

Wheat Forward Contract Pricing: Evidence on Forecast Power and Risk Premia

by

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Wheat Forward Contract Pricing: Evidence on Forecast Power and Risk Premiums

Practitioners Abstract

While the risk premium hypothesis in futures markets has been the subject of a long and continuous controversy, the risk premium hypothesis in forward markets is also of interest among economists. The hypothesis is supported by some theoretical arguments and empirical evidence yet remains an open question. We in this study apply a two-equation regression model similar to those used in Fama and French (1987) and de Roon et al. (1998) to analyze the risk premiums in forward markets, particularly, using the pre-harvest wheat forward markets in Illinois (1982-2004) and Kansas (1990-2004) as an example. The two-equation regression model consists of a forecasting equation, which uses a forward basis during a pre-harvest period to forecast the spot basis at the following harvest period, and a risk premium equation, which uses the forward basis to predict the risk premium to be realized at the harvest.

The empirical results show that, first, the average realized risk premiums for Illinois fluctuate around a level during the entirety of a pre-harvest period, while the risk premiums for Kansas show a slight downward trend as time approaches the harvest. The average realized risk premiums are generally positive and bigger for Illinois than for Kansas. But all mean risk premiums are within one unit of their corresponding standard deviations. Second, the pre-harvest forward bases have reliable forecasting power for the spot harvest bases and contain information regarding the risk premiums, which strongly recommend estimating risk premiums conditional on forward bases.

Keywords: forward basis, futures spread, risk premium hypothesis, forecast power

I. Introduction

The risk premium hypothesis for futures markets has been the subject of a long and nearly continuous controversy since the backwardation theory Keynes (1930). The hypothesis has been extensively studied, see, e.g., Hicks (1939); Working (1948, 1949); Telser (1958); Cootner (1960); Dusak (1973); Breeden (1980); Carter et al. (1983); Hazuka (1984); Fama and French (1987); Bodie and Rosansky (1980); Hirshleifer (1989); Bessembinder and Chan (1992); de Roon et al. (1998). However despite this extensive body of research, there is still little agreement among financial economists on whether there are risk premiums for various futures markets. The purpose of this study is not to resolve the long standing controversy around risk premia for futures markets, instead, against the backdrop of these studies and given the similarity of forward and futures markets, we examine whether there are risk premia in commodity forward markets because both theoretical arguments and empirical evidences suggest that risk premia for forward markets are more evident and significant than those for futures markets.

Consistent with the normal backwardation theory, risk premia in forward markets may exist as fees to cover speculators' hedging activities and risk premia to compensate speculators for their bearing of basis and credit risk. Using the wheat pre-harvest forward markets as an example, where wheat producers forward sell wheat to local elevators, which in turns hedge the long forward positions with short positions in futures markets. Through this process, wheat producers transfer all the price risk to local elevators, which in turn offset the bulk of price risk pertaining to the forward contracts to third parties via futures markets. Nevertheless the local elevators still have to bear basis risk due to the cross hedging nature

of their futures hedging activities and credit risk due to the possibility of producers' defaults.

In the case of pre-harvest wheat forward markets, Whereas the local elevators. From the viewpoint of risk transferring, local elevators have to be compensated for their bearing of basis risk as well as credit risk pertaining to the forward contracting. In addition, since forward markets are in general less efficient and competitive than futures markets, according to the backwardation theory, risk premia for commodity forward markets should supposedly be higher than those for corresponding futures markets.

Empirical evidences support the claim of risk premia in commodity forward markets. For examples, Brorsen et al. (1995) analyze the pre-harvest wheat forward market of hard red winter wheat at the Texas Gulf over 1975 – 1991 and find that one hundred days before harvest the net cost (risk premium) of forward contracting ranges from 2 cents/bushel to 5 cents/bushel. Townsend and Brorsen (2000) examine forward prices for the hard red winter wheat at an Arkansas River terminal from 1986 to 1998 and find that the forward contracting is quite costly: one hundred days before harvest the cost of forward contracting ranges from 6 cents/bushel to 8 cents/bushel.

