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Joseph M. Santos

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[*] The author is Professor of Economics, Department of Economics, South Dakota State University, Box 504, Brookings, S.D. 57007, 605.688.4846, joseph.santos@sdstate.edu.
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Grain Futures Markets: What Have *They* Learned?

Taken together, studies that examine how well commodity futures markets perform find that risk premiums are common—and so unbiasedness is not—and markets are not uniformly efficient across commodities or forecast horizons. This large body of research sheds important light on whether and to what extent commodity-futures markets forecast optimally future spot prices and, so, enable commercials to manage price risk by effectively parsing out much of it to speculators, a process that improves the total welfare of an economy with competitive but otherwise-incomplete markets. Nevertheless, that speculators can, in effect, improve welfare in this way has done little to quell popular hostilities toward futures markets. Such hostilities—and, in particular, those directed at speculators—in North America date to the inception of these markets in the nineteenth century, and have contributed to the unflattering depiction of the early futures exchange as an inchoate and poorly managed institution that initially served only the (illegitimate) aspirations of gamblers, an original-sin creation narrative that surely compromises the legitimacy of modern futures markets. Unfortunately, economists' understanding of early commodity-futures markets is particularly fragmented—the extant literature focuses almost exclusively on the post-World War II era—and, as such, claims regarding the performance of early futures markets remain largely unsubstantiated in any quantitatively measurable sense. In this paper, I test and compare the efficiency properties of wheat, corn, and oats futures prices on the Chicago Board of Trade (CBT) from 1880 to 1890 and from 1997 to 2007. I demonstrate that, on balance, these nascent nineteenth-century grain-futures markets were, like their contemporary counterparts in this case, mostly efficient. As such, these results support the claims of early proponents of futures markets who argued that the development of the futures exchange was shaped primarily by commercial interests who sought to mitigate price risk.

Keywords: commodities futures markets, unbiasedness, efficiency, Chicago Board of Trade.

Introduction

Studies that examine how well commodity futures markets perform abound. Most sample some portion of the late-twentieth century and assess futures-market performance in the contexts of two related properties: efficiency and unbiasedness. Briefly, a futures price is both efficient and unbiased when it equals the expected value of its corresponding future spot price; in contrast, a futures price is efficient but biased when it differs from the expected value of its corresponding future spot price specifically because of a risk premium manifested by risk-averse commercial traders. Because the time-series behaviors of most commodity-price series fail to reject the hypothesis that they contain unit roots, recent studies of their performance employ a two-step co-integration and error-correction methodology and, in doing so, test for these properties in both long-run (dynamic-equilibrium) and short-run (dynamic-disequilibrium) contexts. For example, Beck (1994) tests cattle, orange juice, corn, copper, and cocoa markets; Kellard, Newbold, Rayner, & Ennew (1999) test Brent crude, hog, soybean, gasoil, and cattle (as well as foreign exhange) markets; and, McKenzie & Holt (2002) test, and allow for short-run time-varying risk premia in, cattle, hog, corn, and soybean markets. Taken together, these studies find that risk premiums are common—and so unbiasedness is not—and markets are not uniformly efficient across commodities or forecast horizons.

This large body of research sheds important light on whether and to what extent commodity-futures markets satisfy their raison d'être: namely, to forecast optimally future spot prices and, so, enable commercials to manage price risk by effectively parsing out much of it to speculators, a process that improves the total welfare of an economy with competitive but otherwise-incomplete markets. Nevertheless, that speculators can, in effect, improve welfare in this way has done little to quell popular hostilities toward futures markets. Of course, this is nothing new. Such hostilities—and, in particular, those directed at speculators—in North America date to the inception of these markets in the nineteenth century, when producers grew to resent exchanges for registering weak grain prices around harvest (when most sought to sell their crops), and the population more generally grew to resent exchanges for ostensibly gambling on, of all things, the price of food. Perhaps not surprisingly, these hostilities have contributed to a popular and unflattering depiction of the early futures exchange as an inchoate and poorly managed institution that initially served only the (illegitimate) aspirations of gamblers, an original-sin creation narrative that surely compromises the legitimacy of modern futures markets.

Of course, futures exchanges throughout North America survived early populist attempts to extinguish them. The historical record reveals clearly that governments, courts, and legislatures held consistently to the notion that futures exchanges, though neither infallible nor above the law, benefited producers and the grain trade more generally. Agricultural historians have largely agreed; at the very least they have marginalized the damaging effects that welfare-reducing (irrational) speculation had on the performance of early grain-futures trading. Nevertheless, economists' understanding of early commodity-futures markets is particularly fragmented—the extant literature focuses almost exclusively on the post-World War II era—and, hence, such claims regarding their performance remain largely unsubstantiated in any quantitatively measurable sense. Even so, futures-price data are available as early as 1877, when the CBT—which pioneered grain futures trading in May, 1865—began to publish the daily prices of several of their contracts, a practice that it continued until 1890.

So, in this paper, I test and compare the efficiency properties of wheat, corn, and oats futures prices on the Chicago Board of Trade (CBT) then—1880 to 1890—versus now—1997 to 2007. Because the futures prices and their corresponding future spot prices that I examine are all non-stationary, I employ a co-integration and error-correction methodology. I also introduce and apply a measure of relative efficiency. My results demonstrate that, on balance, these nascent nineteenth-century grain-futures markets were, like their contemporary counterparts in this case, mostly efficient. As such, these results support the claims of early proponents of futures markets, including many early grain-trade historians, who argued that the development of the futures exchange was shaped primarily by commercial interests who sought to mitigate price risk (based on their and speculators' rational expectations of future spot prices).

The Origins of Commodity Futures Trading in the United States

Grain futures trading in the United States was spurred by the completion of the Illinois-Michigan Canal (1848), the growth of Lake Michigan commerce that followed, and a confluence of innovations, including grain elevators, railroads, grain exchanges, and forward contracts. The canal allowed farmers in the hinterlands along the Illinois River to ship grain to Lake Michigan dealers, who collected and transported much of it to Chicago, Milwaukee, and Racine. Elevators and the railroad facilitated high-volume grain storage and shipment, respectively. Meanwhile commodity exchanges, spawned from boards of trade along Lakes Erie, Michigan, and St. Clair, established a system of staple grades, standards and inspections that rendered grain fungible and, hence, made possible organized trading in spot and forward markets (Baer & Saxon, 1949, p. 10; Chandler, 1977, p. 211). According to Hieronymus (1977), the first such recorded "time contract" was made on March 13, 1851 (74).[1]

The Board of Trade of the City of Chicago (CBT) was established in 1848 by a State-of-Illinois corporate charter (Boyle, 1920, p. 38; Lurie, 1979, p. 27). In 1859 the CBT became a state-chartered private association. As such, the Illinois legislature sanctioned it to establish rules "for the management of their business and the mode in which it shall be transacted, as they may think proper"; to arbitrate over and settle disputes with the authority as "if it were a judgment rendered in the Circuit Court"; and to inspect, weigh and certify grain and grain trades such that these certifications would be binding upon all CBT members (Lurie, 1979, p. 27). On March 27, 1863, the Chicago Board of Trade adopted its first rules and procedures for trading in forward contracts (Hieronymus, 1977, p. 76). And in May 1865, it transformed actively traded and reasonably homogeneous forward contracts into futures contracts.[2] Most grain-trade historians agree that futures trading ripened in the mid-to-late 1860s, by which time the CBT had become the U.S.'s premier organized grain (and provisions) futures exchange (Baer & Saxon, 1949, p. 87; Chandler, 1977, p. 212; Hoffman, 1932, p. 29; Rothstein, 1982, p. 67).[3]

By the late 19th century, the CBT and other similarly private and, to a large extent, self-regulated futures exchanges facilitated the North American grain trade, which depended heavily on bank finance to plant, harvest, store, and transport crops.[4] Futures contracts enabled the trade to parse out grain-price risk to speculators and, by doing so, garner bank loans in larger quantities and at lower rates than it could otherwise (Baer & Saxon, 1949, p. 212). Evidence that trading—both commercial and speculative—was by this time thick is strong. As early as the 1870s, CBT officials disclosed that traders settled more than 90% of grain futures contracts by offset rather than delivery (Lurie, 1979, p. 59), and "by 1885, the volume of trading [on the CBT] was as large and perhaps somewhat larger than it [was in the 1930s]" (Hoffman, 1932, p. 30). Figure 1, which reports futures trading volume for cereal grains on United States exchanges in the early nineteenth century, suggests much the same: for the period 1884 to 1888, the five-year average annual futures trading volume was 23.6 billion contract bushels, or eight times the five-year average annual amount of cereal grain produced during the same period; the comparable figure for the period 1966 to 1970 was 25.8 billion contract bushels, or four times the five-year average annual amount of cereal grains produced during the same period. These data support Ferris (1966), who notes that "[t]rading in wheat futures was already highly developed in the late-nineteenth century and probably understood by relatively more people than now" (107).

Of course, futures trading had its discontents. Many North American producers alleged that these exchanges conspired with elevators, railroads, and banks to supply suboptimal markets, storage, transportation, and credit, respectively. Most resented that grain prices were weakest during and shortly after the harvest, when most sought to sell their crops, a resentment that they directed squarely at the exchanges, which registered these low prices (Irwin, 2001, p. 90). Others opposed futures trading on moral grounds: speculating was tantamount to gambling, and gambling on grain—which ostensibly moved foodstuff prices (to the consternation of either consumers or producers)—was unethical (Baer & Saxon, 1949, p. 56; Hoffman, 1932, p. 5; Lurie, 1979, pp. 53, 115). That some traders attempted throughout the late-nineteenth century to manipulate grain prices only fueled such sentiments.[5] Consequently, the CBT struggled throughout much of the late-nineteenth century to disassociate itself with these and other such abuses and, hence, secure its legitimacy. It fought to distinguish itself from bucket shops—gambling houses to which the CBT bore a largely superficial resemblance; and it fought to defeat the anti-option bills of the 1890s that sought to outlaw options and, by association, futures trading (Lurie, 1979, pp. 76, 110).

Ultimately, futures trading in Chicago as well as throughout North America escaped these and other early threats largely unscathed. Governments, courts, and legislatures held consistently to the notion that futures markets, though neither infallible nor above the law, benefited producers and the grain trade more generally. To be sure, agricultural historians have largely agreed and, as such, have mostly marginalized the damaging effects that gratuitous—and, often, amateur—speculation had on the performance of early grain-futures trading (Boyle, 1920, pp. 62-74; Hieronymus, 1977, p. 76; Rothstein, 1982, p. 60). Nevertheless, such claims remain largely unsubstantiated in any quantitatively measurable sense.

Methodology

Economists assess the performance of a futures market in the contexts of two related futures-price properties: efficiency and unbiasedness. A futures price, F_t, is both efficient and unbiased when $F_t = E(S_{t+h}/\Omega_t)$: that is, F_t equals the expected value of its corresponding h-period-ahead spot price, S_{t+h}, where Ω_t represents the information set available to traders at time t. In contrast, a futures price, F_t, is efficient but biased when $F_t \neq E(S_{t+h}/\Omega_t)$ *because* of a risk premium manifested by risk-averse commercial traders (whose net-short or net-long hedging positions effectively bias the futures price away from the expected value of its corresponding spot price), a condition that Keynes identified as either normal backwardation $[F_t < E(S_{t+h}/\Omega_t)]$ or contango $[F_t > E(S_{t+h}/\Omega_t)]$ (Keynes, 1930, pp. 143-144); otherwise, $F_t \neq E(S_{t+h}/\Omega_t)$ indicates futures-market inefficiency.

