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An Analysis of Default and Liquidity Risk in Farm Credit System Bonds

Farrell E. Jensen and Christoffer K. Perry

This study tests for the existence of default and liquidity risk premiums in Farm Credit System bonds. ARCH models are used with over eight years of daily data on yields to maturity of Farm Credit System bonds and U.S. Treasury bonds. Matching five-year maturities for both types of bonds were used. Our data contain evidence of both default and liquidity risk in the spread between the two securities. Elasticity estimates show that the yield spreads are more responsive to default risk than liquidity risk. These sources of risk likely increase the rates agricultural borrowers must pay for loans from the Farm Credit System.

Key words: ARCH model, default risk, Farm Credit System bonds, liquidity risk, yield spreads

Introduction

As a government-sponsored agency (GSA), the Farm Credit System (FCS) issues bonds in primary bond markets to raise funds to lend to agricultural borrowers. Yields to maturity for FCS securities are higher than U.S. Treasury securities of the same maturity, indicating there is a risk premium for FCS bonds. The difference between the market yield to maturity and the corresponding pure rate of interest is defined as the risk premium (Fisher, 1959). Higher risk premiums, or yield spreads, associated with the FCS bonds are evident in our data covering the period from October 29, 1993 to June 28, 2002. Over this period, the average yield spread over U.S. Treasury bonds of the same maturity was 36 basis points.

Based on findings reported in the literature, the risk premium, or yield spread, between yields to maturity on FCS bonds and U.S. Treasury bonds depends upon default, liquidity, and maturity risk (Fisher, 1959; Elton et al., 2004). Specifically, Elton et al. (2004) report that yield differences within a bond class depend upon default risk, liquidity risk, tax liability, recovery rates, and age of bond. Other research suggests taxes (Elton et al., 2001) and the expected recovery in the event of default (Katchova and Barry, 2005; Barry, Brake, and Banner, 1993) can also affect the spread.

In the agricultural economics literature, Garbade and Hunt (1978) used FCS data from the 12 Federal Intermediate Credit Banks and the 13 Banks for Cooperatives and concluded that market ill-liquidity (liquidity risk) rather than credit risk (default risk)

Farrell E. Jensen is a professor of economics, and Christoffer K. Perry is a former undergraduate student, both in the Department of Economics, Brigham Young University. The authors gratefully acknowledge Micah S. Allred for obtaining the data and for early contributions to the paper. We also thank the anonymous reviewers for helpful comments that improved the paper.

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was the source of risk premiums for the FCS bonds. In a later study of the FCS, Duncan and Singer (1992) found evidence of default risk in FCS bonds during the 1980s.

In this investigation we extend previous research on FCS bonds and test for the existence of default and liquidity risk premiums in the yield spread, and also the yield ratio, for FCS bonds compared to U.S. Treasury bonds. To the extent possible, given our data, we test for the presence of default and liquidity risk while controlling for maturity risk and other factors that exist in the spread. Of course, all factors that cannot be controlled, measured, or observed get folded into the error term in the empirical model.

This study uses ARCH models and a data set of daily prices and yields to maturity for FCS and Treasury bonds for the analysis. Since development by Engle, ARCH models have found wide application in time-series analysis of financial data (Engle, Lilien, and Robins, 1987). OLS regression models assume errors are independent through time and the error variances are constant. Because financial data are characterized by error variances which are time dependent and changing, the assumptions of OLS are violated. When OLS assumptions don't hold, ARCH models are more efficient estimators of parameters, as they correct for heteroskedasticity in the error variances. The evolution of risk premiums over time has been modeled by Engle and Wooldridge (1988). ARCH models have been previously used in agricultural economics research. For example, Holt (1993) examined risk premiums in beef margins, and Shively (1996) measured changes in maize price variability in Ghana.

A time series of over eight years of daily yields was used to create the yield spread for FCS and U.S. Treasury bonds with five-year maturities. By standardizing on five-year bonds, maturity risk is controlled and the yield spread should not contain this type of risk. Evidence from our data indicate both default and liquidity risk premiums are in the spread between U.S. Treasury bonds and FCS bonds. These results are important to agricultural producers because borrowing costs are directly related to the size of the risk premiums. Any policies that would reduce the size of the risk premiums would potentially reduce interest rates for agricultural borrowers.

Recent Changes in the Farm Credit System

In the 1980s, agriculture suffered a severe depression (Stam and Dixon, 2004). As a result, many agricultural producers were in financial difficulty, along with lenders like the FCS which had maintained large agricultural loan portfolios. The combination of financial turmoil in agriculture and FCS internal procedures for setting interest rates on loans placed the FCS in severe financial duress. Several agricultural credit acts were passed to strengthen the FCS and its regulatory agency in an attempt to bolster confidence in the system. [For an excellent review of the FCS and its history and function, see Barry et al. (2000).]

The organizational structure of the FCS was substantially changed by the Farm Credit Amendments Act of 1985, the Farm Credit Amendments Act of 1986, and the Agricultural Credit Act of 1987. Major structural changes in these acts involved consolidating many local Federal Land Bank Associations (FLBAs) and Production Credit Associations (PCAs) into Agricultural Credit Associations (ACAs). Funds for FCS loans to agricultural producers are obtained from financial markets with the assistance of the Federal Farm Credit Banks Funding Corporation (FFCBFC). The FFCBFC determines the amount and terms of the security issue and markets the securities through security dealers.

