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The Weather Premium in the U.S. Corn Market

The objectives of this paper are to:

1. formally define the weather premium in the U.S. corn market;
2. explore the factors that influence the weather premium; and
3. evaluate trading strategies that seek to exploit the weather premium.

Motivation

PARTICIPANTS IN the U.S. corn futures market often refer to a '**weather premium**,' which refers to the tendency of the futures market to *over-predict* the actual harvest price.

If it exists, a weather premium rewards those who accept risk primarily associated with weather uncertainty. Market participants pay a premium to insure against adverse weather shocks.

Data from 1968 – 2015 suggests there may be a weather premium, as the December futures price in spring over estimates the realized harvest price by 4 percent.

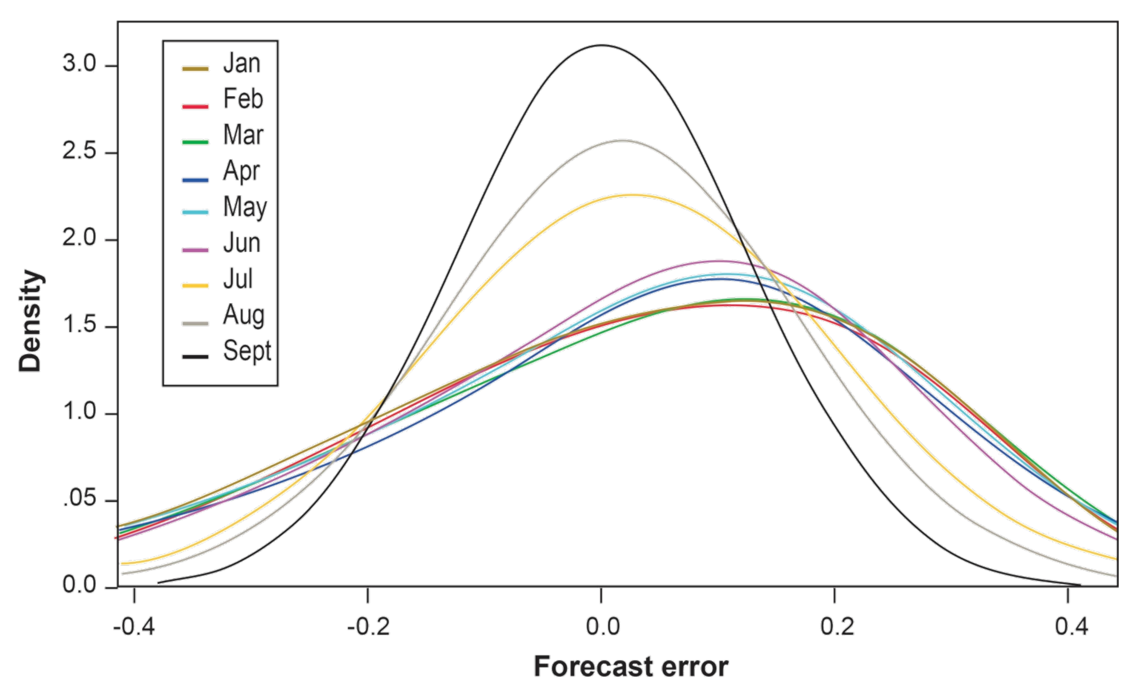


Figure 1. Density plots of the monthly average December futures price of corn minus the harvest price, expressed as a percentage of the harvest price, 1968- 2015.

Theoretical Framework

SUPPOSE A CONVEX demand function $D(p_T)$

- p_T is the harvest price of corn in year T
- $S_T = z_T + c_T$, supply at harvest
- c_T: carryout available upon harvest
- z_T: new production
  - $z_T = \begin{cases} \bar{z} + \epsilon, & \text{with probablity } \frac{1}{2} \\ \bar{z} - \epsilon, & \text{with probablity } \frac{1}{2} \end{cases}$