The standard test for unbiasedness is the test of the null hypothesis $c_0 = 0 \; and \; c_1 = 1$ in Equation (1), where u_{t+h} is a white-noise disturbance term with constant variance.

$$S_{t+h} = c_0 + c_1 F_t + u_{t+h} \tag{1}$$

Because unbiasedness requires efficiency *and* risk neutrality, if we reject the null hypothesis that the market is unbiased, we do so because either the market is efficient and commercial traders are risk averse, or the market is inefficient (regardless of whether traders are risk averse) (Beck, 1994, p. 249; Danthine, 1978, pp. 90-91). Co-integration techniques permit researchers to infer statistically which of these characterizations—unbiased, efficient but biased, or inefficient—are appropriate when commodity-price data are not stationary—the data contain unit roots (and, so, conventional hypotheses tests for the significance of the magnitudes of the estimated coefficients $\hat{c}_0$ and $\hat{c}_1$ in Equation (1) are inappropriate in any case).

In particular, if the current futures price, F_t, and its corresponding future spot price, S_{t+h}, are individually $I(1)$ but co-integrated, then a long-run relationship exists between them; that is, a so-called co-integrating vector, $[c_0, -c_1]$ from Equation (1), exists that renders u_{t+h} a stationary series. As such, the current futures price reflects in the long run the (rationally expected) fundamentals that determine its corresponding future spot price; and, so, the futures price is, at the very least, efficient in the long run. When the co-integrating vector is not significantly different from $[0, -1]$, the futures price is also unbiased in the long run.

If the futures price is efficient in the long run, and the short-run disequilibrium dynamics of the futures price reflect this long-run efficiency, then the futures price is also efficient in the short run. In order to infer statistically the short-run characteristics of co-integrated series, the Granger Representation Theorem instructs that Equation (1) be written in the error-correction-model (ECM) form specified in Equation (2), where $\hat{u}_t$ is the residual from Equation (1) (Engle & Granger, 1987, p. 255).

$$\Delta S_{t+1} = a_0 - a_1 \hat{u}_t + a_2 \Delta F_t + \sum_{i=1}^{m} \beta_i \Delta S_{t+1-i} + \sum_{i=1}^{n} \delta_i \Delta F_{t-i} + \varepsilon_{t+1} \tag{2}$$

Specifically, if the futures price is efficient but biased in the long run, then it is efficient in the short run when the joint hypothesis $a_1 = 1, \; a_1 c_1 = a_2 \neq 0 \; and \; \beta_i = \delta_i = 0 \; \forall \; i$ holds; whereas, if the futures price is unbiased in the long run, it is efficient in the short run when the joint hypothesis $a_1 = a_2 = 1 \; and \; \beta_i = \delta_i = 0 \; \forall \; i$ holds (where, in this case, u_t is defined as $S_t - F_{t-1}$) (Beck, 1994, p. 250; McKenzie & Holt, 2002, p. 1521).

As Beck (1994, p. 250) demonstrates, the justifications for these linear restrictions are apparent when: we rewrite Equation (2) as Equation (3); we choose values for $a_1, \; a_2, c_1, \beta_i$, and δ_i so that prior (to period t) realizations of the futures and spot prices explain none of the behavior of S_{t+1}; and we impose the restrictions, $c_0 = 0$ and $c_1 = 1$, when the futures price is unbiased in the long run.

$$S_{t+1} = (a_0 + a_1 c_0) + (1 - a_1)S_t + a_2 F_t + (a_1 c_1 - a_2)F_{t-1} + \sum_{i=1}^{m} \beta_i \Delta S_{t+1-i} + \sum_{i=1}^{n} \delta_i \Delta F_{t-i} + \varepsilon_{t+1} \quad (3)$$

Finally, to get a sense of the relative short-run efficiency of futures markets today versus in the nineteenth century, I propose the following relative measure inspired by the work of Kellard, et al. (1999). That is, when the short-run efficiency restrictions hold, we can rewrite Equation (2) as Equation (4).

$$\Delta S_{t+1} = A + B(c_1 F_t - S_t) + \varepsilon'_{t+1} \quad (4)$$

Where $A = (a_0 + c_0)$ and $B = 1$. I let a_0, c_0, and c_1 in Equation (4) take the values of their respective least-squares estimators from OLS regressions of the models specified in Equations (1) and (2), and I compute the relative variance of ε'_{t+1}, which I denote $1 - \tilde{R}_R^2$. Because $\tilde{R}_R^2$ is necessarily less than the R_{UR}^2 recovered from an unrestricted regression of the model specified in Equation (2), $1 - \tilde{R}_R^2$ is necessarily greater than $1 - R_{UR}^2$. Hence, Equation (5) amounts to a relative measure of efficiency, φ, that is bounded by 0 and 1, where $\varphi = 0$ implies that the market is completely inefficient, and $\varphi = 1$ implies that the market is completely efficient.

$$\varphi = \frac{1 - R_{UR}^2}{1 - \tilde{R}_R^2} \quad (5)$$

The Data

The data consist of open-outcry futures prices for wheat, corn, and oats contracts traded on the Chicago Board of Trade from 1997 to 2007 and from 1880 to 1890.[6] The spot-price is in every case the corresponding closing futures price at contract expiration [See Beck (1994, p. 251)].[7] I acquired the contemporary data from the Chicago Board of Trade.[8] Five contracts were available for each commodity throughout each year; in every case, expiration months (followed here by their exchange-assigned labels) were March (H), May (K), July (N), September (U), and December (Z). I collected the nineteenth-century data from the individual editions of the *Annual Report of the Board of Trade of the City of Chicago.* Twelve contracts were available for each commodity throughout each year.

As is evident from the preceding methodology section, my analysis requires, for each commodity in each era, futures prices, F_t, and their corresponding spot prices, S_{t+h}. As such, the maximum number of observations is, in every case, limited by the number of contracts available in each year. And, because the forecast horizon, h, between the observation of F_t and its corresponding observation of S_{t+h} must be less than or equal to the time between contracts (so as not to overlap forecast horizons and, by doing so, induce a moving average process in the residuals), the number of observations necessarily falls as the forecast horizon rises beyond the time between contracts.

I limit my analysis to four- and eight-week forecast horizons because of the paucity of nineteenth-century data available at longer forecast horizons. For the period 1997 to 2007, contracts expire at no less than two-month intervals; hence, data on all five contracts comprise both the four- and eight-week forecast-horizon pools for each commodity. For the period 1880 to 1890, contracts expire at one-month intervals. So, in this case, data on all twelve contracts comprise the four-week forecast-horizon pool for each commodity; whereas two subsets of data, each consisting of six contracts (that expire at no less than two-month intervals), comprise the two eight-week forecast-horizon pools for each commodity. Table 1 reports descriptive statistics for these data, which Figures 2A through 3I illustrate. A cursory visual inspection of these data suggests what econometric tests will ultimately reveal: they are, if anything, difference (as opposed to trend) stationary; hence, if they indeed contain a unit root, co-integration analyses of their time-series behaviors are appropriate.

Empirics

In order for two time series to be co-integrated, each must contain a single unit root: each series must be difference rather than deterministic-trend stationary. I use the Augmented-Dickey-Fuller test to determine the stationary properties of each series. Equation (6) specifies the ADF regression model. The null hypothesis is that the price series is not stationary.

$$\Delta x_t = \mu + \gamma x_{t-1} + \delta t + \gamma_1 \Delta x_{t-1} + \cdots + \gamma_p \Delta x_{t-p} + \varepsilon_t \qquad (6)$$

The test statistic—in this case, the so-called τ statistic—on $\hat{\gamma}$ in a regression of this model must exceed the appropriate critical values according to Dickey and Fuller (1981, p. 1063, Table VI) in order to reject $H_0\colon x_t$ is not trend stationary. I choose p—the number of lagged terms of Δx_t to include on the right side of the regression—so as to "whiten" the estimated error term, $\hat{\varepsilon}_t$. Table 2 reports the results of these tests on all series. The time-series behaviors of all futures- and spot-price series in both periods fail to reject the null hypothesis that the data contain a unit root. Hence, futures prices, F_t, and their corresponding h-period-ahead spot prices, S_{t+h}, can in theory be co-integrated.

I test for co-integration two ways in order to both reinforce my results through replication and to take advantage of the unique properties of each test. First, I use the ADF test to determine if the time-series behaviors of the estimated residuals, $\hat{u}_{t+h}$, which I recover from an OLS regression of the model specified in Equation (1), reject the null hypothesis that these data contain a unit root. If so, the OLS estimates of c_0 and c_1 constitute a co-integrating vector, $[\hat{c}_0, -\hat{c}_1]$, that by definition renders u_{t+h} a stationary series; in this case, the corresponding futures and spot prices are co-integrated. Table 3 reports the results of these tests for all series under the column heading $ADF\ \tau$. In every case, the times-series behaviors of the estimated residuals reject the null hypothesis that these data contain a unit root. Hence, according to this test, futures prices, F_t, and their corresponding h-period-ahead spot prices, S_{t+h}, are co-integrated and, hence, these markets are, at the very least, efficient in the long run.

Second, I use the Johansen (1988) trace test for co-integration. This procedure tests for the presence of a co-integrating vector as well as tests for the likelihood that the vector's terms take specific long-run values (something the OLS-based ADF procedure cannot do); hence, the Johansen procedure can test the null hypotheses that, say, $c_0 = 0$ or $c_1 = 1$ or $c_0 = 0$ *and* $c_1 = 1$, the latter is the null hypothesis for unbiasedness. Table 3 reports the results of these Johansen trace tests on all series. In every case, the times-series behaviors of the futures- and spot-price series reject the null hypothesis that no co-integrating relationship exists (column six), but fail to reject the null hypothesis that one co-integrating relationship exists (column seven). Hence, these results reinforce those associated with the preceding ADF approach: these markets are, at the very least, efficient in the long run. Moreover, the time-series behaviors of three subsamples fail to reject the null hypothesis that the market is unbiased in the long run; these subsamples include the four-week wheat series and eight-week oats series for the period 1997 to 2007, and the eight-week (odd-month) oats series for the period 1880 to 1890. Meanwhile, the time-series behaviors of several other series in both periods fail to reject that either $c_0 = 0$ or $c_1 = 1$.

To characterize the short-run properties of these (long-run-efficient) futures prices, I begin by estimating for each series an OLS regression of the ECM specified in Equation (2), where once again $\hat{u}_t$ is the residual from an OLS regression of the model specified in Equation (1). I begin with three lags each of ΔS and ΔF and test down accordingly based on the individual significance levels of the estimated coefficients. I compute all t (and forthcoming Wald) test statistics with heteroskedastic-consistent standard errors (White, 1980). Table 4 reports the results. In every case, the time-series behavior of the data cannot reject the null hypothesis that $a_0 = 0$, while it can reject the two independent null hypotheses that $a_1 = 0$ and $a_2 = 0$. Hence, as economists would expect, changes in the spot price reflect short-run disequilibria, $\hat{u}_t$, and changes in the corresponding current futures price, ΔF_t. Moreover, as columns eight through eleven indicate, information other than the current futures price—and, in particular, information on past futures and spot prices—are not relevant to predicting the corresponding spot price in most cases; exceptions include select oat markets in both periods and select nineteenth-century wheat and corn markets. Adjusted R^2s are generally higher for contemporary markets (column 12); and, based on six-period autocorrelation functions, the null hypothesis that the estimated residuals from the ECM regression are white-noise processes cannot be rejected in any case (column 13), an outcome that supports short-run efficiency.

To this point, evidence from ECM modeling suggests that the short-run properties of contemporary and nineteenth-century futures markets are similar, though evidence of short-run inefficiency is seemingly more prevalent in the nineteenth-century series. Nevertheless, whether the short-run disequilibrium dynamics of these futures prices reflect in a statistically significant way the natures of their respective long-run efficiencies is another matter, which I address next.

