Spring 1996

Volatility Risk Premiums in Futures Markets: Investment Prices and Commercial Bank Performance

Richard P. Gregory
Old Dominion University

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Volatility Risk Premiums in Futures Markets: Investment Prices
and Commercial Bank Performance

A Dissertation in

Business Administration

By

Richard P. Gregory

Submitted in Partial Fulfillment
Of the Requirements
for the Degree of

Doctor of Philosophy in Business Administration

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April 1996

We approve the Dissertation of Richard P. Gregory

Date of Signature

_____   _____

Mohammed Najand
Associate Professor of Finance
Dissertation Advisor
Chair of Committee

_____   _____

Sylvia C. Hudgins
Associate Professor of Finance

_____   _____

Christopher Colburn
Associate Professor of Economics

ABSTRACT

This dissertation is an depth study of the measurement of pricing biases in futures options, and whether this bias is due to volatility risk premia, market overreaction to public information or information asymmetry. Futures options for thirteen different contracts are used. Additionally, the contracts are from three different marketplaces.

Six hypotheses are tested. The first is whether implied option volatilities from the Black (1976) futures option model is the only significant determinant of the volatility processes of the underlying futures contracts. For this estimation, we use both a GARCH (1,1) model and the Partially Non-parametric model of Engle and Ng (1993). We find that implied option volatility is not the sole significant predictor for of conditional volatility for 10 of the thirteen contracts. For three of the contracts, the implied volatility is insignificant.

Second, we test Stein's (1989) hypothesis of market overreaction. We find that in general, the evidence tends to support the prediction of Stein's hypothesis, though there are important exceptions.

Third, we test Nandi's hypothesis of asymmetric information in the market between traders. We test this by testing the significance of option contract volume on the volatility process.

In general, the evidence tends to support Nandi's hypothesis, though again, there are important exceptions.

Fourth, We test the significance of the news response curves as outlined by Engle and Ng (1993). We find that there is little support in the shape and significance of the news response curves to support the presence of volatility risk premiums.

Fifth, we test for differences in the structures of the estimated GARCH models between contracts and model. We find that American based interest-rate futures markets tend to be more highly reactive to innovations than the London (LIFFE) market.

Sixth, we test for the exposure of major commercial banks dealing in futures to a volatility risk premium. While we find evidence that some banks are exposed to our volatility risk premium proxy, the contracts exhibiting significant coefficients generally do not match up with those contracts suspected of harboring volatility risk premiums under the previous tests.

We conclude that there is little empirical support for the presence of a priced volatility risk premium amongst futures and futures options. The presence of pricing biases in such markets seems better explained as being due to information asymmetry or overreaction to news.

TABLE OF CONTENTS

I. Introduction

"You have to do some of this stuff in options because of customer demand. Nobody wants to write a lot of these things because the risk profile is horrible. You end up making a tiny bit of money, or you lose a gigantic amount....you are always vulnerable to a gap move. You just can't hedge it."

-Unidentified risk manager, *Fortune* March 7, 1994, pg. 53.

Market efficiency, the idea that investors behave rationally in incorporating new information into asset prices, is the foundation of the finance discipline. Financial pricing models and the empirical methods used for testing theories are all based on the idea that financial markets rapidly incorporate new information into asset prices, converging to a new equilibrium price given all of the information available.

Current research using the implied volatility of stocks has led to a method of investigating the issue of market efficiency.

If markets are informationally efficient, and the implied volatility of a stock from an option pricing model incorporates all available information, then the implied volatility should be an adequate description of the expected volatility of the underlying stock.

Stein (1989), shows that implied volatilities over a short term overreact to news as compared to longer term volatilities. His results assume the nonexistence of volatility risk premiums. Lamoureux and Lastrapes (1993) demonstrate that the implied volatility is by itself an inadequate explanation of the behavior of the markets volatility expectations. They explain the discrepancy as due to either market inefficiency, or to the pricing of volatility risk by the market. That is, either the market is not efficiently incorporating publically available information into its forecast of future stock volatility, or it is rewarding traders in the stock options market for bearing the risk of volatility.

Whether the options market is inefficient or is pricing volatility risk has some important implications for the fields of finance and economics. If financial markets are found to be inefficient in the processing of what is essentially public information then it follows that investors may be irrational, information has relatively high transactions costs and/or there are impediments in the markets adjustment process. In such cases, the finding for market inefficiency would be useful for the

forming of portfolios, capital structure decisions and hedging in that the inefficiency could be taken advantage of by market participants with superior information.

The possibility of the existence of volatility risk premia is only slightly less troubling for market efficiency. If there are no risk premiums in the pricing of futures then the expected return on a futures contract is zero:

$$E_{t-1} \left(\frac{F_t}{F_{t-1}} \right) - 1 = 0 \qquad (1)$$

Where F_i is the price of Futures Contract at time I, delivered at some future time T.

In this case, the futures contract is an unbiased predictor of future spot rates, and then the amount needed to hedge an expected cash flow can be calculated in a straight forward fashion.