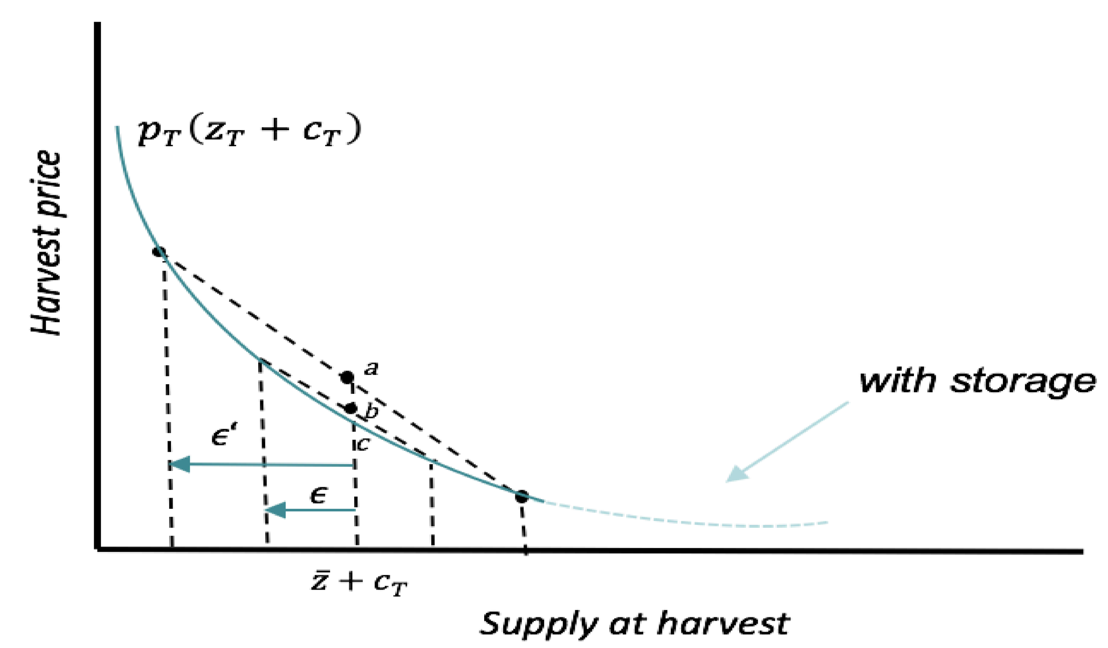
Definition: Weather premium is the expected harvest price minus the price given an average harvest: $E_t[p_T(S_T)] - p_T[E(S_T)]$

By Jensen's inequality: $E_t[p_T(S_T)] - p_T[E(S_T)] \geq 0$

1. An increase in expected supply at harvest will have a negative impact on weather premium.
2. An increase in the variability of harvest quantity increases weather premium.

WEATHER PREMIUM varies with the expectation and variation of supply at harvest. The comparative statics:

- $\begin{cases} \frac{1}{2}\left[\frac{\partial p_T}{\partial c_T}|_{S_T=\bar{z}+c_T-\epsilon} + \frac{\partial p_T}{\partial c_T}|_{S_T=\bar{z}+c_T+\epsilon}\right] - \frac{\partial p_T}{\partial c_T}|_{S_T=\bar{z}+c_T} \leq 0 \\ \frac{1}{2}\left[\frac{\partial p_T}{\partial \bar{z}}|_{S_T=\bar{z}+c_T-\epsilon} + \frac{\partial p_T}{\partial \bar{z}}|_{S_T=\bar{z}+c_T+\epsilon}\right] - \frac{\partial p_T}{\partial \bar{z}}|_{S_T=\bar{z}+c_T} \leq 0 \end{cases}$
- $-\frac{\partial p_T}{\partial \epsilon}|_{S_T=\bar{z}+c_T-\epsilon} + \frac{\partial p_T}{\partial \epsilon}|_{S_T=\bar{z}+c_T+\epsilon} > 0.$



Data and Estimation Procedure

USING CHICAGO Mercantile Exchange corn futures data from 1968 – 2015, we analyze the *forecast errors* of the December futures contract by pooled OLS to test whether carryout, basis, and past yield provide explanatory power. A predictable component of the forecast errors is explained by variables capturing the distribution of the expected harvest.