FCS loans account for about 25% of the annual credit requirements of U.S. agricultural producers (Barry, Brake, and Banner, 1993). Over 80% of the bonds issued by the FFCBFC are short term with maturities of less than one year. Longer-term debt, like the five-year issues examined in this study, comprise a much smaller portion of the issuing volume and are generally issued in blocks of at least $1 billion.

The Farm Credit System Insurance Corporation (FCSIC) was created by the Agricultural Credit Act of 1987. This corporation was formed with the intent of renewing faith in the financial integrity of the FCS and ensuring the timely payment of principal and interest on FCS notes, bonds, and other obligations sold to investors. In essence, these legislative and structural changes in the FCS were put into place to strengthen the financial integrity of the System which should reduce the risk premium, thereby benefiting agricultural borrowers.

Theoretical Basis for Risk Premiums

Theoretical Risk Premiums in Portfolios with Two Types of Assets

Consider a portfolio, held for one period, consisting of risky bonds and risk-free bonds. The following definitions apply for this portfolio:

R = total return (not rate of return) for risk-free asset for the period,
P = price of one risky bond,
Q = random total returns (not rate of return) for risky bond for the period,
S = number of risky bonds in portfolio,
X = number of risk-free bonds in portfolio, and
$1 = price of one risk-free bond expressed as a numeraire.

The variables R, Q, and P can be used to define the risk premium between a risky bond and a risk-free bond as:

$$y = Q/P - R/1.$$

As defined, the risk premium is the difference between the rate of return on the risky asset and the risk-free rate of return to the risk-free asset which, in a one-period model, is the one-period yield to maturity. Assume that the total return to the risky bond is a random variable, so the risk premium (y) will also be a random variable. The expected value and variance of y are expressed as:

$$E(y) = \theta/P - r_F = \mu,$$
$$\sigma_y^2 = \sigma_Q^2/P^2,$$

where θ = expected value of total returns to the risky bond, r_F = rate of return for the risk-free bond, μ = expected value of the risk premium for the risky bond, σ_y^2 = variance of the risk premium, and σ_Q^2 = variance of total returns to the risky bond.

Under CARA, it has been shown that maximization of expected utility occurs when the expected value of the risk premium is (Engle, Lilien, and Robins, 1987):

$$\mu = SP(b\sigma_y^2),$$

where b is the risk-aversion coefficient and SP is the value of the risky bonds in the portfolio. Comparative statics for the relationship between μ, b, and σ_y^2 are of the following form:

$$\partial(\mu)/\partial\sigma_y^2 > 0,$$

$$\partial(\mu)/\partial b > 0.$$

As shown by these comparative static results, the risk premium becomes larger as the variance of the risk premium increases, ceteris paribus. Also, as people become more risk averse, the risk premium increases to provide large enough rates of return for individuals to buy the risky bonds. In the next section, the link between the risk premium (μ) and the observed yield spread will be established.

Empirical Measures of Risk Components in Yield Spread

Controlling for Tax Effects

Studies have documented the tax impacts on bond yields and prices (e.g., Kidwell and Koch, 1983). Both FCS bonds and U.S. Treasury bonds have tax-exempt status from state and local income taxation. The tax-exempt status for FCS bonds was created by the Farm Credit Act of 1971, and has remained unchanged since that time. There were no changes in the tax codes during the 1993–2002 period covered by the data that would have affected the spread. Therefore, taxes are not included in the model.

The Observed Yield Spread and Risk Premium in Treasury and FCS Bonds

We first define the observed yield spread as the difference in yield to maturity of FCS and Treasury bonds maturing in five years to control for maturity risk:

$$\pi_t = Y_{Ft} - Y_{Tt},$$

where Y_{Ft} = yield to maturity at time t for a five-year FCS bond; Y_{Tt} = yield to maturity at time t for a five-year U.S. Treasury bond; and π_t = risk premium for FCS bonds at time t (as such, π_t is the yield spread which includes all types of risk except maturity risk).

In the market, the risk premium will be related to an observed yield spread for Treasury and FCS bonds of five-year maturities. Engle, Lilien, and Robins (1987) use the excess holding yield on a long-term bond relative to a one-period Treasury bill as a measure of the risk premium. Our proxy for the risk-free bond is the five-year Treasury bond. Consistent with Engle, Lilien, and Robins' model, we define:

$$\pi_t = \mu_t + \varepsilon_t, \tag{1}$$

where π_t = observed excess holding yield or spread from the data for period t, μ_t = the risk premium for period t, and ε_t = the difference between the ex ante and ex post excess yields for period t. It is assumed the case that the variance of ε_t is h_t^2. In efficient markets, the error term should be normally distributed (the assumptions about the error variance are described later).

If U.S. Treasury bonds and FCS bonds are substitutes in a portfolio, the equilibrium conditions at the margin occur when the conditions in equation (1) are satisfied. Assuming risk aversion, μ_t, and thus π_t, will be expected to be higher for FCS bonds compared to Treasury issues. In fact, in our data π_t is positive, suggesting there is more perceived risk in the market for the FCS bonds.