Table 5 reports the results of tests of short-run efficiency. The column titled "Co-integration Regression—Unbiasedness," which reports the Johansen procedure's test of the null hypothesis that $c_0 = 0$ *and* $c_1 = 1$, is repeated here (from column 10 of Table 3) for convenience. Recall that, if, on the basis of this test statistic, the futures price is efficient but biased in the long run, then efficiency in the short run requires that the joint hypothesis $a_1 = 1,\ a_1c_1 = a_2 \neq 0\ and\ \beta_i = \delta_i = 0\ \forall\ i$ holds; whereas, if, on the basis of this test statistic, the futures price is unbiased in the long run, efficiency in the short run requires that the joint hypothesis $a_1 = a_2 = 1\ and\ \beta_i = \delta_i = 0\ \forall\ i$ holds (where, in this latter case, u_t is constructed as $S_t - F_{t-1}$). The last column of Table 5 reports the relative measure of efficiency, φ, where $\varphi = 0$ implies that the market is completely inefficient, and $\varphi = 1$ implies that the market is completely efficient.

According to these test results, all wheat series are efficient in the short run. Moreover, the relative measure of short-run efficiency, φ, does not fall below 96% for any wheat series. Indeed, both a contemporary and a nineteenth-century series achieve a measure of 98%. Meanwhile, results for corn and oats markets are mixed: for corn, one contemporary and one nineteenth-century series is efficient in the short run; for oats, only a nineteenth-century series is efficient in the short run. The relative measures of short-run efficiency corroborate these results, and suggest that, in two instances, nineteenth-century futures prices are at least as efficient as their contemporary counterparts. As such, these results indicate that, on balance, nascent nineteenth-century grain-futures markets on the Chicago Board of Trade performed at a level similar to that of their contemporary counterparts.

Conclusion

The large body of research that examines the efficiency properties of commodity-futures markets has focused almost exclusively on markets in the latter part of the twentieth century. Hence, economists' understanding of how well nascent commodity-futures markets performed remains fragmented, even though futures-price data are available for the late-nineteenth century.

In this paper, I tested (on the assumption of a constant risk premium) the efficiency properties of wheat, corn, and oats futures prices on the Chicago Board of Trade (CBT) from 1880 to 1890 and from 1997 to 2007. I found that, in every case, futures prices and their corresponding future spot prices were non-stationary and co-integrated. Hence, futures prices in both periods were efficient in the long run: each reflected the long-run fundamentals that determined their corresponding future spot prices. Moreover, a contemporary four-week-wheat series, a contemporary eight-week-oats series, and a nineteenth-century eight-week-oats series were unbiased.

The short-run disequilibrium dynamics of futures prices and their corresponding spot prices indicated that all wheat series were efficient in the short run. A relative measure of short-run efficiency that I introduced did not fall below 96% for any wheat series; and, both a contemporary and a nineteenth-century wheat series achieved a relative measure of 98%. The corresponding results for corn and oats markets were mixed: for corn, one contemporary and one nineteenth-century series was efficient in the short run; for oats, only a nineteenth-century series was efficient in the short run. Relative measures of short-run efficiency corroborated these results, and suggested that, in two instances, nineteenth-century futures prices were at least as efficient as their contemporary counterparts.

Taken together, these results indicate that nascent nineteenth-century grain-futures markets on the Chicago Board of Trade were mostly efficient and, so, performed at a level similar to that of their contemporary counterparts in this case. As such, these results support the claims of early proponents of futures markets, including many early grain-trade historians, who argued that the development of the futures exchange was shaped primarily by commercial interests who sought to mitigate price risk.

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Table 1: Descriptive Statistics

	Futures	1997 – 2007					1880 – 1890				
					Mean Price Dollars / Bu					Mean Price Dollars / Bu	
	Horizon	Days	Contracts	OBS	Futures	Spot	Days	Contracts	OBS	Futures	Spot
Wheat	4 weeks	25—28	H,K,N,U,Z	52	$3.19	$3.17	26—28	1,2,...,12	121	$0.94	$0.92
	8 weeks	52—55	H,K,N,U,Z	52	$3.27	$3.17	53—55	1,3,..,11	50	$0.96	$0.94
	8 weeks						53--55	2,4,...,12	53	$0.96	$0.93
Corn	4 weeks	25-28	H,K,N,U,Z	52	$2.39	$2.35	26--28	1,2,...,12	108	$0.47	$0.46
	8 weeks	52—55	H,K,N,U,Z	52	$2.40	$2.35	53--55	1,3,..,11	47	$0.47	$0.46
	8 weeks						53--55	2,4,...,12	53	$0.46	$0.46
Oats	4 weeks	25—28	H,K,N,U,Z	52	$1.54	$1.61	26--28	1,2,...,12	121	$0.31	$0.30
	8 weeks	52—55	H,K,N,U,Z	52	$1.55	$1.61	51--55	1,3,..,11	46	$0.31	$0.31
	8 weeks						50--55	2,4,...,12	47	$0.32	$0.31

Table 2: Augmented-Dickey-Fuller Unit-Root Tests

	Futures Horizon	1997 – 2007 Contracts	OBS	$ADF\ \tau$[1] Futures	Spot	1880 – 1890 Contracts	OBS	$ADF\ \tau$ Futures (p)	Spot
Wheat	4 weeks	H,K,N,U,Z	51	-2.19	-2.33	1,2,...,12	120	-2.83	-2.71
	8 weeks	H,K,N,U,Z	51	-2.42	-2.33	1,3...,11	49	-1.83	-2.00
	8 weeks					2,4,...,12	52	-1.84	-2.15
Corn	4 weeks	H,K,N,U,Z	51	-2.03	-2.52	1,2,...,12	107	-2.78 (1)	-2.64
	8 weeks	H,K,N,U,Z	51	-1.12	-2.52	1,3...,11	46	-2.45	-2.90
	8 weeks					2,4,...,12	52	-2.27	-2.40
Oats	4 weeks	H,K,N,U,Z	51	-2.06	-3.02	1,2,...,12	120	-2.13	-2.08
	8 weeks	H,K,N,U,Z	51	-1.40	-3.02	1,3...,11	45	-3.27	-3.38
	8 weeks					2,4,...,12	46	-3.49	-2.77

[1] Tao statistic on γ in the Augmented Dickey Fuller (ADF) regression, $\Delta x_t = \mu + \gamma x_{t-1} + \delta t + \gamma_1 \Delta x_{t-1} + \cdots + \gamma_p \Delta x_{t-p} + \varepsilon_t$. An asterisk indicates significance at the 95% level, according to Dickey and Fuller (1981), p. 1063, Table VI of $H_0\colon x_t$ is not stationary.

Table 3: Co-integration Tests

Commodity, Period	Horizon	Contracts	OBS	$ADF\ \tau$[2]	λ_{trace}[3] $H_0: k = 0$	λ_{trace}[4] $H_0: k \leq 1$	c_0 $H_0: c_0 = 0$	c_1 $H_0: c_1 = 1$	$H_0: c_0 = 0,\ c_1 = 1$	k[5]
Wheat, 1997—2007	4 weeks	H,K,N,U,Z	52	-7.37*	29.81*	0.65	0.02 (0.02)	0.99 (0.09)	1.13	2
	8 weeks	H,K,N,U,Z	52	-7.32*	58.27*	0.79	0.15 (0.93)	0.92 (2.64)	14.12*	1
1880 – 1890	4 weeks	1,2,...,12	121	-10.83*	66.17*	7.70	-0.04 (4.81*)	1.02 (1.88)	21.88*	2
	8 weeks	1,3,...,11	50	-6.90*	84.70*	4.26	-0.08 (5.22*)	1.07 (3.60)	9.62*	1
	8 weeks	2,4,...,12	53	-5.93*	112.20*	6.75	-0.12 (15.52*)	1.10 (11.28*)	25.95*	1
Corn, 1997—2007	4 weeks	H,K,N,U,Z	52	-6.84*	56.87*	5.64	0.14 (1.87)	0.92 (3.11)	8.28*	1
	8 weeks	H,K,N,U,Z	52	-6.90*	85.33*	5.40	0.29 (7.43*)	0.85 (10.52*)	19.74*	1
1880 – 1890	4 weeks	1,2,...,12	108	-10.55*	54.36*	4.21	-0.01 (1.41)	1.01 (0.12)	12.75*	2
	8 weeks	1,3,...,11	47	-8.26*	85.03*	3.91	-0.01 (0.16)	1.00 (0.00)	3.86*	1
	8 weeks	2,4,...,12	53	-6.29*	40.90*	5.72	-0.06 (7.43*)	1.11 (6.00*)	9.10*	2

[2] Tao statistic on γ in the Augmented Dickey Fuller (ADF) regression, $\Delta x_t = \mu + \gamma x_{t-1} + \delta t + \gamma_1 \Delta x_{t-1} + \cdots + \gamma_p \Delta x_{t-p} + \varepsilon_t$. An asterisk indicates significance at the 95% level, according to Dickey and Fuller (1981), p. 1063, Table VI of H_0: x_t is not stationary.
[3] Johansen trace-test statistic for $H_0: k = 0$ ($no\ cointegrating\ relationship$).
[4] Johansen trace-test statistic for $H_0: k \leq 1$ ($at\ most\ one\ cointegrating\ relationship$).
[5] Lag lengths determined according to AIC criteria.

Table 3: Co-integration Tests: continued

Commodity, Period	Horizon	Contracts	OBS	$ADF\ \tau$[6]	λ_{trace}[7] $H_0: k = 0$	λ_{trace}[8] $H_0: k \leq 1$	c_0 $H_0: c_0 = 0$	c_1 $H_0: c_1 = 1$	$H_0: c_0 = 0, c_1 = 1$	k[9]
Oats, 1997--2007	4 weeks	H,K,N,U,Z	52	-7.04*	48.22*	2.40	-0.10 (1.34)	1.11 (3.57)	10.43*	1
	8 weeks	H,K,N,U,Z	52	-6.76*	54.44*	1.45	-0.09 (0.67)	1.08 (1.42)	3.54	1
1880 – 1890	4 weeks	1,2,...,12	121	-9.40*	40.23*	3.14	-0.02 (7.53*)	1.06 (6.41*)	8.54*	5
	8 weeks	1,3,...,11	46	-5.94*	34.17*	3.69	-0.04 (3.68)	1.14 (3.78)	3.78	2
	8 weeks	2,4,...,12	47	-4.88*	29.67*	4.26	-0.11 (9.40*)	1.33 (9.45*)	9.47*	2

[6] Tao statistic on γ in the Augmented Dickey Fuller (ADF) regression, $\Delta x_t = \mu + \gamma x_{t-1} + \delta t + \gamma_1 \Delta x_{t-1} + \cdots + \gamma_p \Delta x_{t-p} + \varepsilon_t$. An asterisk indicates significance at the 95% level, according to Dickey and Fuller (1981), p. 1063, Table VI of $H_0: x_t$ is not stationary.
[7] Johansen trace-test statistic for $H_0: k = 0$ ($no\ cointegrating\ relationship$).
[8] Johansen trace-test statistic for $H_0: k \leq 1$ ($at\ most\ one\ cointegrating\ relationship$).
[9] Lag lengths chosen according to AIC criteria.