But if there is a risk premium on the expected variance of a futures contract, then:

$$E_{t-1} \left(\frac{F_t}{F_{t-1}} \right) - 1 = -R_{t-1} var_{t-1} \left[\frac{F_t}{F_{t-1}} \right] \qquad (2)$$

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The Conditions Needed to Test Market Efficiency

Typically, by asking whether a market is informationally efficient, the question actually asked is "Do investors as a group behave like a Bayesian statistician?". That is, do investors trade at a price that rationally uses all available information, not over- or under-reacting in response to "animal spirits".

The major difficulty in testing for market efficiency is that usually the *a priori* subjective beliefs of investors are unknown. Most investigations of market efficiency have really been tests of whether a particular pricing model correctly describes observable prices. Rejection of the model not implying rejection of market efficiency.

But option pricing models offer a means of assessing a priori market beliefs in a fashion that is appealing in its simplicity. The original Black-Scholes option pricing model for European call options makes clear that given the observable parameters of the current stock price, the option exercise price, the option maturity date, and the risk free rate, that the markets subjective beliefs can be implicitly solved for:

$$c_t = S_t N(d_1) - Xe^{-r(T-t)} N(d_2) \qquad (5)$$

where N(.) is the cumulative normal distribution function,

$$d_1 = \frac{\ln(\frac{S_t}{X}) + (r+(1/2)\sigma^2)(T-t)}{\sigma\sqrt{T-t}} \qquad (6)$$

$$d_2 = d_1 - \sigma\sqrt{T-t} \qquad (7)$$

Where;

S is the current stock price,

X is the exercise price of the option,

T is the date of maturity,

r is the risk free rate,

σ is the expected volatility of the underlying stock.

By making use of various approximation methods, σ can be solved for implicitly. The behavior of this implied volatility can then be tested to see if it incorporates information in an efficient manner.

In order to test market efficiency, two items must be specified correctly. First, the pricing model used must be an adequate description of reality. In this case, this means that the Black-Scholes model should have the appropriate parameters and the appropriate functional form to describe actual pricing behavior. Second, the assumptions the model makes about the time series behavior of the exogenous variables must be in accordance in reality.

In terms of the Black-Scholes model, research has shown that there may be inadequacies. First, most options that are traded are American style options, not the European style options priced by Black-Scholes. The possibility of early exercise for the American option has thus far yielded no closed-form solution similar to the Black-Scholes option model. Only approximation methods as per Barone-Adesi and Waley are available, though the performance of these methods is very good. As Stein (1989), Jarrow and Wiggins (1989), and Rubinstein (1985) show though, as long as at-the-money options are used, the deviations in price due to the early exercise possibility are virtually non-existent.

The second problem is that the Black-Scholes formula assumes non-stochastic exogenous parameters. The problem of non-stochastic interest rates is not the subject of investigation here. Jarrow and Wiggins (1989) have shown that the Black-Scholes implicit volatility can be used for the valuing of options even if interest rates follow a stochastic process. Of interest here

is the constant variance assumption as it is this which will be used to measure for market efficiency and volatility risk premiums. Previous work has documented that asset price volatilities and option implied volatilities vary over time[1]. This in turn leads to the problem of effectively modeling option prices in the face of stochastic exogenous parameters and then the correct time series modelling of the parameters.

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1. See Fama (1965), Black (1976), Merton (1980), Poterba and Summers (1986), French, Schwert and Stambaugh (1987), Harvey and 1. (Cont.) Whaley (1991) for assets; Poterba and Summers (1976), Scott (1987), Bodurtha and Cortadon (1984) and Hull and White (1987b) for implied volatilities.

Functional Form and Option Pricing

Previous research has attempted to adapt the Black-Scholes formula to a stochastic variance setting. Working at the same time, and in conjunction with Black and Scholes, Merton (1973) made the first attempt to incorporate stochastic parameters into the pricing function of an European option. Merton showed that the option in this case could be valued in terms of a bond price, though not in a closed form solution.

It was Garman (1976)·who provided the first breakthrough in evaluating derivative securities on assets with stochastic variance. Though he was unable to solve for an explicit analytical solution, Garman showed that European call option on a stock with a stochastic variance rate must satisfy the following differential equation;

$$\frac{\partial f}{\partial t} + \sum_{i,j} \rho_{ij} V_i V_j \frac{\partial^2 f}{\partial \theta_i \partial \theta_j} - rf = \sum_i \theta_i \frac{\partial f}{\partial \theta_i} [-\mu_i + \beta_i (r_m - r)] \tag{8}$$

Where;

    f is a security whose price is dependent on the state variables represented by the thetas.

    V is the instantaneous standard deviation of the relevant state variables,

r_m is the instantaneous return on the market portfolio,

r is the risk free rate of return,

β is the multiple regression vector of the state variables on the market portfolio.

Johnson (1979), and Johnson and Shano (1987), and Wiggins (1987) used numerical solution techniques to solve for the price of options when the volatility of the underlying asset price is stochastic. This is in contrast to Cox and Ross (1976) where the source of the stochastic volatility was in the actual asset price, not in the rate of return. The result of Cox and Ross in this case holds only if the volatility is a traded asset or if the volatility is uncorrelated with aggregate consumption.