The spread can be expressed as a linear function of liquidity risk, default risk, and other factors in the spread that are included in δ_t (Kidwell and Koch, 1983). Of course, any other factors affecting the spread which are not measured by these variables are folded into the error term. By separating μ_t into default and liquidity risk, equation (1) can be rewritten as:

$$\pi_t = \mu_{Lt} + \mu_{Dt} + \delta_t + \varepsilon_t, \tag{2}$$

where μ_{Lt} = liquidity risk premium, μ_{Dt} = default risk premium, and δ_t = other factors affecting the yield spread including previously defined risk factors. In general functional notation, the relationships are:

$$\pi_t = f\left(\mu_{Lt}, \mu_{Dt}, \delta_t\right).$$

Comparative statics give the following results:

$$\partial \pi_t / \partial \mu_{Lt} > 0, \tag{3}$$

$$\partial \pi_t / \partial \mu_{Dt} > 0, \tag{4}$$

$$\partial \pi_t / \partial \delta_t > 0. \tag{5}$$

Rather than the yield spread, some research has used the ratio of yields to maturity for two different assets as the dependent variable in regression models (Kidwell and Koch, 1983). Following this approach, the ratio of yields to maturity for Treasury bonds and FCS bonds was used as a dependent variable in three model specifications, and is referred to as the yield ratio (π_{Rt}). It is defined as:

$$\pi_{Rt} = Y_{Ft} / Y_{Tt}.$$

The yield ratio can also be defined as a linear function of the risk variables as follows:

$$\pi_{Rt} = f\left(\mu_{Lt}, \mu_{Dt}, \delta_t\right).$$

Comparative statics are:

$$\partial \pi_{Rt} / \partial \mu_{Lt} > 0, \tag{6}$$

$$\partial \pi_{Rt} / \partial \mu_{Dt} > 0, \tag{7}$$

$$\partial \pi_{Rt} / \partial \delta_t > 0. \tag{8}$$

Therefore, as liquidity risk and default risk increase in FCS bonds, the yield ratio increases. The theoretical relationships in equations (3)–(5) and (6)–(8) will be tested in the empirical model.

The Data

The data used in this study include the yield to maturities for five-year U.S. Treasury bonds and five-year FCS bonds to control for maturity risk in the yield spread. The FCS yield data were provided by the FFCBFC, the FCS institution vested with the responsibility of raising money for the FCS in financial markets. Daily quotes of yields to maturity for FCS bonds were based on yields on issued bonds for the period October 29, 1993 to June 28, 2002. Over this period, there are 2,157 observations. Daily yield quotes for the U.S. Treasury data were obtained online from the "economagic.com" website.

Daily yield quotes for 91-day T-bills, an independent variable, were taken from "finance.yahoo.com." Data on the ratio of index of prices received (1990–92 = 100) to index of prices paid by farmers for commodities and services, interest, taxes, and wage rates (1990–92 = 100) were obtained from various annual issues of *Agricultural Statistics* published by the U.S. Department of Agriculture (USDA).

Quarterly and annual financial statements for the FCS were provided by the FFCBFC and included information regarding the ratio of loan reserves to total loans. Earlier statements were provided in hard copy and the remainder are found at "farmcredit-ffcb.com." Macroeconomic data such as farm value added to GDP and GDP were obtained from the Bureau of Economic Analysis, under the "Gross Value Added by Sector" spreadsheet.

Table 1 presents the averages and standard deviations of all variables used in the different specifications of the empirical model. Due to differing collection time periods, the data set includes data published daily (T-bill yields and FCS yields), monthly (USDA index), and quarterly (farm value added to GDP, GDP, and FCS financial statement information). For monthly and quarterly statistics, the monthly or quarterly values of the variables were repeated daily to match the structure of the daily yield quotes.

Plots of the yield spread and yield ratio are shown in figures 1 and 2. The noticeable increase in the yield spread and yield ratio in August 1998 was caused by the Russian financial crisis and later exacerbated by the Japanese crisis that produced a flight to alternative securities such as U.S. Treasury issues. The substantial shifts, in both the yield spread and yield ratio, seem to suggest the presence of a risk premium or the yields would not have adjusted so markedly to these events.

Description of Empirical Variables

Default Risk Proxies

Several approaches have been used in the literature to test for default risk. Favero, Giavazzi, and Spaventa (1997) model the spread between government bonds issued by

Table 1. Summary Statistics for Variables in the Empirical Model

Variable	Symbol	Unit	Average	Standard Deviation
Yield Spread	π_t	%	0.36	0.25
Yield Ratio	π_{Rt}	ratio	1.07	0.05
Liquidity Risk	μ_{Lt}	ratio	0.01	0.01
T-Bill Yield	T_t	%	4.59	1.12
Default Risk (proxies):	μ_{Dt}			
▸ USDA Index		index	88.38	6.72
▸ Provision Ratio		ratio	0.028	0.002
▸ Value-Added Ratio		ratio	0.009	0.002

different countries as a function of default risk in a linear regression model. Duffee (1999) considers default risk as an unpredictable jump in a Poisson process but recognizes that yield spreads include both default and liquidity risk premiums. Elton et al. (2001) conclude that default risk explains little of the spread between corporate and government bonds. Instead, tax effects were found to have more impact on the spread, and the rest is explained by commonly accepted risk premiums associated with systematic risk for common stocks. In a theoretical model, Chiang (1987) finds that yield spreads can serve as a proxy for default risk when the probability of default is low or certainly within reasonable parameters of default probabilities.