However, previous empirical studies have been hindered not only by the limited availability of forward basis bids at the level of local cash markets but also by the lack of theoretical basis for their econometric models for estimating the risk premia. For example, some previous studies simply compare the net prices received by producers using forward contracts versus that using futures hedging, (Townsend and Brorsen, 2000) estimate the risk premia using a univariate unit root model. However, the unit root model not only arbitrarily restricts that the risk premia to be a linear or quadratic function of time to harvest, but also estimates the risk premia unconditionally, implying that the current forward basis contains

no information regarding the risk premium to be realized at harvest.

Obviously forward bases observed during the pre-harvest periods can be used to forecast the risk premia yet to be realized at harvests. Intuitively, the observed forward basis should contain information useful to predict the risk premium to be realized at the harvest. For example, a larger than-usual forward basis today on one hand may mean a larger than-usual spot basis at the harvest, on the other hand it likely results in a larger than-usual risk premium as the forward basis eventually evolves and falls back to its typical pattern. The reality usually falls between those two extremes.

Given the similarity between forward and futures contracts, we may estimate the risk premia contained in forward prices using a modified version of the two-equation regression model by Fama and French (1987) and de Roon et al. (1998). Fama and French (1987) decompose a futures basis into an expectation of the spot price change and a risk premium in futures price and derive a two-equation regression model, where the first (second) equation regresses realized spot price changes (realized risk premia) on futures bases. The first equation is called forecast equation since it concerns whether the futures bases have forecast power for spot price change and the second equation is called risk premium equation since it concerns whether futures bases can predict risk premium yet to be realized. Similarly, de Roon et al. (1998) show that the variation in futures spreads can be decomposed into the variation in expected future bases and the variation in risk premia and derive a two-equation regression model that uses currently observed futures spreads to forecast futures basis and risk premia to be realized. Furthermore, assuming an affine term structure model for futures prices, de Roon et al. (1998) suggest that the parameters of the regression model are fully determined by the parameters of the affine model. In particular, the parameters of the re-

gression model at different forecasting horizons vary in according with the lengths of the forecast horizons.

Because of the similarity between forward and futures markets, we apply the two-equation regression models by Fama and French (1987); de Roon et al. (1998) to analyze forward markets, in particular, the pre-harvest wheat forward markets for Southwest regions of Illinois and Kansas over 1982 to 2004. We decompose a forward basis into an expectation of harvest spot basis and a risk premium and derive a similar two-equation regression model consisting of a forecast equation, which regresses realized harvest spot bases on forward bases, and a risk premium equation, which regresses realized risk premia on forward bases. The empirical results show that the forward bases during pre-harvest period have reliable forecast power for the harvest spot bases and contain information regarding the risk premia. The results suggests that the risk premia in forward markets should be estimated conditionally on forward bases and that the risk premia should be jointly estimated with the forecast power of forward bases.

The rest of the paper is organized as follows. In the next section, we modify Fama and French (1987) and de Roon et al.'s (1998) model and derive a two-equation models for estimating the forecast power and risk premium in forward bases. In section three, we apply the theoretical model to the pre-harvest wheat forward markets at Illinois and Kansas and estimate the forecasting power and risk premium of the forward bases. In section four, we summarize and draw conclusions.

II. Theoretical Model

According to most agricultural economics literatures and the convention among practitioners, a forward basis is defined as the difference between the implied forward price and the price of the referent “new crop” futures contract. However, because we in this study adopt the theoretical framework by Fama and French (1987); de Roon et al. (1998), consistent with the tradition in financial literatures, we define a forward basis as

$$(1) \quad B_t^{t^*,T} \equiv F_t^T - f_t^{t^*}$$

where t , t^* and T denote, respectively, the current time, the harvest time, and the expiration time of the referent “new crop” futures contract, and $f_t^{t^*}$ and F_t^T denote, respectively, the log price of the forward contract and that of the referring futures contract, and $B_t^{t^*,T}$ denotes the forward basis.