Hull and White (1987) were the first to derive a closed form solution for European call option prices where asset price volatility is stochastic. Their solution calls for the volatility to be uncorrelated with consumption, and that the volatility risk to be an untraded asset. By assuming that volatility is an unpriced source of risk, the differential condition formulated by Garman proved solvable in an explicit form.

The resulting pricing formula that Hull and White derives is a modified Black-Scholes equation , evaluated over the remaining life of the mean variance of the derivative security;

$$f(S_t, \sigma_t^2, t) = \int [e^{-r(T-t)} \int f(S_t) g(S_t|V^*) dS_t] h(V^*|\sigma_t^2) dV^2 \qquad (9)$$

Hull and White (1987) also provided an analysis of the bias in the Black-Scholes model caused by stochastic volatility. They derived an expression in series form for the pricing bias. This method also allows for the explicit pricing of the risk premium tied to volatility risk, in the form of a constant risk price and volatility processes without drift, with constant drift and constant proportional drift.

Amin (1991) developed a class of discrete, path-independent models to compute the prices of American options in the Black-Scholes framework. The results also extend to the case in which the underlying state variables determining the price path of the underlying asset have time dependent volatility functions.

Amin and Ng (1993) derive an option valuation formula for when the stock return volatility is both stochastic and systematic. In this case, if the mean, volatility, and covariance processes for the stock option returns and consumption processes are predictable, then the option valuation equation may be written in a risk preference free form. It is noteworthy that considering the explosion of alternative models to the Black-Scholes pricing model, the most recent comparison by Rubinstein (1985) shows that no alternative is consistently superior to the Black-Scholes equation.

II. Stochastic Processes and GARCH

The second problem of dealing with stochastic exogenous factors is the correct time series modelling of these parameters. The development of autoregressive conditional heteroscedasticity models in financial literature has led to the investigation of the conditional volatility of stock and option prices, and their relationship with implied volatilities.

Mandlebrot (1963) and Fama (1965) first recognized that the measured variances and covariances of speculative prices changed through time. Engle (1982) first proposed that returns on assets with stochastic volatilities could be modeled in the following manner;

$$R_t = X_t + e_t \qquad (10)$$

$$e_t \mid e_{t-1}, e_{t-2}, \ldots \sim N(0, h_t), \qquad (11)$$

$$h_t = C + \sum_{i=1}^{p} \alpha_i e_{t-1}^2 \qquad (12)$$

where;

R_t is the return on the asset at time t,

X_t is a set of exogenous variables,

e_t is the return innovation or "error" term,

h_t is the conditional variance of e_t given the available

   information at time t,

C is a constant and

p is the order of the lag structure.

In this case, the conditional variance at time "t" is
modeled as an autoregressive process. As a result, the variances
of the error term are time-dependent and are no longer normally
distributed. This matches the empirical observation that there
seems to be time dependencies in the variance process of
financial time series. The ARCH model also allows for "volatility
clustering", where large price changes are followed by large
price changes of unpredictable sign, another feature of financial
time series.

In the case of ARCH-type models, the parameters in Equations
10,11, and 12 can be estimated by maximizing the log-likelihood
function:

$$L = \sum_{t=1}^{T} 1/2 \ [-\ln(2\Pi) - \ln(h_t) - \frac{(\varepsilon)^2}{h_t} \qquad (13)$$

Testing for the presence of ARCH effects can be accomplished
by the regression of the squared error term on lagged values of
itself, for the number of appropriate number of lags to be
tested. The test statistic is then the number of observations
times the coefficient of determination from the regression. The

testing of individuals alphas from equation 12 is somewhat

problematic. Standard t-tests of parameters using the asymetric

standard errors can lead to overrejection of the null

hypothesis. But corrections suggested by Bollerslev and

Wooldridge can correct for the overrejection (1992). The

significance of the model as a whole is tested using the Ljung-

Box test for 12th order autocorelation, which follows a Chi-

square distribution.

Bollerslev (1986) later introduced the General

Autoregressive Conditional Heteroscedasticity (GARCH) model which

replaces equation 12 above with a more generalized structure for

generating the asset volatility;

$$h_t = c + \sum_{i=1}^{p} \alpha_i e_{t-i}^2 + \sum_{i=1}^{q} \beta_i h_{t-i} \qquad (14)$$

The replacement of the ARCH structure by the GARCH

specification leads to less need for a long lag structure to

explain the behavior of time series. In the GARCH context, the

values of parameters are very important, as the parameters must

sum to less than one, otherwise the variance process is non-

stationary. An appealing aspect of the GARCH model is that

usually, only a GARCH (1,1) model is required (i.e. only one α

and one β). Another appealing aspect of the GARCH formulation is

that the discrete time GARCH model converges to a continuous time

stochastic differential equation as the sampling interval grows small (Nelson (1990)).

