, which increased with the VSR until the end of 2011, as predicted by Eq. (7). Since such a development in the calendar spread implies that deferred futures contracts gained in value, relative to closer-to-maturity contracts, farmers were misled, planting and storing additional wheat, despite already abundant supply (Stebbins, 2011).

The case of CBT wheat clearly shows that the VSR can only partially restore the functioning of grain futures markets. Unless index pressure is curbed also, the futures premium spills over to the cash market, resulting in a price increase unwarranted by market fundamentals. Knock-on effects on the term structure via Eq. (7) undermine the information service that grain commodity futures markets provide to farmers. Despite the success of the VSR in restoring convergence and hedging effectiveness, the price discovery function of the CBT wheat market remains impaired.

6. Conclusion

This article shows that index investment into grain futures markets drives a premium of futures prices over cash prices. This index pressure effect is present but concealed in times of effective spatial arbitrage and only visible in times of limits to spatial arbitrage. If limits to spatial arbitrage are present, the effect is manifested in nonconvergence between cash and

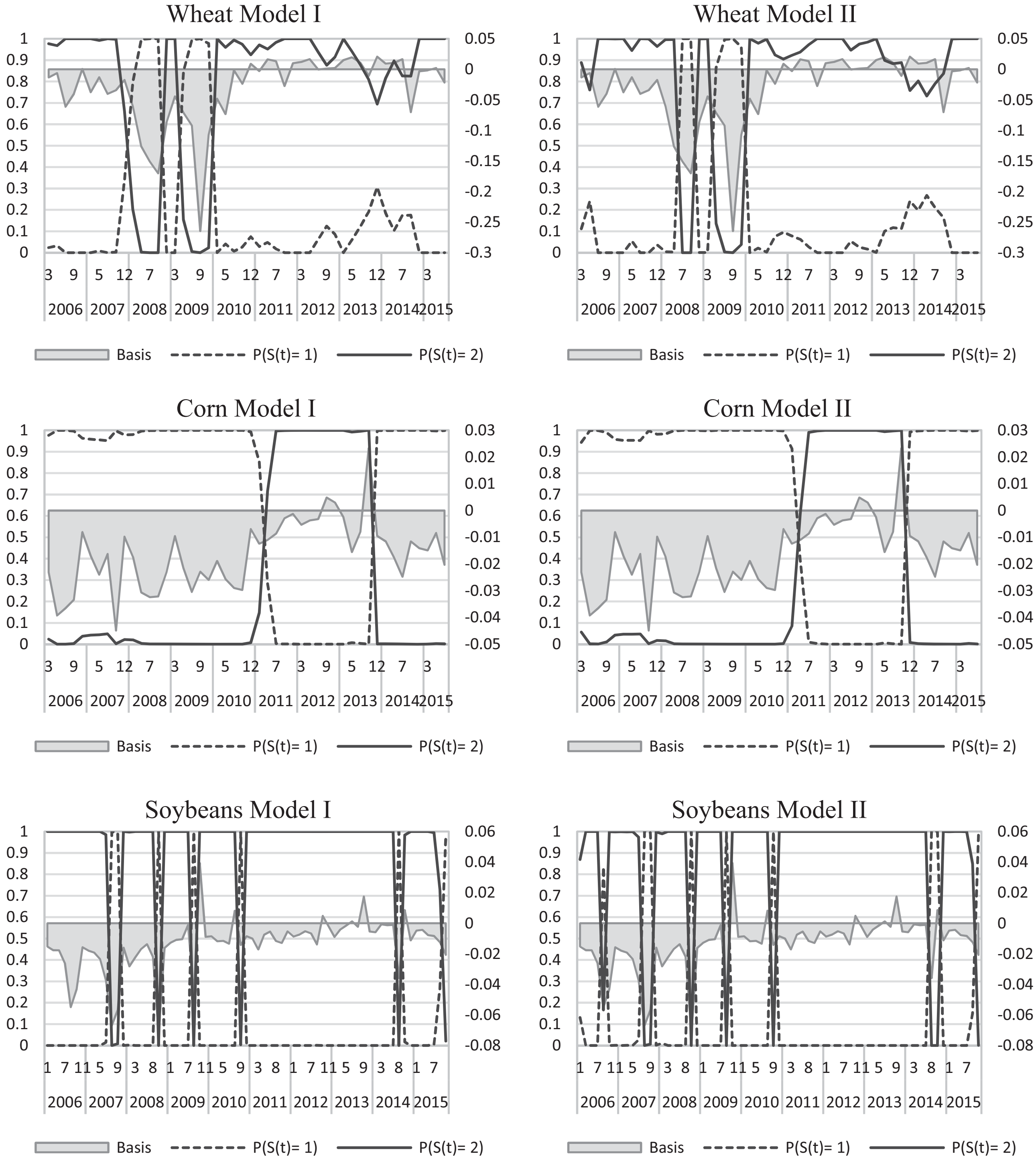


Fig. 2. Markov switching regimes.
Note: Smoothed Markov regime witching probabilities (left axis) and market basis (right axis). Figures corresponding to regression results presented in Table 3.

futures prices of large scope. If spatial arbitrage is effective, although concealed behind feedback mechanisms between cash and futures prices, the effect may spill over to cash markets, leading to a higher price level than warranted by market fundamentals.