- Forecast error in the December futures contract:

$e_{t,j} \equiv \log(f_{t,j}) - \log(S_t)$, (Figure 3)

  - $f_{t,j}$: monthly average prices of December futures in year t month j, $j = January, \ldots, June$
  - S_t: December futures price in the maturity month in year t

- Carryout is detrended by its 5-year average:

$$carry_t = \frac{carry_t}{\sum_{i=t-5}^{i=t-1} carry_i / n};$$

$carry_t$: marketing year's ending stock including harvest reported on August 31 in the USDA WASDE report.

- Temporal basis reflects cost of carry, and is the difference between the log futures prices for September and December delivery: $basis_{t,j} = \log(f_{t,Sept}) - \log(S_t)$

- Past Yield Measures Realizations
  - Yield variability is normalized by its mean: $vy_t = \sqrt{5\sum_{i=t-5}^{t-1}(y_i - \sum_{i=t-5}^{t-1} y_i / n)^2} / (\frac{\sum_{i=t-5}^{t-1} y_i}{n})$
  - Detrended Yield level: $dy_t = \log(y_t) - \log(\frac{\sum_{i=t-5}^{t-1} y_i}{n})$.

Results

Empirical Model

$$e_{t,j} = \beta_1 + \beta_2 carry_{t-1} + \beta_3 carry_{t-1}^2 + \beta_4 vy_{t-1} + \beta_5 dy_{t-1} + \gamma_1 basis_{t,j} \cdot 1_{\{basis_{t,j}<0\}} + \gamma_2 basis_{t,j} \cdot 1_{\{basis_{t,j}>0\}} + \rho_j + \xi_{tj}$$

Table 1. OLS Estimation of Corn Forecast Errors

	(1) Basis (*Nearby futures – Dec. futures*)	(2) Basis (*Sep. futures – Dec. futures*)	(3) Carryout	(4) Basis and carryout	(5) Full model
const	0.078***	0.094***	0.510	1.059***	-0.595
$carry_{t-1}$	(0.022)	(0.022)	(0.657)	(0.665)	(0.854)
			-0.436	-1.255	1.403
			(1.234)	(1.236)	(1.509)
$carry_{t-1}^2$			<0.001	0.319	-0.663
			(0.576)	(0.572)	(0.674)
vy_{t-1}					0.028
					(0.386)
dy_{t-1}					-0.858***
					(0.190)
$basis_{t,j} < 0$	-0.716**	-2.456***		-0.792	-1.274***
	(0.354)	(0.992)		(1.008)	(0.922)
$basis_{t,j} > 0$	0.241	1.405***		2.293***	2.695***
	(0.245)	(0.637)		(0.641)	(0.625)
R^2	0.014	0.025	0.066	0.107	0.171
BP test for random effects	0.0890	0.0970	0.0870	0.0880	0.091
BP test for heteroscedasticity	0.273	0.666	<0.001	<0.001	<0.001
Marginal impact of carryout at trend			-0.436*** (0.026)	-0.616*** (0.142)	0.077 (0.217)
F-test				<0.001	0.005