A forward basis defined as above consists of a nearby leg, the implied price of the forward contract, and a distant leg, the price of the referent futures contract, thus it can be considered as a futures spread, albeit “localized” due to a forward price as its nearby leg. Extending the risk premium hypothesis in futures markets de Roon et al. (1998) to forward markets, we can decompose a forward basis into a conditional expectation of the harvest futures basis and a conditional expectation of risk premium to be realized at the harvest. The risk premium hypothesis in forward markets is stated as

$$(2) \quad B_t^{t^*,T} \equiv F_t^T - f_t^{t^*} = \pi_t^{t^*,T} + E[F_{t^*}^T - S_{t^*} | I_t]$$

where $\pi_t^{t^*,T}$ and $E[F_{t^*}^T - S_{t^*} | I_t]$ denote, respectively, the conditional expectation of the risk premium and the conditional expectation of the harvest spot basis at current time, t .

Similar to Fama and French (1987); de Roon et al. (1998), the risk premium hypothesis in forward markets as stated in equation (2) suggests that the variation in risk premium and the variation in harvest futures basis should show up in the variation in forward basis, therefore, , we consider the regression of , the realized harvest spot basis ($F_{t^*}^T - S_{t^*}$), and the realized risk premium ($[S_{t^*} - f_t^{t^*}] - [F_{t^*}^T - F_t^T]$) on the forward basis ($F_{t^*}^T - S_{t^*}$). The two-equation regression model is:

$$(3) \quad \begin{aligned} F_{t^*}^T - S_{t^*} &= \alpha_1 + \beta_1[F_t^T - f_t^{t^*}] + \eta_{1,t^*} \\ [S_{t^*} - f_t^{t^*}] - [F_{t^*}^T - F_t^T] &= \alpha_2 + \beta_2[F_t^T - f_t^{t^*}] + \eta_{2,t^*} \end{aligned}$$

where the realized risk premium is measured as the realized profit/loss of a spreading strategy involving a long position in forward contract and a short position in the referring futures contract. The realized risk premium measures the profit/loss from the perspective of a speculator, while, from a hedger's viewpoint, the risk premium should be measured as $S_{t^*} - f_t^{t^*}$ since it measures how much a hedger has to sacrifice in order to completely eliminate the price risk. Therefore we can further divide the realized risk premium into two components: a risk premium in forward market ($S_{t^*} - f_t^{t^*}$) and a risk premium in futures market ($F_{t^*}^T - F_t^T$). In addition, note that time to harvest ($t^* - t$) is also the forecast horizon within the regression setting.

Within the two-equation regression model, the first regression uses a forward basis to forecast the harvest basis, answering the question whether a forward basis has power to predict the harvest basis. Evidence that $\beta_{1,t}$ is positive indicates that the forward basis observed

at t contains information about the harvest basis observed at t^* . The second regression uses a forward basis to project the risk premium to be realized at the harvest. Evidence that $\beta_{2,t}$ is positive indicates that the forward basis observed at t contains information about the risk premium to be realized at time t^* .

Notice that the parameters of the regression model (equation 3) are subject to adding-up constraints:

$$(4) \quad \alpha_1 + \alpha_2 = 0$$

$$(5) \quad \beta_1 + \beta_2 = 1$$

$$(6) \quad \eta_{1,,t^*} + \eta_{2,,t^*} = 0.$$

because the sum of the realized risk premium and the realized harvest spot basis is the observed forward basis. As β_1 and β_2 are usually between 0 and 1, the variation of forward bases should partially attribute to the variation in the harvest spot bases, partially to that in the risk premia.

Fama and French (1987) estimate a two-equation regression model similar to equation (3) with forecast horizon fixed. However, when being applied to analyzing the pre-harvest wheat forward markets, this approach severely limits the size of the sample available for estimating the regression. Since for each region and during the pre-harvest period of a particular crop year, we only observe a sequence of forward basis, each of which has a distinct forecast horizon (time to harvest), Consequently, with forecast horizon fixed, we may end up with estimating an array of regression models, each of which has to be estimated with a handful sample of forward bases, because the sample size is bound by the number of crop years of

the forward price data set.

