Understanding the non-convergence of agricultural futures via stochastic storage costs and timing options

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\textbf{A B S T R A C T}
This paper studies the market phenomenon of non-convergence between futures and spot prices in the grains market. We postulate that the positive basis observed at maturity stems from the futures holder's timing options to exercise the shipping certificate delivery item and subsequently liquidate the physical grain. In our proposed approach, we incorporate stochastic spot price and storage cost, and solve an optimal double stopping problem to give the optimal strategies to exercise and liquidate the grain. Our new models for stochastic storage rates lead to explicit no-arbitrage prices for the shipping certificate and associated futures contract. We calibrate our models to empirical futures data during the periods of observed non-convergence, and illustrate the premium generated by the shipping certificate.

\section{1. Introduction}
Standard no-arbitrage pricing theory asserts that spot and futures prices must converge at expiration. Nevertheless, during 2004–2009 traders observed significantly higher expiring futures prices for corn, wheat, and soybeans on the CBOT compared to the spot price of the physical grains. As shown in Fig. 1, the unprecedented differential between cash and futures prices reached its apex in 2006, where at the height of the phenomenon, CBOT corn futures had surpassed spot corn prices by almost 30%\textsuperscript{1}! In the literature, Adjemian et al. (2013) and Aulerich et al. (2011) reported that on July 1, 2008, the price for a July 2008 CBOT wheat futures contract closed at $8.50 per bushel. On the other hand, the corresponding cash price in the Toledo, Ohio delivery market was only $7.18 per bushel, a price differential of $1.32/bu (+15%). Irwin et al. (2009) first coined the term “non-convergence” for this phenomenon of observed positive premium, which recurred persistently from 2004 onwards. According to their study, “performance has been consistently weakest in wheat, with futures prices at times exceeding delivery location cash prices by $1.00/bu, a level of disconnect between cash and futures not previously experienced in grain markets.”

However, a small difference between expiring futures and cash prices does not necessarily imply a market failure. Before expiration, futures and cash prices may differ due to the convenience yield, storage costs, or financing costs. Upon expiration, if cash

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prices are lower/higher than futures prices, then arbitrageurs may profit from trading simultaneously in the spot and futures markets. If sufficient numbers of arbitrageurs engage in these trades, they will drive cash and futures prices to convergence at expiration. In fact, the futures expiration date and delivery date may also differ. After the last trade date, the exchange contacts the longest outstanding long who is notified of his obligation to undertake delivery. Before the month’s end, the delivery instrument is then exchanged at the settlement price between long and short parties. Therefore, since the delivery process does not occur immediately after the last trade date, cash and futures prices might still differ by a spread called the basis. In this paper, we use the following definition for the basis:

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basis = \text{futures price} - \text{spot price}.\]

**Fig. 1** displays the basis time series associated with the expiring futures on soybeans and corn.

Since the short party may choose the location and time to deliver, Biagini and Bjork (2007) posit that futures price should be biased below the spot price on the last trade date. However, their theoretical model would yield the opposite of the empirical observations in the grain markets. In fact, the positive basis in the CBOT grain markets between 2004 and 2009 were too large to have been caused by the small inefficiencies of the delivery process. This motivates us to investigate the factors that drive the non-convergence phenomenon.

In order to explain the positive premium, one must turn to embedded long-side options in the futures. Long-side options in futures markets depend totally on the idiosyncrasies of each commodity’s exchange traded structure. The survey paper by Carmona and Coulon (2013) demonstrates the appropriate model for a commodity varies highly depending on storability, instantaneous utility, and alternatives. At expiration, a CBOT agricultural futures contract does not deliver the physical grains but an artificial instrument called the shipping certificate that entitles its holder to demand loading of the grains from a warehouse at any time. Before exercising the option to load, the holder must pay a fixed storage fee to the storage company,\(^1\) as stipulated in the certificate. Since the storage capacity of grain elevators is limited and expensive, the number of grain elevators is fixed to a minimum necessary to efficiently carry out transfers of grain from one transport system to another.\(^2\) Thus, like a fractional-reserve banking system, shipping certificates alleviate the congestion of grain elevators by only keeping enough grain on hand to satisfy instant withdrawal demand. A detailed explanation on the structure of the shipping certificate market can be found in Aulerich et al. (2011) and Garcia et al. (2014).

In this paper, our storage differential hypothesis posits that when the certificate storage rate is sufficiently low, investors will pay a premium for the certificate over the spot grain in order to save on storage cost over time, resulting in non-convergence of futures and spot prices. When the storage cost of the certificate is set lower than the true storage cost paid by the regular firm, the regular firm will cease to issue the unprofitable shipping certificates. Since shipping certificates can only be issued by a set number of regular firms with limited inventories, the market cannot issue certificates with lower fixed storage rates to keep the market flowing. Instead, since the supply of certificates remains fixed, the value of existing shipping certificates will be bid up in the secondary market, resulting in a premium over the spot price. On the other hand, during periods where the certificate storage rate is set much higher than the market storage rate, the certificate should not command any premium over the spot because agents would exercise and store at the lower market rate. Therefore, as shown by Aulerich et al. (2011), large quantities of certificates remaining unredeemed under the storage differential hypothesis becomes a strong predictor of non-convergence. In fact, in 2009 under mounting evidence that storage differentials were responsible for non-convergence, the CBOT raised the certificate storage rate for wheat, after which non-convergence decreased significantly.\(^3\) This observation is consistent with our findings in this paper.

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\(^1\) Only a small number of storage companies that have contracts with the futures exchange are allowed to issue shipping certificates. They are also called the regular firms in the industry.


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