Pagan and Schwert (1990), and Akgiray (1989) have shown that low-order GARCH models describe the return volatility of stocks very well. Other research investigating the relation between a stock portfolio's expected return and conditional variance has also seemed to support the use of GARCH modeling.

So seemingly, the stock return process can be taken as being generated by an ARCH-type process. But despite these apparent successes, there does seem to be additional features of the volatility generating process that these simple parameterizations fail to take into account. Popularly referred to as "leverage" effects, these occur when unexpected "bad news" increases predictable volatility more than an unexpected increase in "good news" or more technically, the sign of the innovation term leads to an effect on the conditional variance that is independent of the size of the innovation. Black (1976); French, Schwert and Stambaugh (1987); Nelson (1990); Schwert (1990); and Engle and Ng (1993) all find substantial evidence of such asymmetric effects in the pricing of assets.

In response, Nelson (1990) developed the EGARCH model, where non-negativity constraints are imposed on the conditional variance process:

$$\ln h_t = W + \sum \gamma_i \, g(z_{t-i}) + \sum \beta_i \ln(h_{t-i}) \qquad (15)$$

$$z_t = \frac{\varepsilon_t}{\sqrt{h_t}} \qquad\qquad (16)$$

$$E|Z_t| = (2/\Pi)^{1/2} \ where \ Z_t \sim N(0,1) \qquad (17)$$

$$g(z_{t-i}) = \theta z_t + \kappa[|z_t| - 1/2E|z_t|] \qquad (18)$$

In this case, if K < 0, then the conditional variance falls when innovations are positive and increases if innovations are negative. This aspect of the model mirrors the available evidence on the time series behavior of asset returns. If θ = 0 , then large (small) innovations increase (decrease) the changes in the variance process if the absolute value of the innovation is greater (smaller) than the mean absolute value of the innovations.

While the EGARCH model is appealing, it forces the data into a symmetrical response to innovations of similar absolute size, but of different sign. As pointed out by Engle and Ng (1993), some time series display a phenomenom where large innovations of a certain sign have different impacts on the time series than do similar signed, but smaller innovations. As a result, Engle and

Ng (1993) have proposed bias tests for the sign of the
innovations of the varince process, of which greater detail is
provided in the methodology section following.

III. Recent Research on the Information
    Content of Implict Volatility from Option Models

Recent research by Lamoureux and Lastrapes (1993) examines the behavior of implied variances from option market pricing and the underlying stock prices. Testing the joint hypothesis that markets are informationally efficient and that option prices are explained by a model derived by Hull and White (1987). The model used is based on the continuous-time process for the underlying stock of:

$$dS = \phi S \, dt + \sqrt{V}S \, dw \qquad (19)$$

$$dV = \mu V \, dt + \xi V dz \qquad (20)$$

Where;

S is the instantaneous stock price,

V is the volatility process,

and dw and dz are Brownian Motions processes with an instantaneous correlation of p.

The volatility process is the time path that the volatility of the stock price follows over time. Brownian Motion Processes are increments of normally distributed random variables with zero mean and finite variance.

If volatility risk is not priced, a call option on this stock will have the price;

$$c_t = \int_t^T BS(V_t^*) h(V_t^* | I_t) \, dV_t^* \qquad (21)$$

$$= E[BS(V_t^*) | I_t] \qquad (22)$$

where,

$$V_t^* = \frac{1}{T-t} \int_t^T V_i d_i \, , \qquad (23)$$

Where;

$h(V_t^* I \, V_t)$ is the density of V_t^* , the mean variance over the life of the security, conditional on V_t, the current instantaneous variance,

T is the expiration date of the call option,

I_t is the information available at time t,

BS(.) is the Black-Scholes option pricing model.

Lamoureux and Lastrapes use at-the-money options of ten stocks to solve for the implied volatility. As shown by Cox and Rubinstein (1985), the Black-Scholes formula is linear in the standard deviation for at-the-money options. In this case, the implied variance can be used as the market's assessment of

average stock-return volatility over the life of the option under the assumption that the Hull and White model is valid.

Lamoureux and Lastrapes then propose two tests for using the implied variance as a predictor of actual variance. Given that the stock returns are generated by a GARCH (1,1) model, then if σ_t is taken as the implied standard deviation from the option price of a stock, the α and β terms in the following model will be insignificant if the implied volatility reflects all available information concerning the stock's expected volatility;

$$R_t = X_t + e_t \qquad (24)$$

$$e_t \mid e_{t-1}, e_{t-2}, \ldots \sim N(0, h_t), \qquad (25)$$

$$h_t = c + \alpha e_{t-1}^2 + \beta h_{t-i} + \gamma \sigma_{t-1} \qquad (26)$$

This GARCH model is estimated for a sample of daily returns for 10 non-dividend paying stocks over the period of April 19, 1982 to March 30, 1984[2]. Lamoureux and Lastrapes note that there are two possible sources of bias which they will estimate through simulation. The first source of bias is that due to the virtual

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2. The companies are Computer Sciences Corp., Digital Equipment Corp., Datapoint, Federal Express, National Semiconductor, Paradyne, Rockwell, Storage Technologies, Tandy Corp., and Toys R Us. Data was available for Toys R Us beginning June 30, 1982.

linearity of the Black-Scholes formula for at-the-money options, large values for the standard deviation of the variance process can lead to large implied volatilities for at-the-money options. The second source is that if the stock return distribution is skewed, then the assumption that the Brownian motion processes are not instantaneously correlated in the continuous time process model of the stock price is amiss. To investigate the size of these possible biases the authors run a Monte Carlo simulation of the continuous time process.