Then, how about pooling regression models with different forecast horizons to increase the size of the sample? de Roon et al. (see, 1998, equations 15 and 16.) show that with a simple one-factor model for the term structure assumed for the futures prices, the parameters of the regression model like equation (3) are fully determined by the term structure model. In particular, the parameters of the regressions vary as the forecast horizon changes. Although a simple one-factor affine model may not capture the real dynamic of futures prices as acknowledged by de Roon et al. (1998), it does raise the doubt regarding the validity of pooling regression models with different forecast horizons. Theoretically, we may derive the exact relationship of regression parameters at different horizons assuming a two-factor affine term-structure model (e.g., Longstaff and Schwartz, 1992) or even a multiple-factor term structure model (Heath et al., 1992), but the term structure model nevertheless still imposes certain restrictions on the dynamic of forward prices besides that the derivation is quite technically complicated. In this study, we take a compromised approach: we estimate the pooling regression models with different forecast horizons and test the structural change using Chow test.

Notice that the forecast horizons of forward bases observed overlap with each other during the pre-harvest period of a particular crop year. The forecast horizon of a forward basis quoted earlier overshadow the ones quoted later. This overlapping of forecast horizons causes the error terms of the regression model to be autocorrelated (Hansen and Hodrick, 1980; Fama and French, 1987; de Roon et al., 1998). To overcome the problem, we estimate the regression model using Generalized Moment Method (GMM).

III. Empirical Results

We collect wheat forward prices during pre-harvest periods and spot prices during harvest periods, for for the Southwestern production regions in Illinois during crop years through 1982 to 2004 and for Southwestern production regions in Illinois and Kansas during crop years through 1990 to 2004. These two regions are representative of production regions for the two largest classes of wheat grown in the US: soft red winter wheat (Illinois) and hard red winter wheat (Kansas). For Illinois, the data are collected at weekly frequency during 1982 and 1994 and at daily frequency during 1995 and 2004, for Kansas, the data are collected at daily frequency during 1990 and 2004. We also collect nearby July futures prices that correspond the forward and spot prices above. The futures contracts are CBOT (Chicago Board of Trade) July contracts for Illinois and KCBOT (Kansas City Board of Trade) July contracts for Kansas.

Some summary statistics of forecast forward bases, risk premia and harvest spot bases are presented in table 1. First, notice that the forecast horizon (time to harvest) of a forward contract is computed as the difference between the day when a forward price is quoted and the harvest day, which is defined as the mid-point of the three-week harvest period of a particular crop year. The forecast horizons range from 190 to 9 days and from 260 to 9 days before a harvest for Illinois and Kansas, respectively. Second, notice that the standard deviation of forward bases is comparable with that of risk premia. As argued by Fama and French (1987), the pattern suggests that we may obtain reliable estimates for the coefficients of the regression model (equation 3).¹ Third, the pattern of risk premia suggests that on average

¹Fama and French (1987) argue that in order to obtain reliable coefficient estimates the variation of the regressor (risk premia) should be comparable with that of the regressand (forward bases).

local elevators profit from forward contracting, while wheat producer does not necessarily forward sell their crop at prices lower than harvest spot prices. The average risk premia measured from the perspective of local elevators are 0.017% and 0.004% for Illinois and Kansas, respectively, while the average risk premia in forward market that are the average risk premia measured from wheat producers' viewpoint are -0.021% and -0.021%, for Illinois and Kansas, respectively, and the average risk premia in futures market are -0.038% and -0.025%, for Illinois and Kansas. The pattern in the average risk premia alone may suggest that local elevators lose money in their forward contracting activities, i.e., wheat producers receive risk premia for forward selling, but make money in their futures hedging activities. However, these numbers have to be interpreted with precautions because that the standard deviations of risk premium in forward market and that in futures market are much larger than the risk premium measured as the difference of these two premia. This pattern of variation of risk premia also suggests that risk premia measured from wheat producers' viewpoints may not be difficult to predict using forward bases.²

We further illustrate the results with plots that compare the average realized risk premia and the risk premia predicted by the regression model using average forward bases (figures 1 and 2). First, Notice that realized risk premia for Illinois on average (unconditionally) are positive and fluctuate around 0.18% during entirety of a pre-harvest period, while realized risk premia for Kansas are smaller than for Illinois, particular within 100 days before the harvest, and the realized risk premia show a slight downward trend to the forecast horizons. However, the time series of average realized risk premia only show how on average the risk

²Perhaps the managers of elevators are a bunch of shrewd business people, who know how to exploit the basis trading strategies aforementioned.

premia change over forecast horizons, they smooth out the variations of risk premia due to the variation of forward bases year by year. In addition, the plots show that unconditional predictions of risk premia by the regression model match reasonably well the time series of average realized risk premia are. But more important is the predictions conditional on forward bases discussed about (table 2).