Table 4: ECM Estimation [Equation (2) : $\Delta S_{t+1} = \hat{a}_0 - \hat{a}_1 \hat{u}_t + \hat{a}_2 \Delta F_t + \sum_{i=1}^{m} \hat{\beta}_i \Delta S_{t+1-i} + \sum_{i=1}^{n} \hat{\gamma}_i \Delta F_{t-i} + \hat{\varepsilon}_{t+1}$][10]

Commodity, Period	Horizon	Contracts	OBS	$\hat{a}_0$	$\hat{a}_1$	$\hat{a}_2$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\gamma}_3$	$\bar{R}^2$	$\chi^2(6)$[11]
Wheat, 1997--2007	4 weeks	H,K,N,U,Z	51	-0.00 (-0.08)	0.97 (6.29*)	0.82 (6.58*)					0.53	7.11
	8 weeks	H,K,N,U,Z	51	0.00 (0.01)	0.92 (4.07*)	0.69 (4.48*)					0.27	10.23
1880 -- 1890	4 weeks	1,2,...,12	117	0.00 (0.22)	1.14 (4.99*)	1.13 (5.59*)			0.12 (1.38)		0.25	2.77
	8 weeks	1,3,...,11	49	0.00 (0.01)	0.83 (2.55*)	0.72 (3.21*)					0.18	2.20
	8 weeks	2,4,...,12	52	0.00 (0.10)	0.99 (3.45*)	1.11 (4.81*)					0.25	2.35
Corn, 1997--2007	4 weeks	H,K,N,U,Z	51	-0.01 (-0.37)	1.10 (7.94*)	1.07 (18.55*)					0.80	2.00
	8 weeks	H,K,N,U,Z	51	-0.02 (-0.64)	1.39 (6.61*)	1.27 (7.44*)					0.59	1.62
1880 – 1890	4 weeks	1,2,...,12	105	0.00 (0.21)	1.30 (5.90*)	1.22 (6.37*)		0.18 (2.16*)			0.43	3.29
	8 weeks	1,3,...,11	43	0.00 (0.02)	1.40 (6.29*)	1.12 (4.78*)				0.20 (2.01)	0.46	2.66
	8 weeks	2,4,...,12	52	0.00 (0.09)	0.84 (5.13*)	0.93 (6.49*)					0.39	5.22
Oats, 1997--2007	4 weeks	H,K,N,U,Z	48	0.00 (0.01)	1.13 (7.37*)	1.22 (13.96*)				0.32 (4.23*)	0.68	2.57
	8 weeks	H,K,N,U,Z	48	-0.01 (-0.26)	1.10 (5.31*)	1.15 (4.44*)			0.25 (1.79)		0.40	6.26
1880 – 1890	4 weeks	1,2,...,12	119	0.00 (0.38)	0.59 (2.99*)	0.96 (6.21*)	-0.36 (2.37*)				0.38	10.94
	8 weeks	1,3,...,11	45	0.00 (0.25)	0.83 (3.66*)	0.84 (5.85*)					0.44	5.43
	8 weeks	2,4,...,12	46	0.00 (0.07)	0.52 (2.28*)	0.76 (4.46*)					0.42	11.75

[10] An asterisk indicates significance at the 95% level. t statistics in parentheses.
[11] P-value for a Box-Pierce Q-statistic for H_0: *no autocorrelation on ECM regression*; lag length on autocorrelations is 6.

Table 5: Unbiasedness, Efficiency[12]

				Co-integration Regression	ECM-Based Measures of Efficiency		
Commodity, Period	Horizon	Contracts	OBS	Unbiasedness[13]	LR Unbiasedness[14]	LR Efficiency[15]	$\varphi = \frac{1 - R_{UR}^2}{1 - R_R^2}$
Wheat, 1997--2007	4 weeks	H,K,N,U,Z	51	1.13	5.64		0.98
	8 weeks	H,K,N,U,Z	51	14.12*		8.72	0.97
1880 – 1890	4 weeks	1,2,...,12	117	21.88*		10.30	0.97
	8 weeks	1,3,...,11	49	9.62*		10.36	0.98
	8 weeks	2,4,...,12	52	25.95*		4.32	0.96
Corn, 1997--2007	4 weeks	H,K,N,U,Z	51	8.28*		15.00	0.93
	8 weeks	H,K,N,U,Z	51	19.74*		20.12*	0.85
1880 – 1890	4 weeks	1,2,...,12	105	12.75*		16.55*	0.91
	8 weeks	1,3,...,11	43	3.86*		15.62*	0.87
	8 weeks	2,4,...,12	52	9.10*		3.21	0.98
Oats, 1997--2007	4 weeks	H,K,N,U,Z	48	10.43*		29.81*	0.86
	8 weeks	H,K,N,U,Z	48	3.54	37.83*		0.92
1880 – 1890	4 weeks	1,2,...,12	119	8.54*		22.89*	0.91
	8 weeks	1,3,...,11	45	3.78	15.06		0.98
	8 weeks	2,4,...,12	46	9.47*		39.75*	0.86

[12] An asterisk indicates significance at the 95% level.
[13] Wald test statistic for $H_0: c_0 = 0, c_1 = 1$ in Equation (1). These statistics appear in the second-to-last column of Table 3; I report them here for convenience.
[14] Wald test statistic for $H_0: \alpha_1 = \alpha_2 = 1, \beta_i = \gamma_i = 0$ in Equation (2), the co-integrating [long run (LR)] regression, where u_t equals $S_t - F_{t-1}$.
[15] Wald test statistic for $H_0: \alpha_1 = 1, \alpha_2 = c_1, \beta_i = \gamma_i = 0$ in Equation (2), the co-integrating [long run (LR)] regression.

Figure 1

Volume of Futures Trading, Wheat, Corn, Oats, Barley, Rye, on U.S. Exchanges
Source: Hieronymus (1977, p. 23)

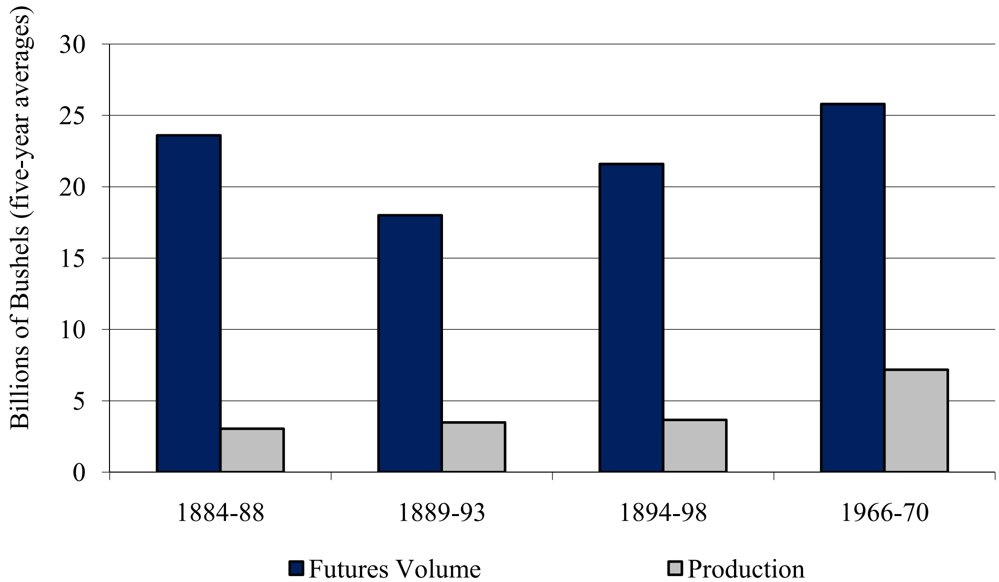
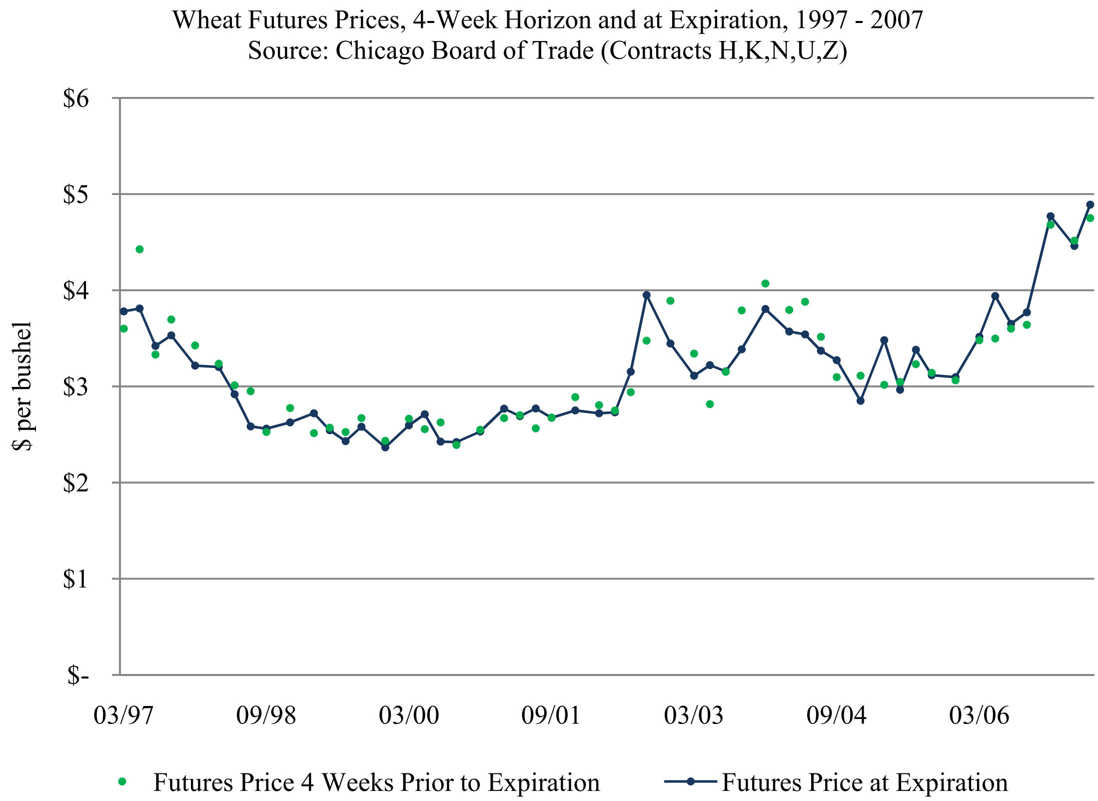


Figure 2A



Wheat Futures Prices, 4-Week Horizon and at Expiration, 1997 - 2007
Source: Chicago Board of Trade (Contracts H,K,N,U,Z)
$6
$5
$4
$3
$2
$1
$-
$ per bushel
03/97
09/98
03/00
09/01
03/03
09/04
03/06
Futures Price 4 Weeks Prior to Expiration
Futures Price at Expiration

Figure 2B

Wheat Futures Prices, 8-Week Horizon and at Expiration, 1997 - 2007
Source: Chicago Board of Trade (Contracts H,K,N,U,Z)