Their results show that for the set of stocks used, the mean bias of the analytic approximation of the Hull and White model is never more than 1.3% of the actual variance of the variable generated in the Monte Carlo analysis. Therefore, they conclude that their variance extraction technique is insensitive to the nonlinearity assumption and skewness in the context of their data.

The regression based tests of Lamoureux and Lastrapes find that in general, the GARCH coefficients are not equal to zero. Thus they find that the implied volatility is not an exact predictor of the conditional volatility of the stock return process. These results are consistent with earlier results by Day and Lewis (1992) that past information seemingly improves the volatility forecast of the market.

As an even stronger test, Lamoureux and Lastrapes conduct an out-of-sample test. For each day they construct the GARCH

forecasts h_{t+1}, h_{t+2},...h_{t+N} for the volatility over the remaining life, N, of the intermediate term option on day t by setting the coefficient on the implied volatility term equal to zero. Then a mean G_t is constructed of those forecast conditional volatilities.

The joint null hypothesis of market efficiency and correct model specification asserts that G_t will not be a better predictor of realized return volatility than the implied volatility from the option formula.

Their results show that in general the optimal forecast of average realized volatility places statistically significant weights on the implied variance option market and on the updated conditional variance forecast.

These results together suggest that the joint hypothesis of market efficiency and correct model specification is rejected. Implied variance tends to underpredict realized future variance.

Given market efficiency, Lamoureux and Lastrapes point out that their results could be explained by the presence of a risk premium applied to the untraded variance process in the options market. The Hull and White model used assumes that such risk is unpriced. If variance uncertainty gives negative utility to traders, then the observed option price will be lower than the model predicted risk-neutral price. When the observed price is applied to the Black-Scholes formula, the derived implied variance will be lower than the actual expected variance of the

stock, thus explaining the under-prediction found in the out-of-sample results. They conclude that models ignoring the presence of risk premiums in options markets are inadequate in describing the prices found in options markets assuming market efficiency.

Stein (1989) examines the term structure of the implied volatilities for S&P 100 index options. He reasons that if options are thought of as reflecting a speculative market in asset volatility, then the implied volatility of the option should equal the average volatility that is expected to prevail over the life of the option. Thus Stein immediately suggests that the mispricing observed in options pricing using implied volatilities could be due to the option contract ending before the life of the asset. Thus there would be a difference in the implied volatility constructed from an option with a definite maturity date and the actual forecast of an assets average expected volatility over the entire future.

Stein assumes that markets will conform to rational expectations in its formation of implied volatility for options with different maturities and then tests to see if they do. If it is assumed that the instantaneous volatility, V, follows a continuous-time mean-reverting AR1 process:

$$dV_t = -\psi (V_t - V^*) dt + \chi V_t dz \qquad (27)$$

then the expected volatility as of time t+j will be given by:

$$E_t(V_{t+j}) = V^* + e^{-\psi j}(V_t - V^*) \qquad (28)$$

Where V* is the long-run value of the volatility

process.

If we let $i_t(T)$ be the implied volatility on an option with time interval T remaining till expiration, then this should equal the averaged expected instantaneous volatility over the interval:

$$i_t(T) = \frac{1}{T}\int_{j=0}^{T}[V^* + e^{-\psi j}(V_t - V^*)]dj \qquad (29)$$

$$= V^* + \frac{e^{-\psi T} - 1}{T \ln e^{-\psi}}[V_t - V^*] \qquad (30)$$

Equation 30 provides the basis of the empirical test Stein conducts. Given that there are two options on the same asset, one with a time to expiration T and a second with a time to expiration of K>T, then the following restriction is derived:

$$[i_t(K) - V^*] = \frac{T(e^{-\psi K} - 1)}{K(e^{-\psi T} - 1)}(i_t(T) - V^*) \qquad (31)$$

Obviously, if there is a movement in the implied volatility

of the nearby option (the one that expires at time T) then the corresponding mcvement in the longer term option should be smaller.

Stein uses options expiring within one month for the nearby option and options expiring from one to two months as the distant option. Stein uses the binomial Cox-Ross-Rubinstein (1979) option pricing model to calculate the implied volatilities of at-the-money call and put options, then uses the average as the implied volatility.

Regressing the implied volatility of the distant option on the implied volatility of the nearby option as per equation 31 above, Stein finds that the coefficient is typically 0.818 or greater, and statistically significant. Theoretically, the coefficient will be equal to:

$$\frac{T(e^{-\psi(T+4)} - 1)}{(T+4)(e^{-\psi T} - 1)} \qquad (32)$$

Where,

$e^{-\varphi}$ =autocorrelation coefficient

A coefficient value of 0.818 would presuppose an autocorrelation coefficient between the implied volatility of the nearby contract of 0.94 or higher. Time series evidence presented by Stein shows that the highest autocorrelation coefficient on

the implied volatility is 0.88.