Other studies link the size of the default premium to the expected level of recovery in the event of default (Katchova and Barry, 2005; Barry, Brake, and Banner, 1993; Chiang, 1987). Hazard models have also been used for pricing default risk (Madan and Unal, 2000). Thus, default premiums are represented by a higher yield when the probability of being repaid is less than one. Included in this premium are estimates of the probability of default and the magnitude of loss in the event default occurs.

To test for the existence of default risk, we first followed a methodology similar to that used by Ferri and Gaines (1980) where the Index of Leading Indicators served as a proxy for default risk. In their model, increases in the index correspond to a better economy, fewer bankruptcies, and thus fewer defaults. Since the financial state of agricultural producers is more closely linked to profitability in agriculture, the USDA index described in the previous section was selected as one of our proxy variables for default risk. In equation (4), the theoretical relationship between default risk (μ_{Dt}) and π_t is positive. However, when the USDA index is used as a proxy variable for default risk, the relationship should have a negative and opposite sign to the theoretical sign in equation (4) for reasons explained below:

$$\partial \pi_t / \partial \mu_{Dt} < 0, \tag{9}$$

where μ_{Dt} is the USDA index used as a proxy for default risk at time t.

If the index increases, it should signal an improvement in the financial condition of agricultural producers as prices received for outputs have increased relative to prices paid for inputs, and therefore the probability of default decreases—hence the negative relationship between the spread and the proxy for default risk as shown in equation (9).