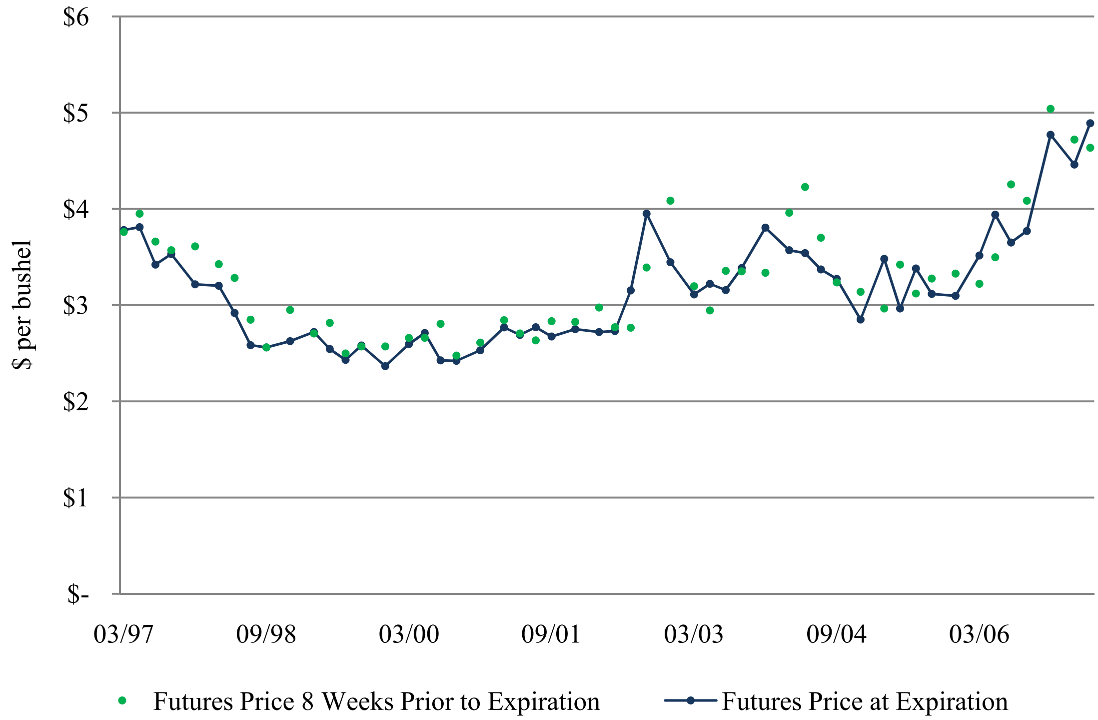


Figure 2C

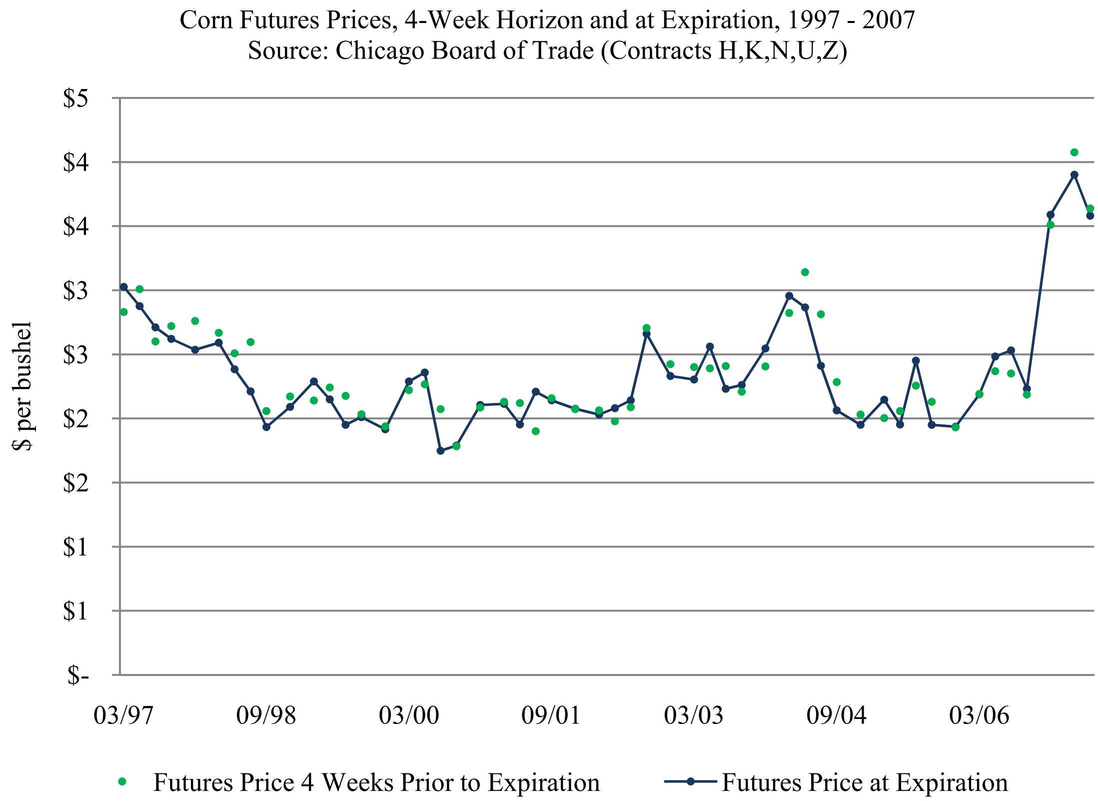

Corn Futures Prices, 4-Week Horizon and at Expiration, 1997 - 2007
Source: Chicago Board of Trade (Contracts H,K,N,U,Z)
$5
$4
$4
$3
$3
$2
$2
$1
$1
$-
$ per bushel
03/97
09/98
03/00
09/01
03/03
09/04
03/06
Futures Price 4 Weeks Prior to Expiration
Futures Price at Expiration

Figure 2D

Corn Futures Prices, 8-Week Horizon and at Expiration, 1997 - 2007
Source: Chicago Board of Trade (Contracts H,K,N,U,Z)

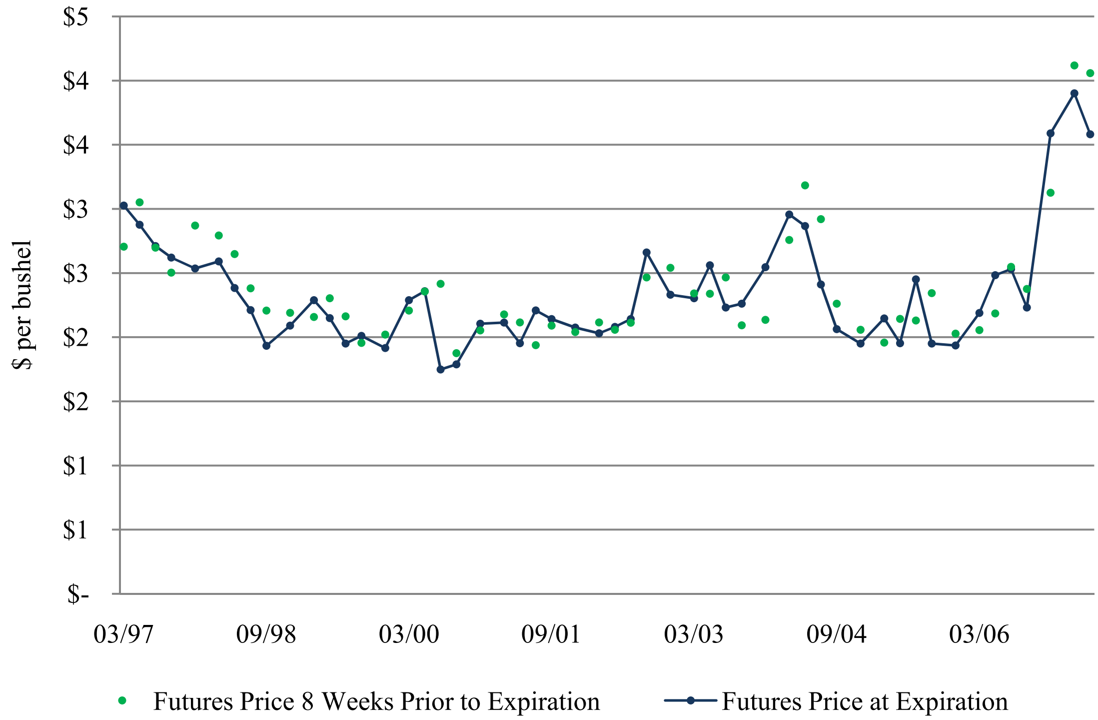
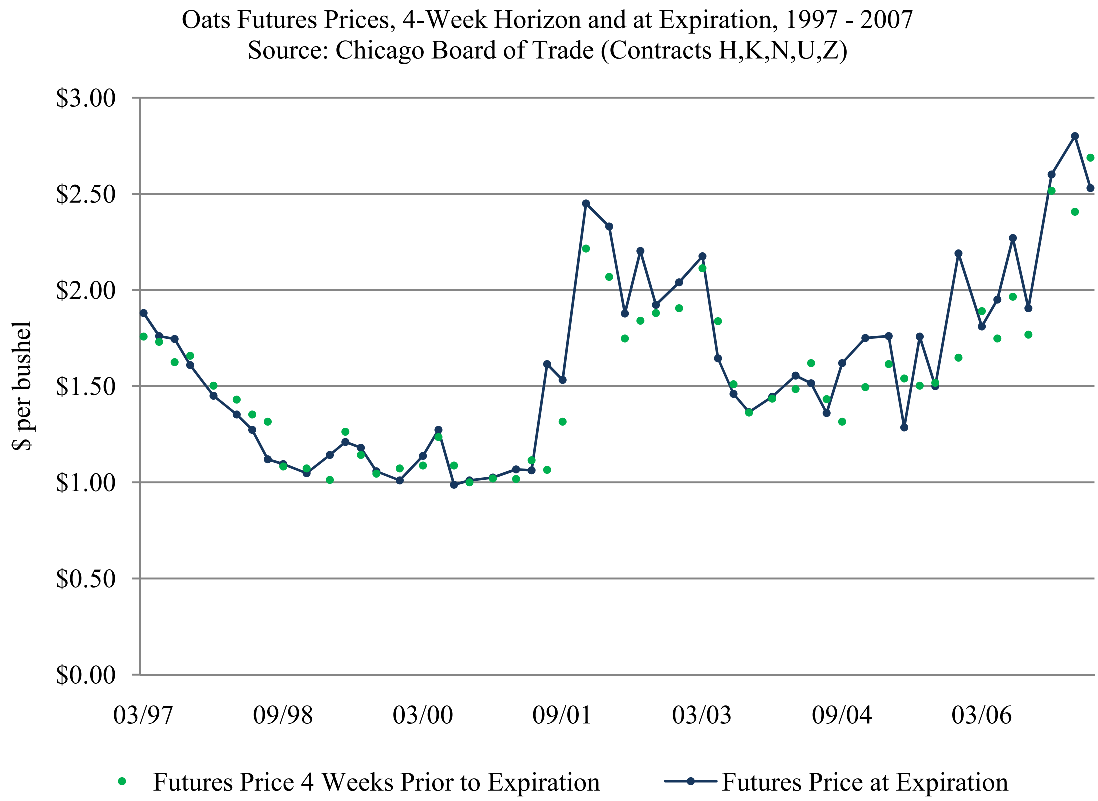


Figure 2E



Oats Futures Prices, 4-Week Horizon and at Expiration, 1997 - 2007
Source: Chicago Board of Trade (Contracts H,K,N,U,Z)
$3.00
$2.50
$2.00
$1.50
$1.00
$0.50
$0.00
$ per bushel
03/97
09/98
03/00
09/01
03/03
09/04
03/06
Futures Price 4 Weeks Prior to Expiration
Futures Price at Expiration

Figure 2F

Oats Futures Prices, 8-Week Horizon and at Expiration, 1997 - 2007
Source: Chicago Board of Trade (Contracts H,K,N,U,Z)