Previous studies have linked the extent of nonconvergence to a mismatch in storage cost at exchange-registered warehouses and commercial storage rates. Although empirical evidence presented here supports this theory, it has been shown that the storage cost differential fails to explain empirically, as well as theoretically, the extent of nonconvergence. Instead, the excess in market basis is successfully explained by index pressure effects.

Despite the success of the VSR in restoring convergence in the CBT wheat market, insights gained from this article suggest that the problems underlying the extent of nonconvergence remain unresolved. This is especially worrisome because, if the hypothesis put forward here is correct, the two key functions of commodity futures markets are at stake. First, if spatial arbitrage mechanisms are effective, then financial liquidity driving the futures market price is likely to spill over to the cash market price, impeding the market's price discovery function and leading to a higher price level across futures and cash markets. Second, if spatial arbitrage is limited, hedging and, hence, risk management become ineffective under a volatile and large basis.

The VSR can only effectively restore the functioning of commodity futures market if index pressure is curbed. The Dodd–Frank Act of 2010 empowered the CFTC to impose position limits for traders other than commercial hedgers. However, since index positions are synchronized, the *total* market weight of index traders and trend-following speculators needs to be monitored and curbed, but not necessarily the positions by individual traders—an argument that has already been made by Schmidt (2016, pp. 134–139). If commercial hedgers outweigh index traders, the latter provide valuable liquidity and ease hedging pressure. An outright ban on index traders and portfolio insurance instruments is therefore undesirable. What is needed instead is a policy that carefully monitors and balances the composition of traders in the market. Unfortunately, this appears politically unattainable as the Act will most likely be weakened rather than strengthened under the new U.S. presidency of 2017.

Acknowledgments

The research was supported financially by the German National Academic Foundation and Andrey Kuleshov and Elena Ivashentseva. This article greatly benefitted from comments by Prof Machiko Nissanke, Prof Jane Harrigan, and two anonymous referees. The author also expresses thanks to participants of the July 2013 SIRE Conference "Financialisation and Commodities" for helpful comments on an earlier version of the article.

References

Acharya, V.V., Lochstoer, L.A., Ramadorai, T., 2013. Limits to arbitrage and hedging: Evidence from commodity markets. J. Finan. Econ 109(2), 441–465.

Adjemian, M.K., Garcia, P., Irwin, S., Smith, A., 2013. Non-convergence in domestic commodity futures markets: Causes, consequences, and remedies. Economics Information Bulletin No. 115, U.S. Department of Agriculture (USDA) Economic Research Service.

Algieri, B., 2014. A roller coaster ride: An empirical investigation of the main drivers of the international wheat price. Agr. Econ. 45(4), 459–475.

Algieri, B., 2016. Conditional price volatility, speculation, and excessive speculation in commodity markets: Sheep or shepherd behaviour? Int. Rev. Appl. Econ. 30(2), 210–237.

Aulerich, N.M., Fishe, R.P., Harris, J.H., 2011. Why do expiring futures and cash prices diverge for grain markets? J. Futures Markets 31(6), 503–533.

Bessembinder, H., 1992. Systematic risk, hedging pressure, and risk premiums in futures markets. Rev. Finan. Stud. 5(4), 637–667.

Brennan, M.J., 1958. The supply of storage. Am. Econ. Rev. 48(1), 50–72.

Brunetti, C., Reiffen, D., 2014. Commodity index trading and hedging costs. J. Finan. Markets 21, 153–180.

Chang, E.C., 1985. Returns to speculators and the theory of normal backwardation. J. Fin. 40(1), 193–208.

Cheng, I.-H., Xiong, W., 2014. The financialization of commodity markets. Ann. Rev. Finan. Econ. 6, 419–444.

CME Group, 2009. An introduction to variable storage rates in wheat futures, Research and Product Development. Accessed February 2016, available at https://www.cmegroup.com/trading/agricultural/files/vsr-whitepaper.pdf

Dorward, A., 2011. Getting real about food prices. Dev. Pol. Rev. 29(6), 647–664.

Garcia, P., Irwin, S.H., Smith, A., 2015. Futures market failure? Am. J. Agr. Econ. 97(1), 1–25.