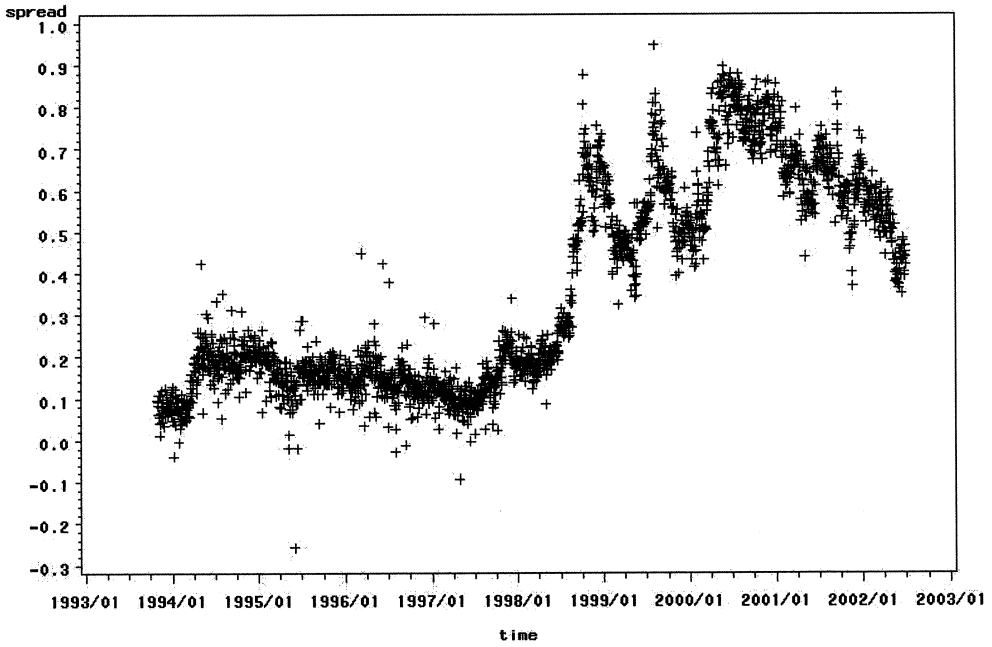

Figure 1. Yield spread: FCS bond yields minus Treasury bond yields

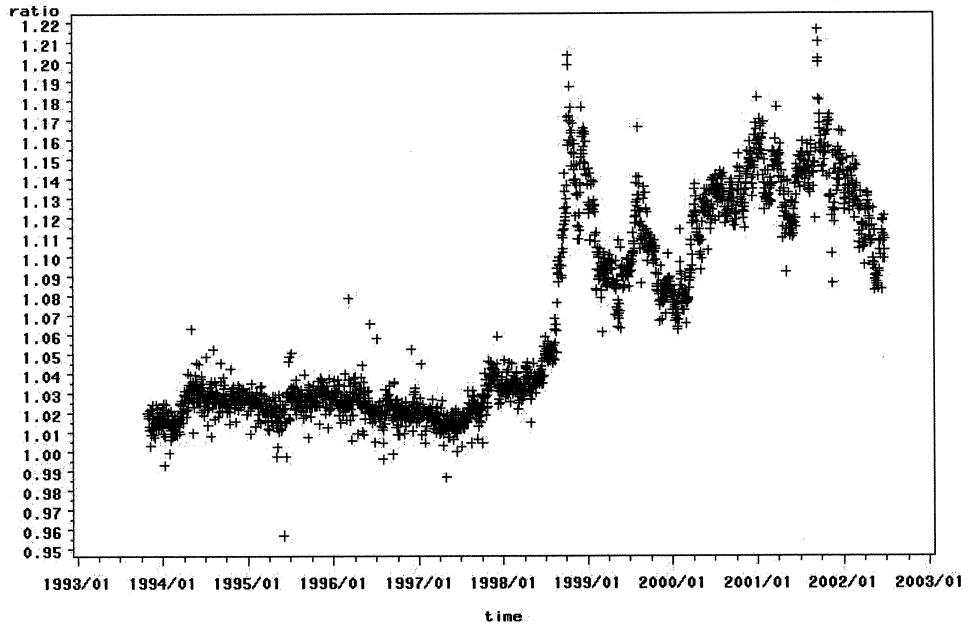

Figure 2. Yield ratio: FCS bond yields divided by Treasury bond yields

Another proxy tested, the provision ratio, was constructed using the ratio of FCS loan reserves to FCS total loans, defined as:

$$\text{Provision Ratio} = \frac{\text{Loan Reserves}}{\text{Total Loans}}.$$

This variable is an indicator of the ability of the FCS to cover all losses incurred from charge-offs. The ratio changes depending on the discretion of the banks and quality of their general loan portfolio. We assume that an increase in the amount of loan reserves indicates a safer financial position for the FCS, and thus better ability to cover losses and vice versa. The provision ratio will show how the yield of FCS bonds responds to perceived changes in the financial position of the FCS. Comparative statics for this variable are as shown in equation (9).

The last proxy tested was constructed from macroeconomic GDP data. Our model uses a ratio of the farm value added to total GDP:

$$\text{Value-Added Ratio} = \frac{\text{Farm Value Added}}{\text{Total GDP}}.$$

This variable should be closely tied to performance of the farm sector. Any increase in the ratio will display an improvement of farms' financial conditions relative to the economy and vice versa. Also, this relationship is consistent with equation (9).

Liquidity Risk Proxies

Liquidity risk is related to the price adjustment which must occur for the market to clear when bonds are issued. It would be expected that larger and more frequent issues such as U.S. Treasury bonds would be more liquid and have a lower risk premium (Fleming, 2003). Liquidity risk is associated with lower prices and higher yields that provide incentives for individuals to readjust portfolios and compensate them for other problems associated with selling a bond before maturity. As such, liquidity risk is caused by imperfections in the bond market that increase the size of the liquidity premium. Measures of liquidity risk have included the variance of the difference between transaction prices and equilibrium prices for the asset, time between market clearings (Garbade and Silber, 1979), changes in the relative supplies of assets (Fair and Malkiel, 1971), and the bid-ask spread (Duncan and Singer, 1992).

The ratio of the quantity of FCS bonds issued over the quantity of U.S. Treasury bonds issued was included as the proxy for liquidity risk (Fair and Malkiel, 1971). Because these two types of bonds are not perfect substitutes, changes in the relative quantity issued can affect the yield spread. In this case, as the ratio increases, we would expect to see an increase in the spread due to the change of volume of new FCS issues relative to U.S. Treasury issues (Fleming, 2003). In order for the increased volume of FCS securities to be sold, prices would need to fall and the yield to maturity would need to increase to provide incentives for investors to adjust their portfolios and the relative supply variable should have a positive sign in the empirical model. In their study, Duncan and Singer (1992) used the bid-ask spread as a proxy for liquidity risk, as did Elton et al. (2004).

For the time period studied, the bid-ask spread quoted by the *Wall Street Journal* was generally reported as a constant with very little variability in the values. Likely, the

small variability was due to the infrequent trading activity of FCS bonds, making the bid-ask spread in our data an unreliable estimator of liquidity risk.

Other Variables

The data show a large shift in both the yield spread and yield ratio precipitated by a combination of the Russian financial crisis on August 17, 1998, and the Long-Term Capital Management (LTCM) bailout in the United States by the New Federal Reserve on September 23, 1998. These events led to increased volatility in international financial markets called "financial contagion." Specifically, contagion was created by (*a*) Russia announcing intentions to restructure domestic currency debt obligations, (*b*) a moratorium on the repayment of private external debt instituted by Russia, and (*c*) the near collapse of LTCM. Several articles have examined the impact of financial contagion on stock prices (Rigobon, 2002) and spreads in bond markets (Dungey, Martin, and Pagan, 2000).

As would be expected, bond prices in financial markets around the world adjusted to the higher levels of risk associated with the two events described above, whereby yield spreads of securities with higher levels increased relative to lower risk bonds. Consistent with other bond markets, our data show an increase in the yield spread and ratio due to differences in the level of risk between Treasury and FCS bonds. In essence, bond prices and relative yields changed due to an increase in the demand for lower risk assets such as Treasury issues and a decrease in demand for riskier assets such as FCS securities.

To account for the mean shift in the data, a binary variable was introduced to improve the precision of our estimates and make the error term consistent with the assumptions in the empirical model. Binary variables have been used to model transitions of similar mean shifts previously (Hamilton and Susmel, 1994; Lastrapes, 1989). In a recent paper, a method was shown for identifying innovations in a time series (Smith, 2004). In our data, the cause and timing of the mean shift are clearly identified by the two events discussed above. Following methodologies in previous research, a binary dummy variable was used to model the mean shift.