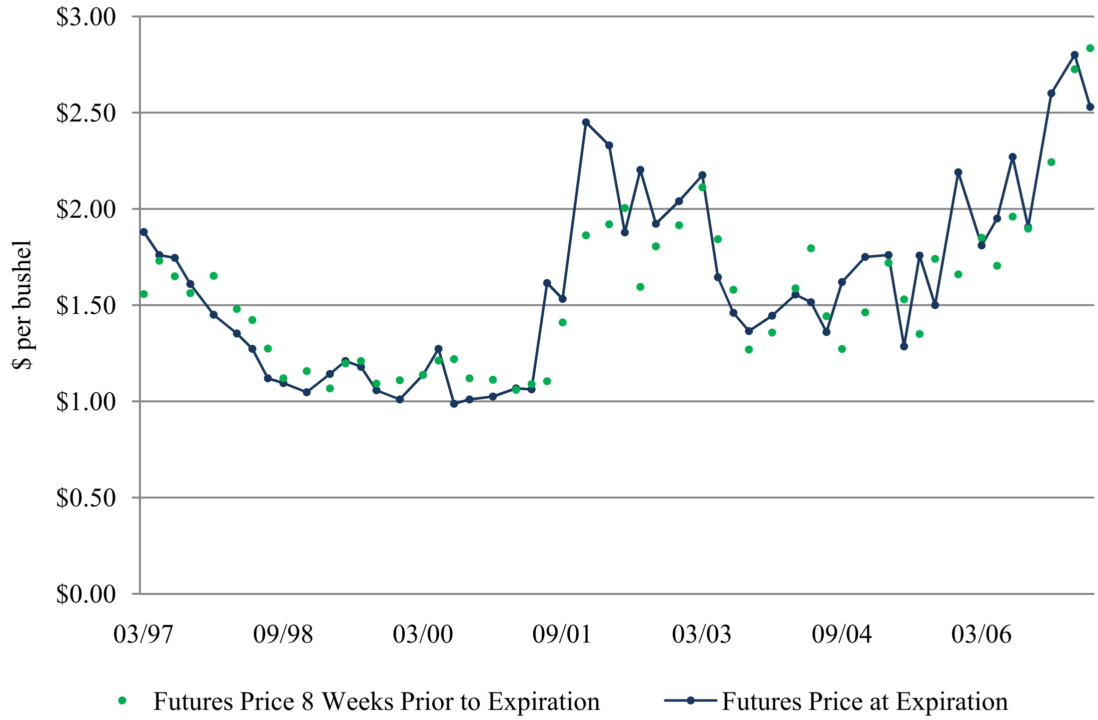


Figure 3A

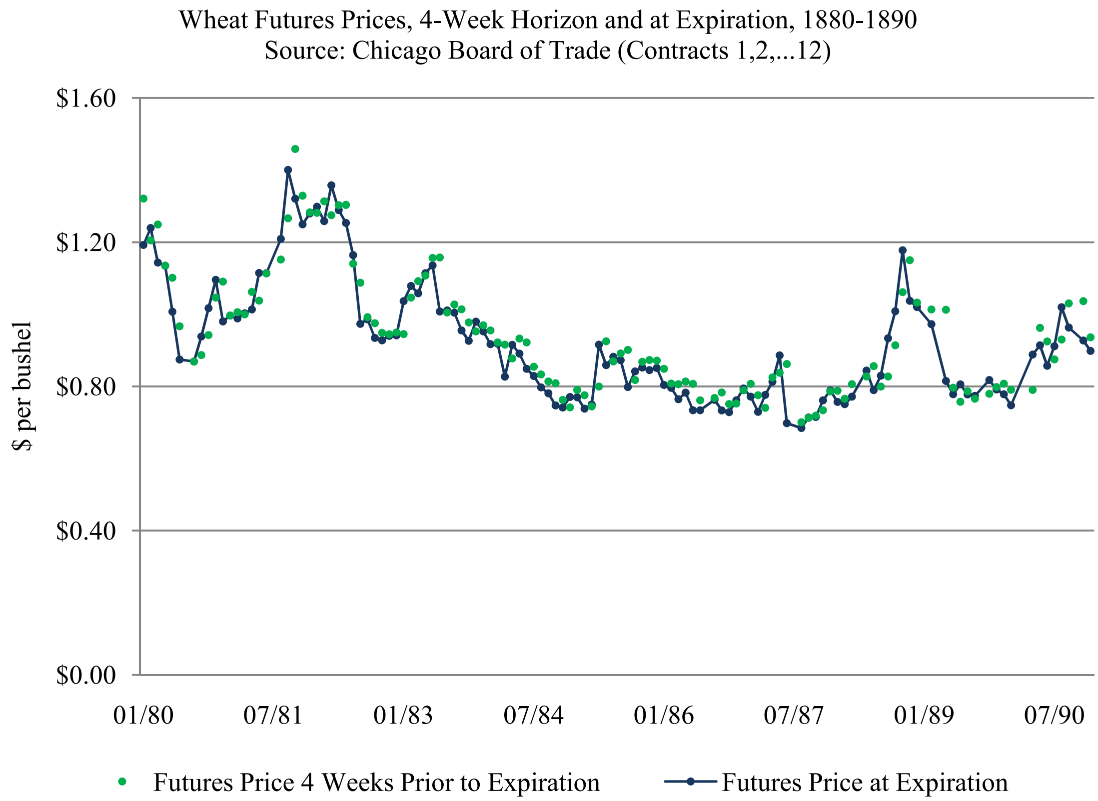
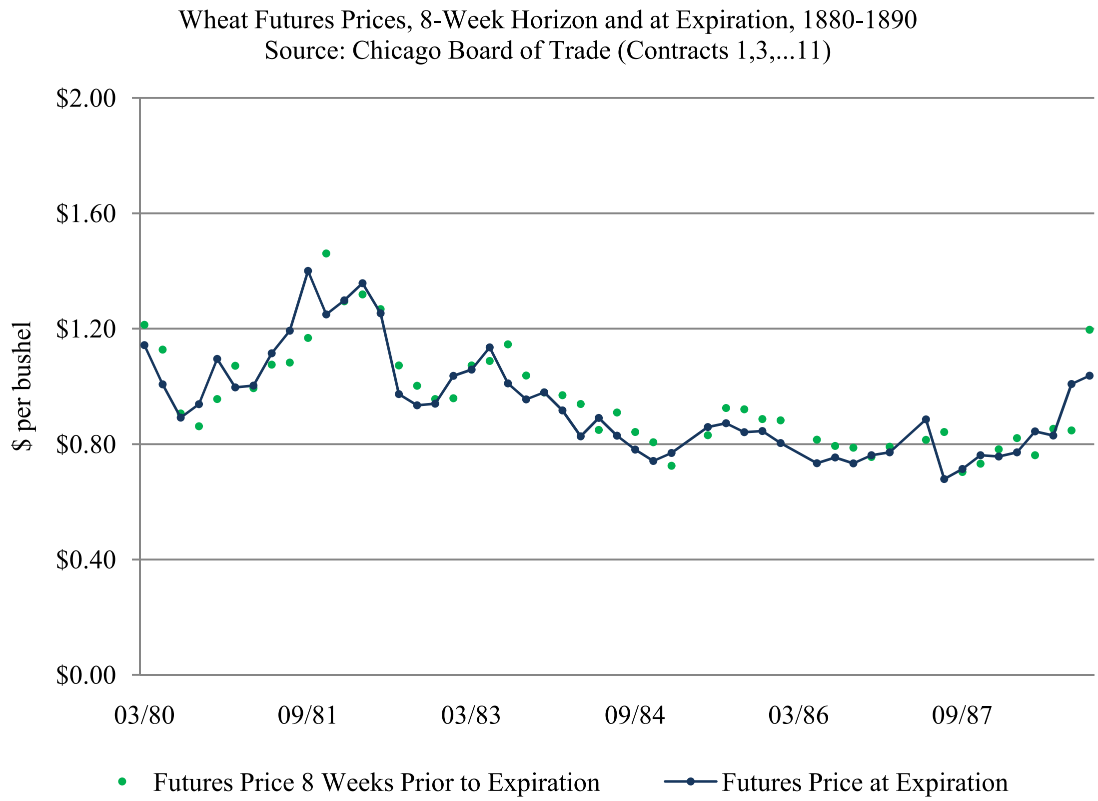
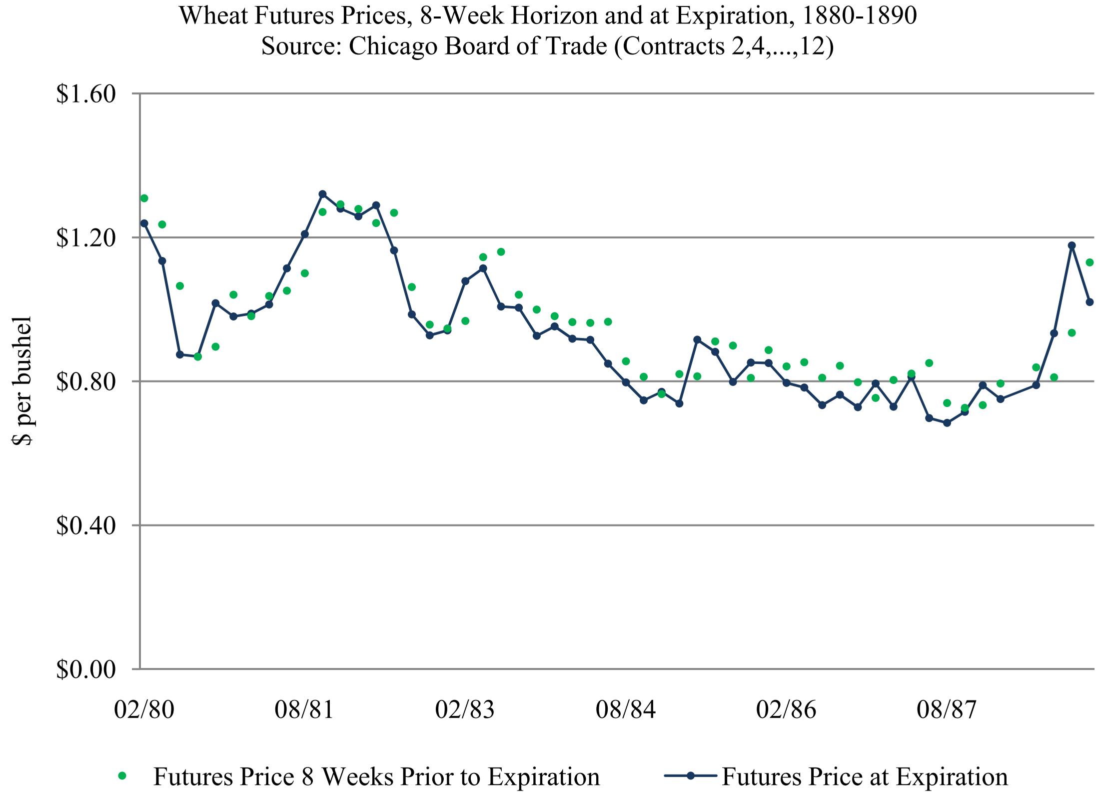

Wheat Futures Prices, 4-Week Horizon and at Expiration, 1880-1890
Source: Chicago Board of Trade (Contracts 1,2,...12)
$1.60
$1.20
$0.80
$0.40
$0.00
$ per bushel
01/80
07/81
01/83
07/84
01/86
07/87
01/89
07/90
Futures Price 4 Weeks Prior to Expiration
Futures Price at Expiration

Figure 3B



Wheat Futures Prices, 8-Week Horizon and at Expiration, 1880-1890
Source: Chicago Board of Trade (Contracts 1,3,...11)
$2.00
$1.60
$1.20
$0.80
$0.40
$0.00
$ per bushel
03/80
09/81
03/83
09/84
03/86
09/87
Futures Price 8 Weeks Prior to Expiration
Futures Price at Expiration