As a result, the reaction of the implied volatilities of the longer term options are more reactive to news than theory would suggest. This implies market inefficiency. Stein additionally notes that the effect seems to be rather small. In order for there to be large pricing errors worth exploiting, the time difference in the options would have to be much longer than the one month separation he uses.

Recent research has followed up on the term structure aspect first explored by Stein. Heynen, Kemna, and Vorst (1994) construct models for the relation between short- and long-term implied volatilities based on three different assumptions of volatility behavior for stock returns, including mean-reversion, GARCH, and EGARCH. They find that EGARCH model gives the best description of the three of asset price and the term structure of the implied volatilities.

Xu and Taylor (1994) look at the term structure of the volatilities of foreign exchange options. Using data from the Philadelphia options exchange over the period of 1985-1989. Throughout this period, important differences between short- and long-term expectations are found. They estimate the term structure and find that the slope changes frequently and that the markets exhibits significant variation in long-term volatility expectations.

Nandi (1995) develops a model of asymmetric information in

which shows that where information asymmetry about the future volatility exists, the option price is a function of the option trading volume. His model predicts that the expected average variance of the underlying asset is an increasing function of the net order flow in the option market. Thus this model predicts there will be a more substantial difference between the implied option variance and the conditional variance when there is a greater volume in the options market. This could mean that what is attributed to being the result of market overreaction or volatility risk premium is due to a lack of consideration to the effects of asymmetric information about the future volatility.

Summation of the literature on implied volatilities

The use of implied volatilities to test for market efficiency is not new. Latane and Rendleman (1976) made the first use of Black-Scholes implied volatilities (hereafter referred as IV) by showing that IV's could be used on a weekly basis to predict future volatilities of the underlying stock price ratios. Poterba and Summers (1976) use weekly data and find that the IV is a stationary series and that shocks to the volatility process do not persist for a long period of time.

Chiras and Manastar (1978) followed up the work of Latane and Rendleman and confirmed that the IV' s from the Black-Scholes equation predicted future volatilities. Schmalensee and Trippi (1978) found similar results for option premia. Beckens (1981) also found that iv's predicted future volatilities.

MacBeth and Merville (1979,1980) examined possible systematic biases in the Black-Scholes option model employing the implied volatilities of six actively traded stocks, they find that overall, the Black-Scholes model has a tendency to underprice in-the-money options and overprice -out-of-the-money call options. These mispricings increases to the extent to which the option is in- or out-of the money. The mispricings also increase as the time to expiration increases.

Manastar and Rendleman (1982) used the Black-Scholes equation to solve for the implied stock price and volatility of stock prices simultaneously. They reject the hypothesis that the implied stock prices provide no information regarding future stock prices and show that traders could generate abnormal profits if they can trade at stock prices that indicate deviation from the implied price.

Up to this point, the implied deviations had been calculated using close price data, subject to criticism in that the stock prices used were not synchronous with the call option price used as the option markets closed later than the stock market supplying the closing stock price. Brenner and Galai (1987) made use of transaction data to compute daily average implied variances and found these to be predictors of future average implied variances.

Scott (1987) tested the hypothesis that observed option prices are consistent with stochastic volatility, and finds evidence consistent with this hypothesis.

Bhattacharya (1987) reexamined the ability of Black-Scholes implied parameters to predict future parameter values. Using intra day price data and adjusting for the bid-ask spread, Bhattacharya found that intra day strategies based on implied parameters resulted in losses, while overnight strategies resulted in trading profits. These results lead to the conclusion that Black-Scholes option implied parameters do contain some

information not contained in contemporaneous stock prices, although this information may not be sufficient to overcome bid-ask spreads and search costs.

Engle and Chowdury (1989) estimated the implied stochastic process of the volatility of the S&P 500 index. They investigate the persistency of the volatility process for pre and post October 1987. They find that implied persistence of volatility after October 19,1987 is much weaker than the pre-October 19,1987 volatility persistence.

Kumar and Shastri (1990) reexamine the predictive ability of implied volatility. They accept the hypothesis that implied stock prices provide no information regarding the future movement of observed stock prices.

Morse (1991) looks at the intra-week behavior of implied volatility and finds that the differential between call implied volatility and put implied volatility tends to drop on Friday and rise on Monday.

Swidler and Diltz (1992) use data containing bid and ask quotes for both options and stocks. Adjusting for the bid-ask spreads, they find evidence that is inconsistent with the constant volatility assumption. Their tests also reveal a strong negative correlation between implied volatility and stock price. In light of their results, they suggest that instead of the Black-Scholes model, that a nonconstant volatility model would be more appropriate, particularly for longer-term options.

Day and Lewis (1992) make the first explicit comparison of the information content of implied volatilities and ARCH models. Day and Lewis find that adding the implied volatility as an exogenous variable to GARCH and EGARCH models suggests that implied volatilities may contain additional information not captured by the ARCH processes.