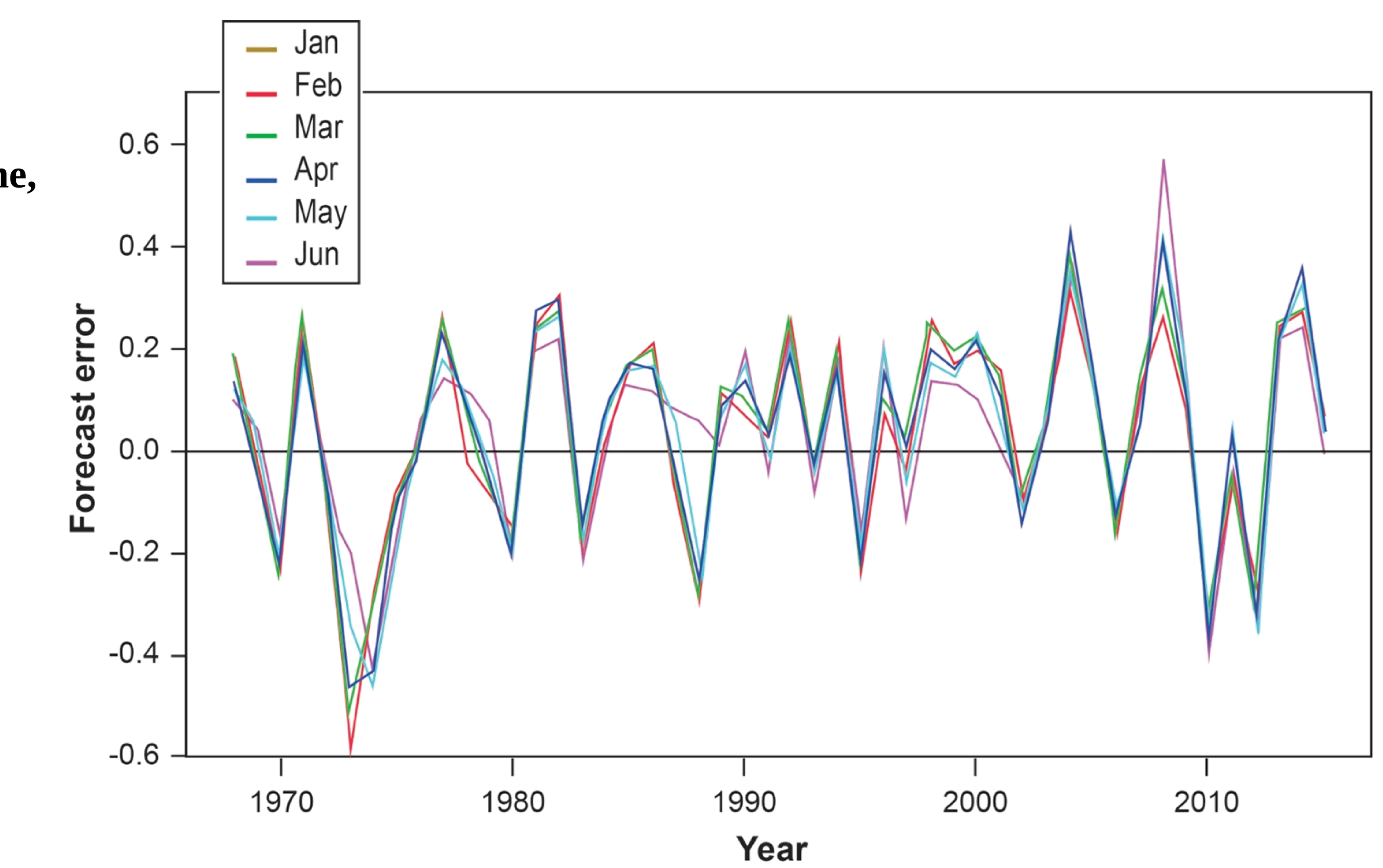
Note: Estimated robust standard errors are given in parentheses. Asterisks denote significance levels as follows: * indicates 10 percent; ** 5 percent; and *** 1 percent significance. Breusch-Pagan (BP) tests are performed for the presence of random effects and heteroscedasticity and the p-values are reported. The p-values of F-tests that compare model specification 4 to 3, and 5 to 4 are reported in columns 4 and 5, respectively.

Table 2. Returns of selected strategies.

Strategies		Annualized Return	Standard Deviation	Sharpe Ratio
Panel A: Short in spring and cover in October	Jan	0.014	0.279	0.049
	Feb	0.026	0.291	0.088
	Mar	0.037	0.304	0.121
	Apr	0.043	0.327	0.133
	May	0.044	0.339	0.131
	Jun	0.079	0.368	0.215
Panel B: Short in spring and cover in October, when carryout below trend	Jan	0.142	0.168	0.847
	Feb	0.161	0.181	0.892
	Mar	0.180	0.206	0.874
	Apr	0.204	0.235	0.870
	May	0.212	0.275	0.772
	Jun	0.284	0.297	0.957
Panel C: Other alternatives	Buy in Jan and Cover in June, when carryout above trend	0.082	0.250	0.328
	S&P 500 Index	0.078	0.165	0.476

Note: Panel A results are based on 48 years of data, 1968 – 2015. Panel B results are based on 14 of those years when carryout was below the average of the past 5 years. Panel C results are based on 34 of the years when carryout was above the average of the past 5 years. Data for the historical S&P 500 Index: https://finance.yahoo.com/quote/%5EGSPC/history?p=%5EGSPC.

Figure 2. Forecast errors by months from January to June, 1968- 2015.



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