Figure 3C



Wheat Futures Prices, 8-Week Horizon and at Expiration, 1880-1890
Source: Chicago Board of Trade (Contracts 2,4,...,12)
$1.60
$1.20
$0.80
$0.40
$0.00
$ per bushel
02/80
08/81
02/83
08/84
02/86
08/87
Futures Price 8 Weeks Prior to Expiration
Futures Price at Expiration

Figure 3D

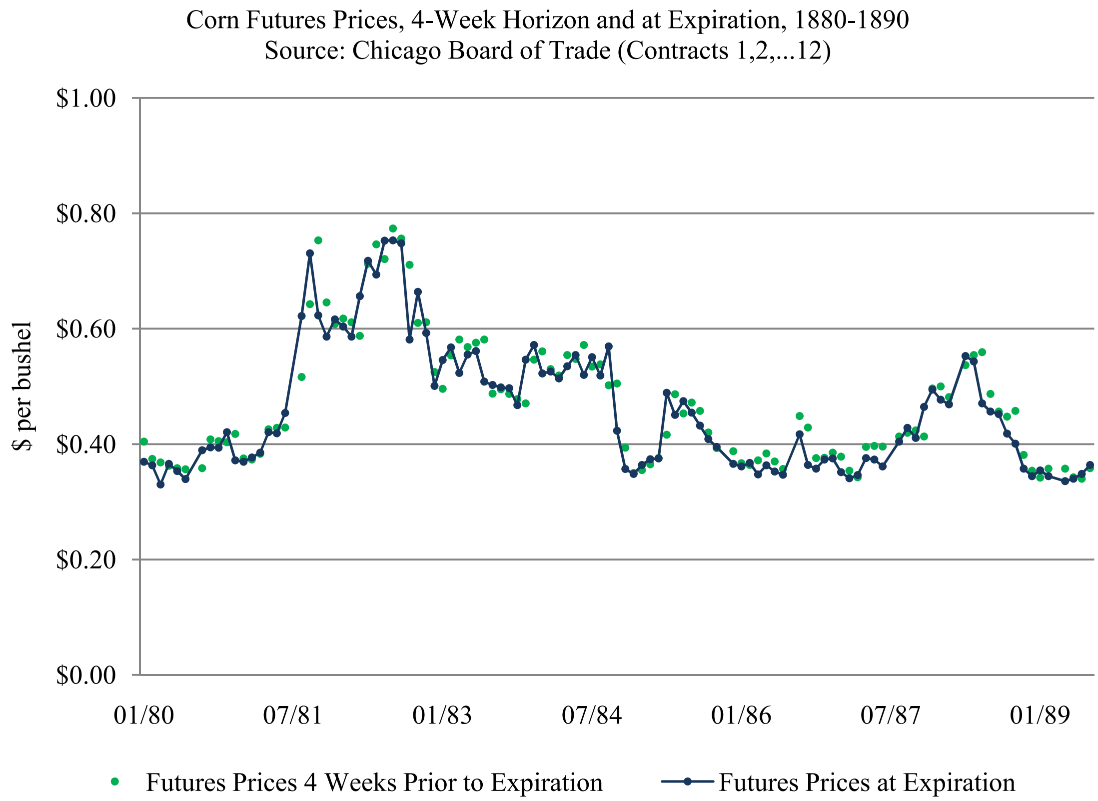
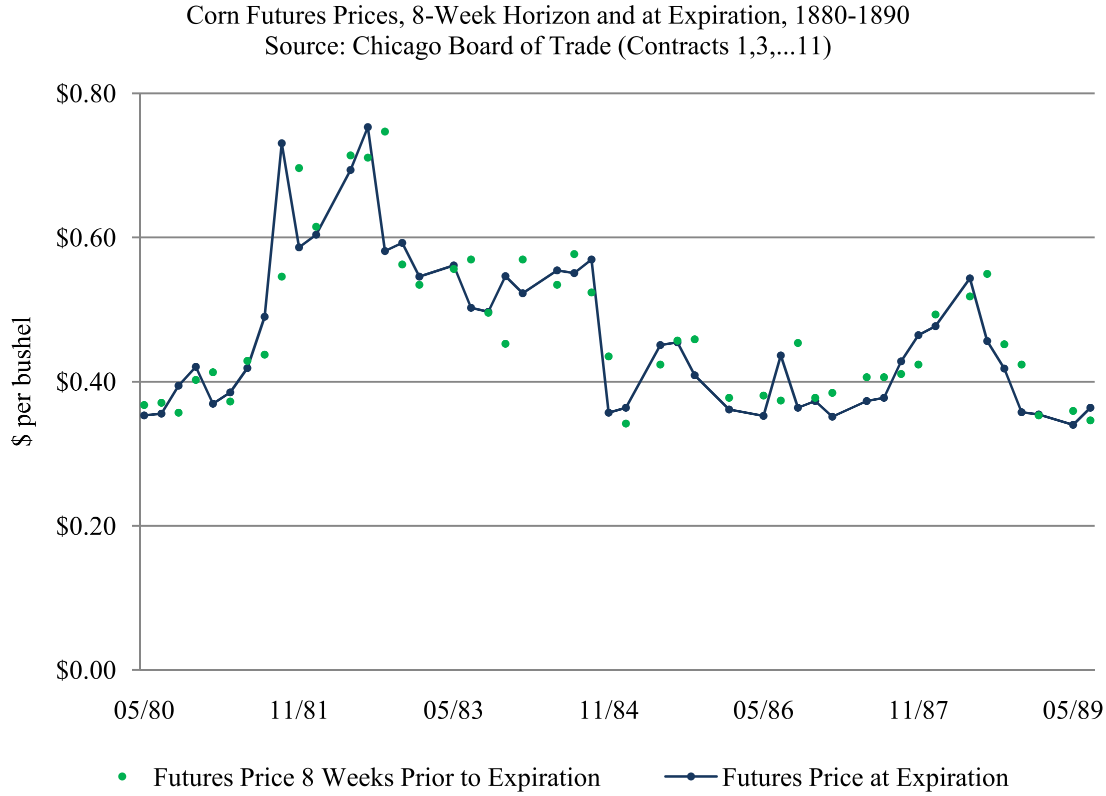

Corn Futures Prices, 4-Week Horizon and at Expiration, 1880-1890
Source: Chicago Board of Trade (Contracts 1,2,...12)
$1.00
$0.80
$0.60
$0.40
$0.20
$0.00
$ per bushel
01/80
07/81
01/83
07/84
01/86
07/87
01/89
Futures Prices 4 Weeks Prior to Expiration
Futures Prices at Expiration

Figure 3E



Corn Futures Prices, 8-Week Horizon and at Expiration, 1880-1890
Source: Chicago Board of Trade (Contracts 1,3,...11)
$0.80
$0.60
$0.40
$0.20
$0.00
$ per bushel
05/80
11/81
05/83
11/84
05/86
11/87
05/89
Futures Price 8 Weeks Prior to Expiration
Futures Price at Expiration

Figure 3F

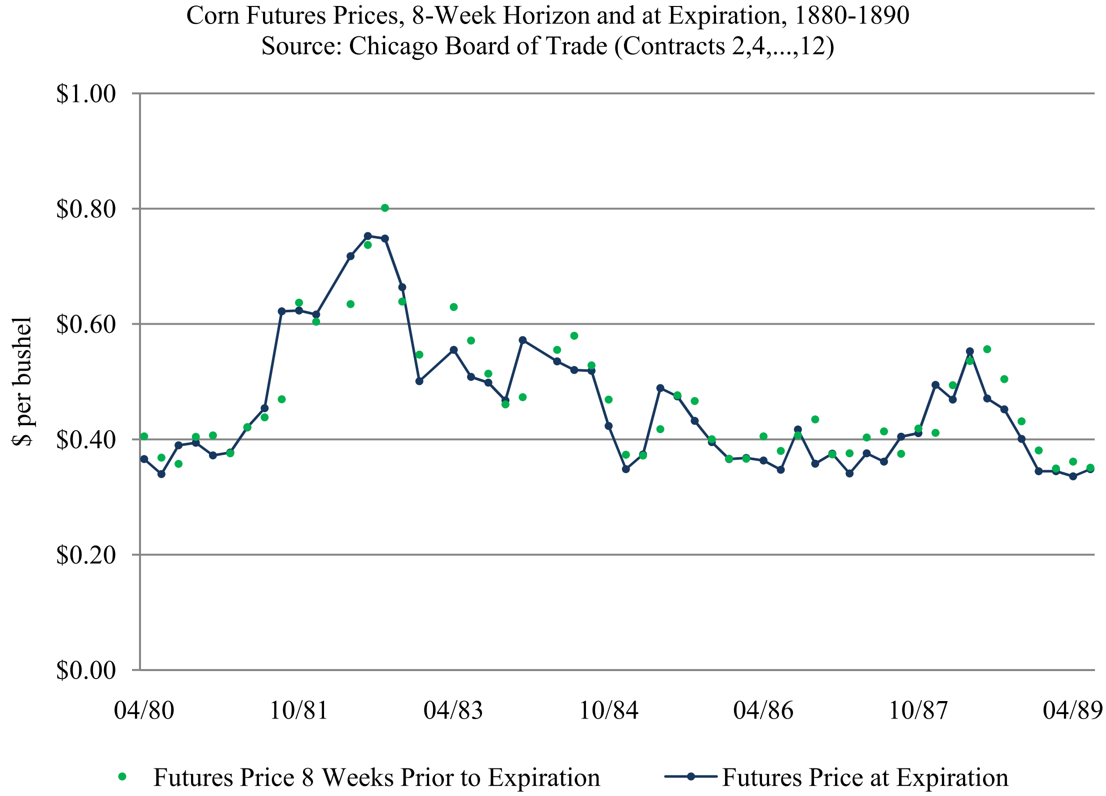

Corn Futures Prices, 8-Week Horizon and at Expiration, 1880-1890
Source: Chicago Board of Trade (Contracts 2,4,...,12)
$ per bushel
$1.00
$0.80
$0.60
$0.40
$0.20
$0.00
04/80
10/81
04/83
10/84
04/86
10/87
04/89
Futures Price 8 Weeks Prior to Expiration
Futures Price at Expiration