Ghosh, J., 2010. The unnatural coupling: Food and global finance. J. Agrar. Change 10(1), 72–86.

Guilleminot, B., Ohana, J.-J., Ohana, S., 2014. The interaction of speculators and index investors in agricultural derivatives markets. Agr. Econ. 45(6), 767–792.

Hamilton, J.D., 2008. Regime switching models. In: Durlauf, N., Blume, L.E. (Eds.), The New Palgrave Dictionary of Economics, 2nd edition. Palgrave Macmillan, London.

Hansen, B.E., 1992. Test for parameter instability in linear models. J. Pol. Modeling 14(4), 517–533.

Harrigan, J., 2014. The Political Economy of Arab Food Sovereignty. Palgrave Macmillan, London, UK.

Headey, D., 2011. Rethinking the global food crisis: The role of trade shocks. Food Pol. 36(2), 136–146.

Hicks, J., 1939. Value and Capital. Oxford University Press, Cambridge, UK.

Hirshleifer, D., 1988. Residual risk, trading costs, and commodity futures risk premia. Rev. Finan. Stud. 1(2), 173–193.

Hirshleifer, D., 1990. Hedging pressure and futures price movements in a general equilibrium model. Econometrica 58(2), 411–428.

Irwin, S.H., 2013. Commodity index investment and food prices: Does the "Masters Hypothesis" explain recent price spikes? Agr. Econ. 44(s1), 29–41.

Irwin, S.H., Sanders, D.R., 2012. Testing the Masters Hypothesis in commodity futures markets. Energy Econ. 34(1), 256–269.

Irwin, S.H., Garcia, P., Good, D.L., Kunda, E.L., 2011. Spreads and nonconvergence in Chicago Board of Trade corn, soybean, and wheat futures: Are index funds to blame? Appl. Econ. Perspect. Pol. 33(1), 116–142.

Kaldor, N., 1939. Speculation and economic stability. Rev. Econ. Stud. 7(1), 1–27.

Keynes, J.M., 1930. A Treatise on Money, Vol. 2. Macmillan, London, UK.

Lautier, D., 2005. Term structure models of commodity prices: A review. J. Alternative Invest. 8(1), 42–64.

MacKinnon, J.G., 1996. Numerical distribution functions for unit root and cointegration tests. J. Appl. Economet. 11(6), 601–618.

Mayer, J., 2012. The growing financialization of commodity markets: Divergences between index investors and money managers. J. Devel. Stud. 48(6), 751–767.

Newey, W.K., West, K.D., 1987. A simple positive semi-definite, heteroscedasticity and autocorrelation consistent covariance matrix. Econometrica 55(3), 703–708.

Ng, S., Perron, P., 2001. Lag length selection and the construction of unit root tests with good size and power. Econometrica 69(6), 1519–1554.

Nissanke, M., 2012. Commodity market linkages in the global financial crisis: Excess volatility and development impacts. J. Dev. Stud. 48(6), 732–750.

Ott, H., 2014. Extent and possible causes of intrayear agricultural commodity price Volatility. Agr. Econ. 45(2), 225–252.

Sanders, D.R, Irwin, S.H., 2017. Bubbles, froth and facts: Another look at the Masters Hypothesis in commodity futures markets. J. Agr. Econ. 68(2), 345–365.

Schmidt, T.P., 2016. The Political Economy of Food and Finance. Routledge, New York.

Stebbins, C., 2011. Insight: CME says wheat converging, but traders scoff. Reuters Business News, September 16. Accessed March 29, 2013, available at http://www.reuters.com/article/2011/09/16/us-markets-wheat-cme-idUSTRE78F68Y20110916.

Tadesse, G., Algieri, B., Kalkuhl, M., von Braun, J., 2014. Drivers and triggers of international food price spikes and volatility. Food Pol. 47, 117–128.

Tang, K., Xiong, W., 2012. Index investment and financialization of commodities. Finan. Anal. J. 68(6), 54–74.

Timmer, C.P., 2009. Did speculation affect world rice prices? ESA Working Paper No. 09-07, Agricultural Development Economics Division, Food and Agriculture Organization of the United Nations (FAO).

U.S. Senate, 2009. Excessive speculation in the wheat market. Majority and Minority Staff Report, Permanent Subcommittee on Investigations, Committee on Homeland Security and Governmental Affairs, United States Senate.

Ventosa-Santaularia, D., 2012. Unbalanced regressions and spurious inference. Open J. Statist. 2, 297–299.

Working, H., 1948. Theory of the inverse carrying charge in futures markets. J. Farm Econ. 30(1), 1–28.

Working, H., 1949. The theory of price and storage. Am. Econ. Rev. 39(6), 1254–1262.

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Online-Appendix