Choi and Wohar examine whether the volatility of stock returns forecasted by a GARCH-M model is consistent with the implied volatility observed in the option prices on the indexes of the S&P 500 and New York Stock Exchange Composite Indexes. The results suggest that the implied volatility in the options markets reflect conditional variances observed in stock markets. The results imply that traders expectations of volatility are formed based on observed conditional variances. The GARCH model also seems to explain the variation of implied volatilities and the term structure of implied volatilities very well.

Sheikh (1993) finds that implied volatilities are significantly positively related to forecasts of market return volatility and to recent realizations of stock and market volatilities. In addition, stock returns are found to be significantly positively related to lagged implied volatilities.

Laux and Ng (1993) provide more definitive evidence that autocorrelation in the time-varying rate of information arrival leads to the volatility dependencies captured by GARCH models. They find that while the autocorrelation explains substantial

proportions of the risk in currency futures, significant systematic GARCH effects remain.

In support of the results of Laux and Ng, Ederington and Lee (1993) find that much of the observed time of day and day of the week patterns in volatility can be tied to announcements of macroeconomic news concerning foreign exchange and interest rates.

Noh, Engle and Kane (1993) assess the performance of ARCH and implied volatilities in predicting the future prices of S&P 500 index from Sept. 1986 to December 1991, employing straddles to asses forecasts. They find that an agent using GARCH generated forecast earn greater profits that an agent using implied volatilities to form straddles.

Content of Implicit Volatilities from Option Models

The research summarized above shows that there are six stylized facts about implied volatilties (and hence subjectivve volatilities) that are known.

(1) Implied volatilities have predictive power concerning future volatility of the underlying asset.

(2) Observed option prices and implied volatilities are consistent with a hypothesis that the underlying asset volatilities are stochastic.

(3) The implied volatilites derived from option pricing models tend to be stationary series.

(4) Implied volatilities seem to reflect information not captured by standard ARCH processes. This information seems to be related news announcements, market variances, underlying asset volatilities, and lagged implied variances.

(5) Implied volatilities seem to exhibit a "term structure" over contracts with different maturities.

(6) Implied volatilities seem to be affected by the arrival rate of information and thus the volume of trading taking place.

What the previous literature suggests is that mispricing does exist in the options market in regards to the existing models used. The features exhibited due to these mispricings suggest that they may be due to a risk premium for the systematic volatility of the market. But, that since implied volatilities do reflect market volatility, there remains a degree of market inefficiency in incorporating information.

What previous research shows us is that there is an interesting question to be asked in the pricing of options that is testable. Are options mispriced due to market inefficiency or due to improper model specification? Implied volatility of options models provide an easy way of testing this in that the implied variance should be a measure of the markets average expected variance of the underlying asset. If the implied variance from the option pricing model by itself explains the variance structure of the conditional volatility of the

underlying asset in a GARCH framework, then this would imply both
market efficiency and correct model specification.

Lamoureux and Lastrapes argue based on their test of the
Hull and White model, that the implied variance by itself does
not provide the entirety of the current information embedded in
the conditional volatility that the model of Hull and White is
wrong, and that the discrepancy, given market efficiency, is due
to the fact that the Hull and White model does not price
volatility risk in the options market.

But as Stein(1989), Heynen, Kemna, and Vorst (1994) and Xu
and Taylor (1994) show, there is reason to suspect that the
options market overreacts to news on occasion. And Nandi's
hypothesis about the volume of futures option trading revealing
uncertainty about the future variance could also lead to biases.
Thus the question now is, "What is being detected in option
mispricing? Risk Premium, Market Inefficiency, or Asymmetric
Information amongst market participants about the future
volatility of the markets?

IV. Outline of Methodology

Recent research in option pricing by Lamoureux and Lastrapes (1993) has raised the issue of whether participants in options markets are rewarded for bearing variance risk. Lamoureux and Lastrapes, using data on stock options, have found that markets seem to reward option buyers for bearing risk on non-dividend paying stocks.

While intriguing, the evidence they present is hardly satisfying. Several important, and testable, questions remain. These are the focus of the present research work. Foremost," Is what Lamoureux and Lastrapes find that the market is pricing a risk premium?". Concurrent research by Heynen, Kemna and Vorst (1994) and Xu and Taylor suggests that part of what is being priced is the term structure, or further forecasts ahead , of the underlying assets' volatility. Is the priced risk premium that Lamoureux and Lastrapes detect present in other option markets? This will be tested in this work by examining a variety of options on futures contracts. Futures were chosen in that they are widely available and traded in many different markets. Futures typically have higher trading volumes than individual stocks, allowing the testing of whether the results obtained by Lamoureux and Lastrapes are due to lack of liquidity. Futures

also have an advantage over using individual non-dividend paying stock options in that they avoid the issue of agency costs. After all, it can be argued that the presence of a risk premium in the case of non-dividend paying stocks could be a reward for bearing larger risk of agency costs, not of variance risk. Finally, futures and options on futures are well synchronized in the sense that the actual trading of the contracts are physically close together, allowing floor traders to observe prices and make trades very easily.