Figure 3G

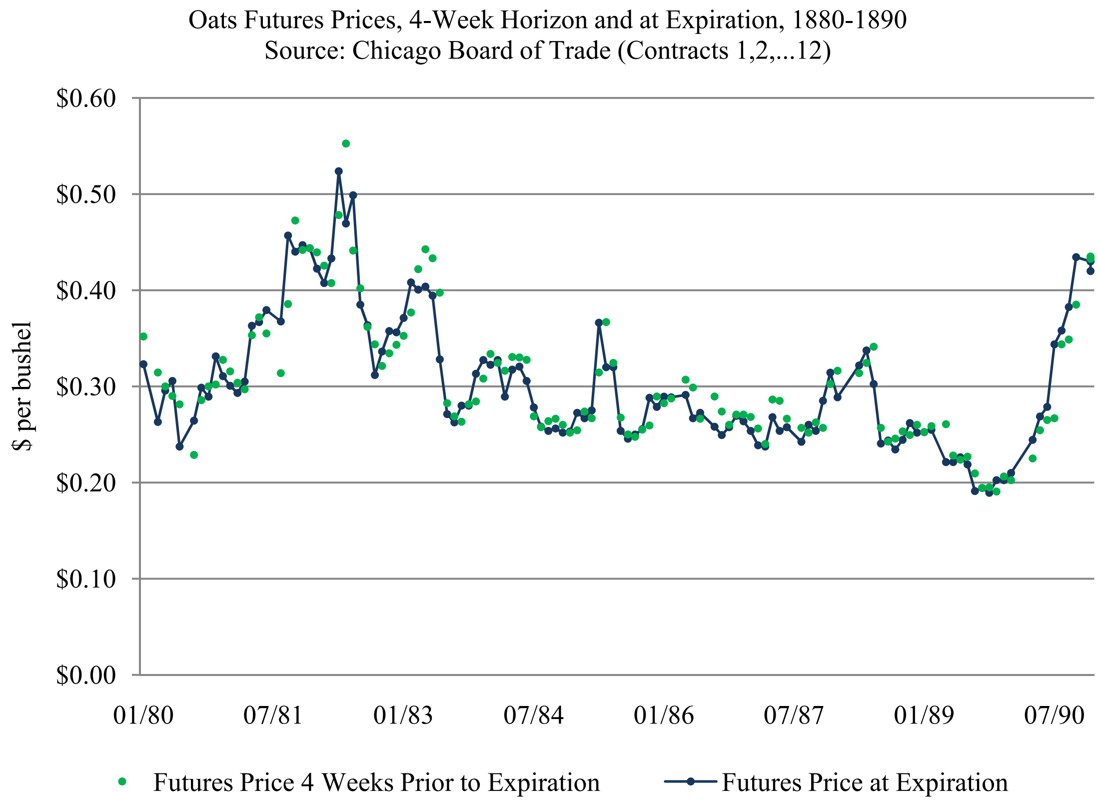

Oats Futures Prices, 4-Week Horizon and at Expiration, 1880-1890
Source: Chicago Board of Trade (Contracts 1,2,...12)
$0.60
$0.50
$0.40
$0.30
$0.20
$0.10
$0.00
$ per bushel
01/80
07/81
01/83
07/84
01/86
07/87
01/89
07/90
Futures Price 4 Weeks Prior to Expiration
Futures Price at Expiration

Figure 3H

Oats Futures Prices, 8-Week Horizon and at Expiration, 1880-1890
Source: Chicago Board of Trade (Contracts 1,3,...11)

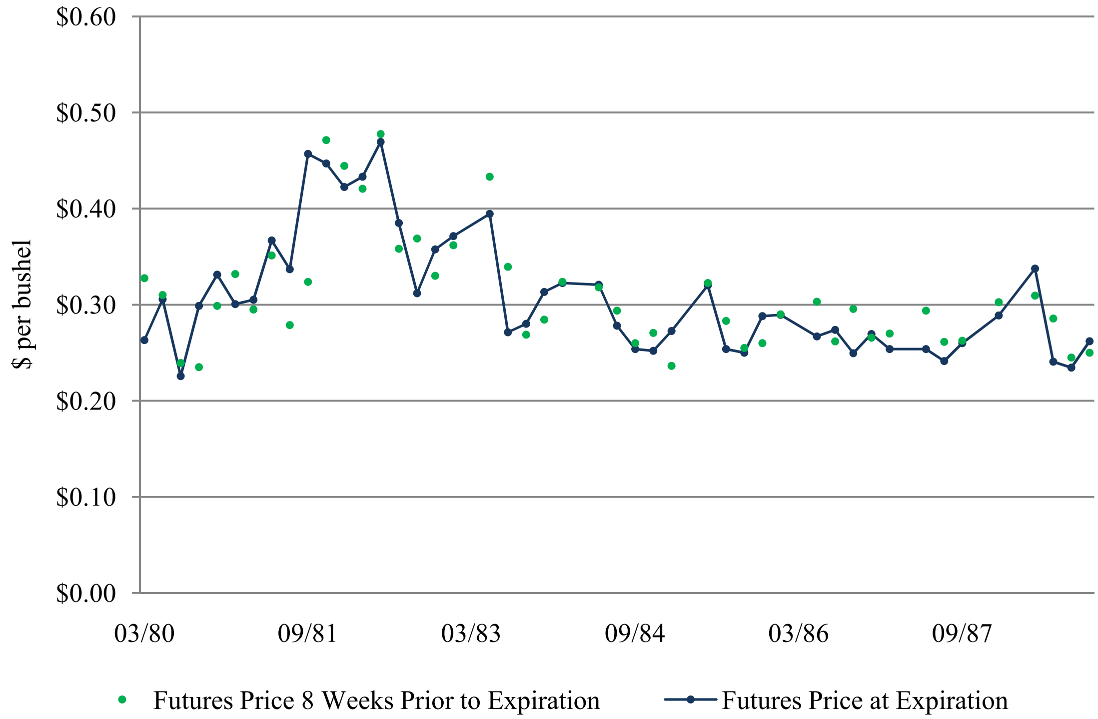
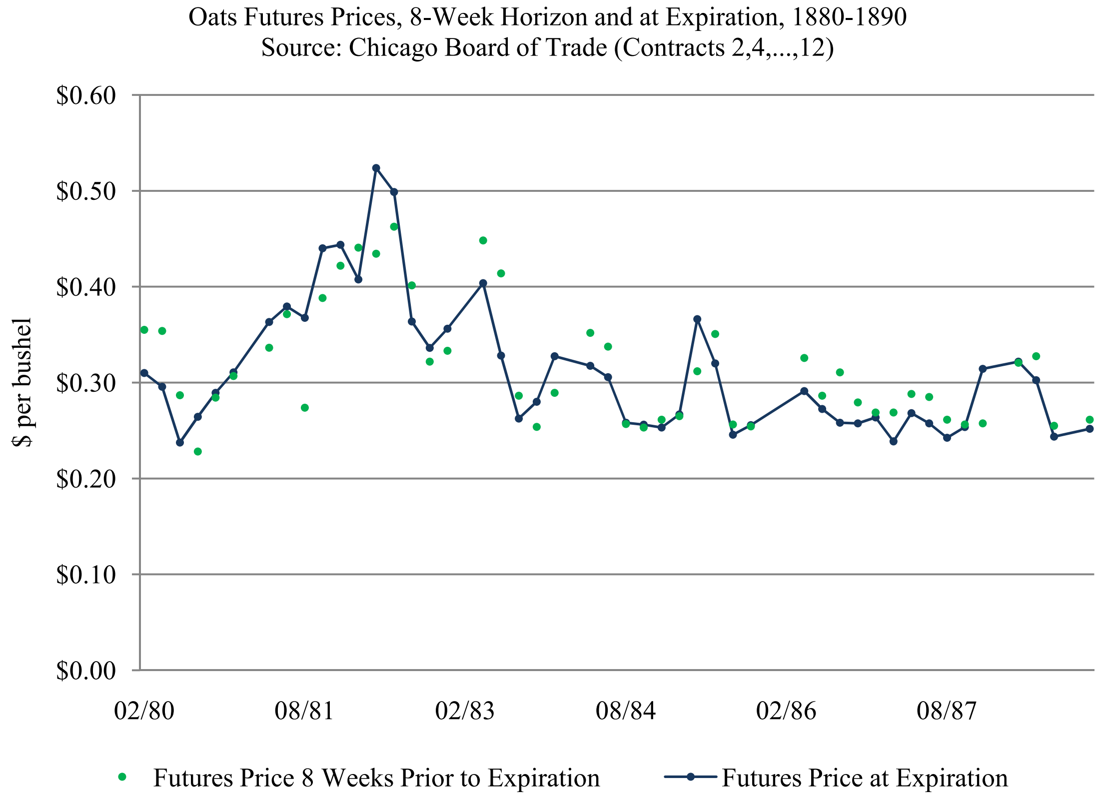


Figure 3I


Oats Futures Prices, 8-Week Horizon and at Expiration, 1880-1890
Source: Chicago Board of Trade (Contracts 2,4,...,12)
$ per bushel
$0.60
$0.50
$0.40
$0.30
$0.20
$0.10
$0.00
02/80
08/81
02/83
08/84
02/86
08/87
Futures Price 8 Weeks Prior to Expiration
Futures Price at Expiration

Endnotes

[1] The contract specified that 3,000 bushels of corn were to be delivered to Chicago in June at a price of one cent below the March 13th cash market price. This date is consistent with Odle (1964) who states that "the creators of the new system of marketing [forward contracts] were the grain merchants of the Great Lakes" (Odle, 1964, p. 439). Though Williams (1982) presents evidence of such contracts between Buffalo and New York City as early as 1847 (Williams, 1982, p. 309). To be sure, Williams (1982) proffers an intriguing case that forward and, in effect, future trading was active and quite sophisticated throughout New York by the late 1840s. Moreover, he argues that this trading grew not out of activity in Chicago, whose trading activities were quite primitive at this early date, but rather trading in London and ultimately Amsterdam. Indeed, "time bargains" were common in London and New York securities markets in the mid- and late 1700s, respectively. A time bargain was essentially a cash-settled financial forward contract that was unenforceable by law, and as such "each party was forced to rely on the integrity and credit of the other (Werner and Smith 1991, 31)." According to Werner and Smith (1991), "time bargains prevailed on Wall Street until 1840, and were gradually replaced by margin trading by 1860 (68)." They add that, "margin trading … had an advantage over time bargains, in which there was little protection against default beyond the word of another broker. Time bargains also technically violated the law as wagering contracts; margin trading did not (135)." Between 1818 and 1840 these contracts comprised anywhere from 0.7% (49-day average in 1830) to 34.6% (78-day average in 1819) of daily exchange volume on the New York Stock & Exchange Board (Werner & Smith, 1991, p. 174).

[2] At this time, the CBT restricted trade in time contracts to exchange members, standardized contract specifications, required traders to deposit margins, and specified formally contract settlement, including payments and deliveries, and grievance procedures (Hieronymus, 1977, p. 76).

[3] Nonetheless, futures exchanges in the mid-1870s lacked modern clearinghouses, with which most exchanges began to experiment only in the mid-1880s. For example, the CBT's clearinghouse began operations in 1884, and a complete and mandatory clearing system was in place at the CBT by 1925. The earliest formal clearing and offset procedures were established by the Minneapolis Grain Exchange in 1891 (Hoffman, 1932, p. 199).

[4] The transformation from forward to futures trading in Chicago grain markets occurred almost simultaneously in New York cotton markets. Forward contracts for cotton traded in New York (and Liverpool, England) by the 1850s. And, like Chicago, organized trading in cotton futures began on the New York Cotton Exchange in about 1870; rules and procedures formalized the practice in 1872. Futures trading on the New Orleans Cotton Exchange began around 1882 (Hieronymus, 1977, p. 77). Other successful nineteenth century futures exchanges include the New York Produce Exchange, the Milwaukee Chamber of Commerce, the Merchant's Exchange of St. Louis, the Chicago

Open Board of Trade, the Duluth Board of Trade, and the Kansas City Board of Trade (Hoffman, 1932, p. 33).

[5] Documented examples include traders' attempts to corner wheat (1868, 1871, 1878/9), corn (1868), oats (1868, 1871, 1874), and rye (1868) (Boyle, 1920, pp. 62-64). This manipulation culminated in the so-called *Three Big Corners*: namely, the Hutchinson (1888), the Leiter (1898), and the Patten (1909). The Patten corner was later debunked (Boyle, 1920, pp. 67-74), while the Leiter corner was the inspiration for Frank Norris's classic *The Pit: A Story of Chicago* (Rothstein, 1982).

[6] Some recent examples of studies that incorporate these early data include Netz (1995) and Santos (2002), both of whom employ them (differently) to conclude that wheat futures markets likely quelled underlying spot-price volatility, a conclusion that supports the notion that these early markets were efficient.

[7] Though the two prices converge at contract expiration in theory, this is not always true in practice. Nevertheless, a complete spot-price series is not available for the nineteenth-century sample period and, so, for consistency, I use the futures price at expiration for both sample periods.

[8] The CBT and the Chicago Mercantile Exchange (CME) merged in July 2007 to form the CME Group.