The yield to maturity for 91-day Treasury bills is included to control for the general level of interest rates. Theory gives no indication of the sign of this variable.

Empirical Model Defined

An ARCH model with autoregressive errors was used to estimate parameters of equation (2) from the time series. ARCH models empirically tested in this paper are variants of ARCH(q) with an *m*th-order autoregressive error structure. The empirical model used is of the form:

$$\pi_t = \beta_0 + \beta_1\mu_{Dt} + \beta_2 T_t + \beta_3\mu_{Lt} + \beta_4 D_t + \nu_t, \tag{10}$$

where π_t, μ_{Dt}, and μ_{Lt} are as defined previously; T_t is the yield rate for 91-day Treasury bills; D is a binary variable taking the value of 0 before August 17, 1998, and 1 thereafter. The error term, ν_t, includes omitted variables that affect the spread and ratio. (An

explanation of the ARCH model is provided in the following section.) Finally, β_0, β_1, β_2, β_3, and β_4 are parameters to be estimated.

Assumptions for the error structure in equation (10) are:

$$\nu_t = \varepsilon_t - \varphi_1 \nu_{t-1} - \dots - \varphi_m \nu_{t-m},$$

$$\varepsilon_t = h_t^{0.5} e_t,$$

and h_t, the conditional variance, is defined as:

$$h_t = \omega + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 .$$

The order of the autoregressive error structure is denoted by m, q is the number of ARCH terms, and $e_t \sim N(0, 1)$. It is assumed that $q > 0$ and $\omega > 0$; $\alpha_i \geq 0$.

Results

Parameter estimates for the models are reported in tables 2 and 3. Table 2 presents the results when π_t (yield spread) is used as the dependent variable, and the coefficients for the three different proxies for default risk as well as the other independent variables described in equation (10) are shown. Similar results are reported in table 3 when π_{Rt} (yield ratio) is used as the dependent variable.

All of these specifications indicate that both liquidity risk and default risk premiums are present in the spread between FCS securities and U.S. Treasury bonds. Significance of the liquidity and default risk proxies suggests market prices and yields respond to risk factors as anticipated.

When π_t is the dependent variable (table 2), the liquidity variable (μ_{Lt}) has positive signs, consistent with theory. Estimated coefficients for the value-added and USDA index models are significant at the 1% level, and the provision ratio model is significant at the 5% level. In table 3, when π_{Rt} is the dependent variable, the liquidity proxy is significant at the 1% level for all three models, with the correct positive signs. Therefore, in our models, as the quantity of FCS bonds increases relative to U.S. Treasury bonds, the yield spread and yield ratio both increase as suggested by theory.

Based on these findings, it appears the price of FCS bonds would have to fall relative to U.S. Treasury bonds and the yield to maturity increase relative to U.S. Treasury bonds for individuals to incur the costs of rebalancing their portfolios and to provide incentives to purchase the FCS issues. The consistency with theory and level of significance for this liquidity variable indicates the presence of liquidity risk in the FCS bonds.

Results for all default risk proxies (μ_{Dt}) when π_t (yield spread) is the dependent variable are presented in table 2. The estimated coefficients for all three default proxies are significant at the 1% level and have the correct sign. When the yield ratio (π_t) is the dependent variable, the value-added and provision ratios are significant at the 1% level (table 3). However, the estimated coefficient for the USDA index was not significantly different from zero. The significant variables have the correct signs as predicted by theory and the proxies. These results suggest the estimates for default risk are robust.

Table 2. Estimated Parameters for ARCH(2) Models Using Three Different Proxies for Default Risk (dependent variable is *Yield Spread*, π_t)

	Default Risk Proxies (μ_{Dt})		
Independent Variable	USDA Index	Provision Ratio	Value-Added Ratio
Intercept	0.2915*	0.8932**	0.1852**
	(0.1596)	(0.3900)	(0.0834)
T_t	0.0683***	0.0827***	0.0666***
	(0.0116)	(0.0114)	(0.0117)
μ_{Lt}	1.2684***	0.9795**	1.2334***
	(0.4027)	(0.4279)	(0.4017)
μ_{Dt}	-0.004006***	-36.5954***	-23.9792***
	(0.001548)	(13.9414)	(5.9779)
D	0.1442***	0.1581***	0.1315***
	(0.0363)	(0.0318)	(0.0392)
ω	0.001582***	0.001547***	0.001567***
	(0.0000403)	(0.0000416)	(0.0000419)
ARCH(1)	0.1398***	0.1504***	0.1466***
	(0.0230)	(0.0231)	(0.0227)
ARCH(2)	0.0904***	0.1010***	0.0908***
	(0.0162)	(0.0174)	(0.0165)
AIC	-7,296.4412	-7,304.7199	-7,303.9198
R^2	0.9665	0.9665	0.9666

Notes: Single, double, and triple asterisks (*) denote statistical significance at the 10%, 5%, and 1% levels, respectively, based on two-tailed T-tests. Values in parentheses are standard errors. The estimated coefficients and standard errors for the AR(1)–AR(6) are not included in this table. However, all coefficients have absolute values of less than one and are significant at the 1% level.