Due to the restrictions imposed on the parameters of the regression model, the parameters and the error terms of one equation are fully determined by those of the other. Because of the autocorrelations and possible heteroscedasticity in the error terms, we estimate the regression model with Generalized Moment Method using Newey-West method to obtain standard deviations of the estimated coefficients.³ In GMM estimation, forward bases w.r.t. the corresponding September and December futures contracts are chosen as instruments variables.

The results of estimation of the regression model are presented in table 2. The results show that forward bases have reliable forecast power for harvest bases and contain information regarding the risk premia as β 's are estimated to be 0.555 and 0.594 for Illinois and Kansas, respectively and both are statistically significant. The significance of the regression for forecast equation and risk premium equation are not trivial for both Illinois and Kansas as indicated by the adjusted R^2 for both regressions.

Because we find that the fitting of pooling regression deteriorate significantly 30 days before the harvest days, we divide a pre-harvest period into two sub-periods: beyond and within 30 days before the harvest and test the structural change in the model. The results of estimation of regression model for each sub-period are also presented in table 1. The

³See de Roon et al. (1998) for an example using Newey-West estimator.

results show that within the 30 days before the harvest, the forward bases may have more forecast power for harvest spot bases and contain more information regarding the risk premia to be realized as indicated by the increasing of *betas*. For both Illinois and Kansas, Chow test further confirms structural change of regression models across two sub-periods at 1% significance level.⁴

While the risk premium hypothesis in futures markets has been the subject of a long and continuous controversy, the risk premium hypothesis in forward markets is also of interest among economists. The hypothesis is supported by some theoretical arguments and empirical evidence yet remains an open question. we in this study apply a two-equation regression model similar to those used in Fama and French (1987) and de Roon et al. (1998) to analyze the risk premia in forward markets, particularly, using the pre-harvest wheat forward markets in Illinois (1982-2004) and Kansas (1990-2004) as an example. The two-equation regression model consists of a forecasting equation, which uses a forward basis during a pre-harvest period to forecast the spot basis at the following harvest period, and a risk premium equation, which uses the forward basis to predict the risk premium to be realized at the harvest.

The empirical results show that, first, the average realized risk premia for Illinois fluctuate around a level during the entirety of a pre-harvest period, while the risk premia for Kansas show a slight downward trend as time approaches the harvest. The average realized risk premia are generally positive and bigger for Illinois than for Kansas, but all mean risk premia are within one units of their corresponding standard deviations. Second, the pre-harvest forward bases have reliable forecasting power for the spot harvest bases and contain information regarding the risk premia, which strongly recommend estimating risk premia

⁴The results of Chow test are not presented in the paper but are available from authors upon request.

conditional on forward bases.

One intriguing stylized fact that we have not explored further is the patterns of means and standard deviations of various types of risk premia. The pattern of mean risk premia suggest that the local elevator make money overall while the wheat producers may not pay premia when they sell their crop using forward contracts. The trick lies in that the local elevator make money in their hedging activities on average. However, the pattern of the standard deviations of risk premia cast doubt on this interpretation as the standard deviations of risk premia in forward market and futures markets are much larger than that of their difference. Further investigation on this issue is warranted. For further study, we also hope analyze the risk premia and their dynamics within the context of a two-factor affine model such as Longstaff and Schwartz (1992) or even a multi-factor term structure model (discrete versions).