The binary (dummy) variable (D) is significant at the 1% level for all six models in the two tables. Significance of this variable suggests there was a shift in the yield structure for FCS bonds after the Russian financial crisis. Estimated coefficients for the 91-day T-bill variable (T_t) that was included to account for the general movement in interest rates were positive and significant at the 1% level in all models. All of the autoregressive terms in each model had values within the unit root circle as required for stability; however, the coefficients and standard errors are not included in the tables.

Determining the Number of Autoregressive Lags

Observation of the residuals from OLS models indicated the potential presence of autocorrelation and/or heteroskedasticity. The residuals from an OLS regression on the yield spread using the provision ratio as the default risk proxy are displayed in figure 3 to illustrate the poorness of fit from the OLS framework. Autocorrelation causes the standard errors for estimated parameters to be biased, and heteroskedasticity causes the OLS estimates to be inefficient.

To test for autocorrelation, the partial autocorrelations were examined for both the yield spread and yield ratio data. The autocorrelations decayed to less than 0.05 by the sixth lag for all models with both dependent variables. For the yield ratio data, lags 1–5 were used, and for the yield spread, lags 1–6 were used in the regression model.

Table 3. Estimated Parameters for ARCH(2) Models Using Three Different Proxies for Default Risk (dependent variable is *Yield Ratio*, π_{Rt})

	Default Risk Proxies (μ_{Dt})		
Independent Variable	USDA Index	Provision Ratio	Value-Added Ratio
Intercept	0.9681***	1.1931***	1.0300***
	(0.0309)	(0.0653)	(0.0148)
T_t	0.0124***	0.0109***	0.0122***
	(0.002133)	(0.002114)	(0.002124)
μ_{Lt}	0.3186***	0.2460***	0.2451***
	(0.0616)	(0.0630)	(0.0610)
μ_{Dt}	0.000123	-7.2118***	-4.3905***
	(0.000289)	(2.3154)	(1.0045)
D	0.0304***	0.0334***	0.0299***
	(0.006436)	(0.005246)	(0.006441)
ω	0.0000475***	0.0000479***	0.0000475***
	(1.3151E-6)	(1.3221E-6)	(1.3612E-6)
ARCH(1)	0.2134***	0.2060***	0.2097***
	(0.0229)	(0.0225)	(0.0227)
ARCH(2)	0.1464***	0.1476***	0.1507***
	(0.0187)	(0.0193)	(0.0194)
AIC	-14,578.723	-14,575.835	-14,577.438
R^2	0.9720	0.9720	0.9720

Notes: Single, double, and triple asterisks (*) denote statistical significance at the 10%, 5%, and 1% levels, respectively, based on two-tailed T-tests. Values in parentheses are standard errors. The estimated coefficients and standard errors for the AR(1)–AR(5) are not included in this table. However, all coefficients have absolute values of less than one and are significant at the 1% level.

ARCH Terms

Heteroskedasticity is caused when the error variance is not constant for all observations. The presence of this condition was tested by the Engle Lagrange multiplier test on the structural models and this test indicated heteroskedasticity was present in the residuals. To correct for heteroskedasticity, ARCH models were used because they model the changing variance in the data with a conditional variance that is a function of the past values in the series.

The number of ARCH terms to include in the final models was determined by first squaring all of the residuals from the structural OLS models using either lags 1–6 or 1–5 (depending on the dependent variable). Lags from 1 to 25 of the residuals were created and all of the lagged squared residuals were regressed on the current squared residual. The first two lags were significant at least at the 10% level for all models; therefore, two ARCH terms were included in the final model.

Diagnostic Test for Normality of Residuals

After running the ARCH models, the residuals should have been normally distributed. Although patterns are less pronounced, they are still evident in the residuals from the regression using the provision ratio and yield spread (figure 4). The test of normality of

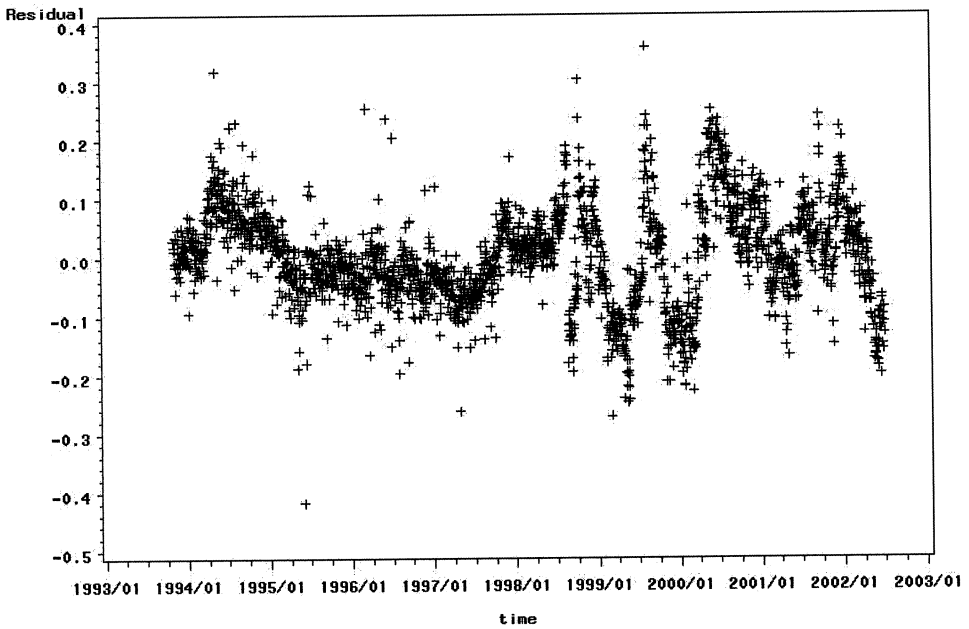

Figure 3. Residuals from the OLS regression on the yield spread, using the provision ratio as a proxy for default risk

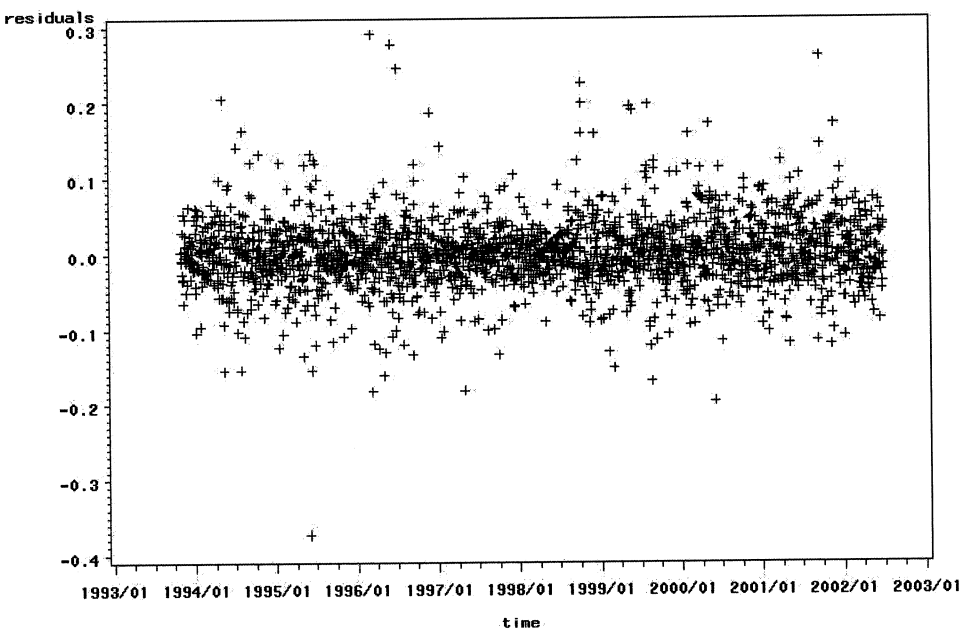

Figure 4. Residuals from the ARCH regression on the yield spread, using the provision ratio as a proxy for default risk

Table 4. Elasticity Estimates for Variables

	Dependent Variable = *Yield Spread* (π_t)			Dependent Variable = *Yield Ratio* (π_{Rt})		
	— Default Risk Proxies —			— Default Risk Proxies —		
Variable	USDA Index	Provision Ratio	Value-Added Ratio	USDA Index	Provision Ratio	Value-Added Ratio
T-Bill Yield (T_t)	0.871	1.054	0.849	0.158	0.139	0.156
Liquidity Risk (μ_{Lt})	0.035	0.027	0.034	0.009	0.007	0.007
Default Risk (μ_{Dt})	-0.983	-2.846	-0.599	0.030	-0.561	-0.110

Note: Elasticities were calculated at the sample means.

the residuals was rejected at the 1% level, indicating that the standardized residuals ($e_t/h^{0.5}$) are not normally distributed and some conditional volatility remains in the residuals, but there was a noticeable improvement over the OLS model. Similar patterns were evident for all models and are not reported here.

Elasticity Estimates

To test the responsiveness of the yield spread and yield ratio to changes in the independent variables in the empirical models, elasticity estimates were calculated (table 4). All elasticity estimates were calculated at the variable means. As observed from table 4, all default risk elasticity estimates have larger absolute values than the liquidity elasticity estimates. For example, liquidity elasticity estimates range from 0.007 to 0.035. Default risk elasticity estimates (absolute values) range from 0.110 to 2.846, ignoring the one insignificant coefficient estimate. Therefore, the yield spread and yield ratio are both more responsive to the default risk proxies than to the liquidity risk proxies.

Conclusions

This study shows the existence of both default and liquidity risk in the spread in yields to maturity between FCS bonds and U.S. Treasury bonds. Furthermore, the results are robust across different specifications of our empirical models. In addition, the elasticity estimates show that yields are much more responsive to default risk than to liquidity risk.

The existence of these risk premiums implies that agricultural borrowers must pay higher rates of interest on loans than if the premiums were lower or did not exist. Given the volume of FCS loans to agricultural producers, any reduction in risk premiums would have significant benefits for agricultural borrowers. Policies that increase investor confidence in the financial viability of the FCS will reduce the spread and borrowing costs for agricultural borrowers.

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