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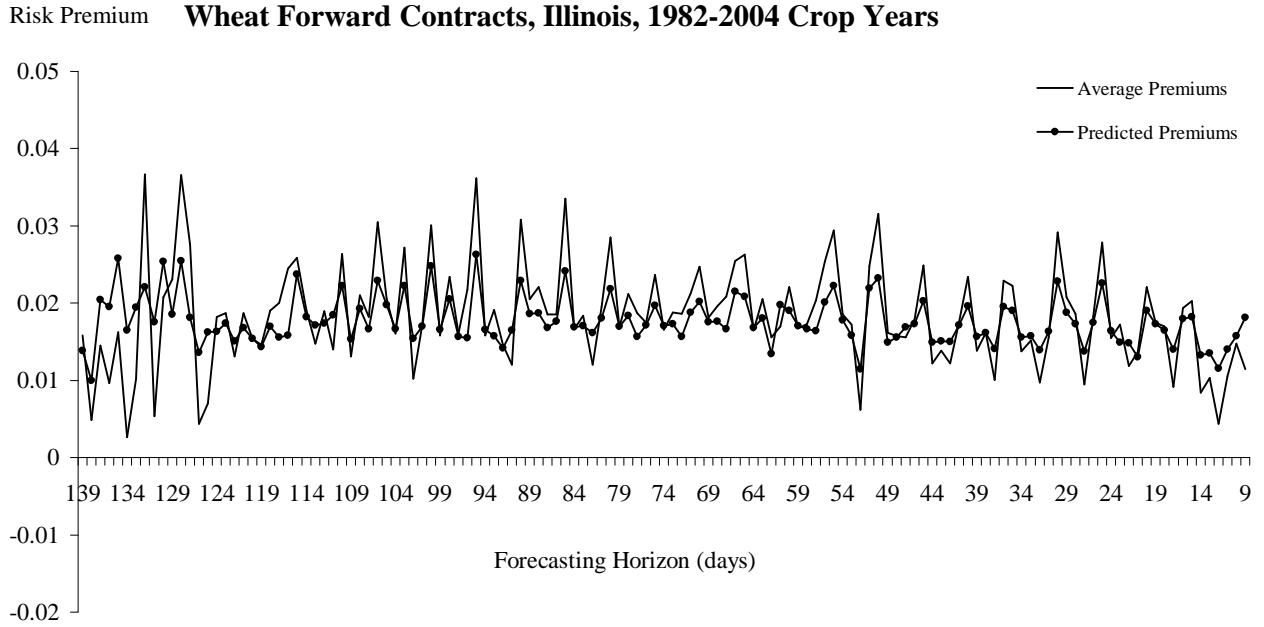
Table 1. Summary Statistics: Wheat, Illinois and Kansas, 1982 to 2004 Crop Years.

Region	Variable	Number of Observations	Mean	StdDev	Minimum	Maximum
Illinois	Forecasting Horizons	1560	75.315	41.357	9	190
	July Forward Bases	1556	0.088	0.045	0.015	0.206
	Risk Premiums	1556	0.017	0.031	-0.052	0.133
	Risk Premiums in Forward Market	1560	-0.021	0.123	-0.337	0.277
	Risk Premiums in Futures Market	1556	-0.038	0.115	-0.324	0.275
	Harvest Spot Bases	23	0.066	0.035	0.007	0.150
Kansas	Forecasting Horizons	3049	117.444	65.827	9	260
	July Forward Bases	3048	0.134	0.033	0.048	0.234
	Realized Risk Premia	3048	0.004	0.040	-0.091	0.134
	Risk Premiums in Forward Market	3049	-0.021	0.165	-0.415	0.450
	Risk Premiums in Futures Market	3048	-0.025	0.145	-0.365	0.409
	Harvest Spot Bases	15	0.131	0.040	0.071	0.225

Table 2. Results of Regression Estimations: Wheat , Illinois and Kansas, 1982-2004

Region	Forecasting Horizon	α	$t(\alpha)$	β	$t(\beta)$	Adjusted R ₁ - Square	Adjusted R ₂ - Square
Illinois	All	0.022	20.060	0.555	41.080	0.515	0.368
	≥ 30 days	0.027	23.010	0.509	35.380	0.469	0.387
	< 30 days	0.005	1.960	0.771	26.160	0.778	0.267
Kansas	All	0.052	19.890	0.594	26.240	0.177	0.174
	≥ 30 days	0.060	19.780	0.522	19.880	0.133	0.191
	< 30 days	0.025	12.040	0.837	54.220	0.696	0.079

**Figure 1. Average Realized Risk Premiums and Forecasted Risk Premiums:
Wheat Forward Contracts, Illinois, 1982-2004 Crop Years**



**Figure 2. Average Realized Risk Premiums and Forecasted Risk Premiums:
Wheat Forward Contracts, Kansas, 1990-2004 Crop Years**