If investors in option markets are being rewarded for bearing risk, then there are recent tests proposed by Engle and Ng (1993) that should make plain whether the observed premiums are in fact for volatility risk. The sign bias test will allow the testing of whether the market is rewarding investors on the basis of the sign of innovations in the variance structure. If negative and positive innovations are rewarded equally, for example, then this would tend to cast doubt on the risk premium hypothesis.

As a final test of the risk premium hypothesis, we use the value weighted returns of the stocks of commercial banks who are participants in financial option markets. If there is a risk premium for participation in these markets, bank equity returns should be positively affected by volatility innovations in the derivatives markets. In this case, implied and actual volatility should be significant in the prediction of bank returns.

The Methodology

The research of Lamoureux and Lastrapes will first be
duplicated making use of futures and the implied volatility of
longer term options as per Stein (1989). Futures are chosen to be
used rather than stocks for the following reasons. The volume of
most futures markets and futures options tends to be higher than
that for the volume of individual stocks and their options. This,
combined with the fact that futures contracts require no initial
investment eliminates any concerns due to low liquidity in the
asset so that its price does not reflect available information.
Also the use of options on futures eliminates the possibility
that the risk premium for volatility detected for the non-
dividend paying stocks used in Lamoureux and Lastrapes is not due
to any agency cost considerations[3]. The use of futures and
futures options also offers a much broader array of underlying
commodities and assets, and different markets to use than does
the use of individual stocks. The Black-Scholes option formula
does not apply directly to futures and their options, but this
has been dealt with in the theoretical literature.

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3.   If the firms are not paying dividends, then there may be
uncertainty over the degree to which management is committed to
maximizing the value of shareholder equity. Ceteris paribus, this
would increase the expected volatility of the underlying stock, a
phenomenon which may not be reflected in the implied volatility
as the option holder does not have to execute the contract. The
option holder will not be interested in long term gains if they
are speculators.

The first explicit application of the Black-Scholes model to the pricing of futures option was Black (1976). Black provided a valuation formula for European options on futures contracts when the short-term interest rate is non-stochastic. This formulation also established that since the up-front investment in futures is nil, then the model does not need an interest rate term in the definition of the standard normal terms.

On the subject of futures options, Jarrow(1987) provided an arbitrage pricing model for commodity options on futures within a stochastic interest rate context. The resulting formula is again reminiscent of the Black-Scholes formula. Jarrow notes that for European type calls, the Black-Scholes formula with the implicit volatility determined keeping times to maturity fixed will provide an estimate of the above result. For American options, the opportunity to early exercise leads to Merton's (1973) call option model under stochastic interest rates.

Jarrow and Oldfeld (1988) furthered the study of futures options by studying the distinction between forward and future options given stochastic interest rates. They show that a futures option's value depends upon the covariance between the spot price and a transform of the instantaneous rate of reinvestment.

Recent research has shown that the Black-Scholes is, however, a useful approximation to future call option prices. Ball and Torus (1985) find that despite the violation of the assumption of nonstochastic variance, the Black-Scholes price

does not differ substantially from the actual price of American options when the call options are at-the-money.

The Black (1976) futures option model is used for the estimation of implied volatilities.

<u>Data</u>

The options and futures contracts used consist of the five major currency contracts traded at the Chicago Mercantile Exchange (CME)(Canadian Dollar, Deutsche Mark, Japanese Yen, Pound Sterling, and Swiss Franc), two interest rate contracts traded at the CME (3-month Treasury Bill Futures and 3-month Eurodollar futures), 2 interest contracts traded at the Chicago Board of Trade (CBOT) (U.S. 5-Year Treasury Notes and U.S. 10-Year Treasury Notes), and four interest rate contracts traded on the London International Financial Futures Exchange (LIFFE) (3-month Eurodollar, U.K. Long Gilt, German Government Bond(BUND) and 3-month Eurodeutschemark). The American exchanges data is comprehensive from December 31, 1990 thru March 31, 1995, with the exception of the 5-Year Treasury Note and the 3-month Eurodollar which begin on September 1, 1991. As a result there are 1319 daily observations for the American exchanges data, excluding the above mentioned contracts for which there is 878 daily observations. For the London exchange data, there are 1319 daily observations for the same time period as the American exchanges, excepting the Eurodeutschemark, which has 1235 as the futures option contract only began as of February 1990.

For the American market options, the risk free rate was taken as the trading days closing rate on a 90-day U.S. Government Treasury Bill. For the London market, the risk free

rate was taken to be the spot rate of the closing price of a 90-day Eurodolllar deposit in the London market as reported.

The data were primarily collected by hand from the *Wall Street Journal* and *The Financial Times*. Additional data was downloaded via the Economics Server at Sam Houston State University "NIORD.SHSU.EDU" from the Investment Data Collection at Data General.

In order to create a continuous time series for each contract, the prices used were for the futures with the largest trading volume, and the option matching the expiration date of the underlying futures contract. A recent article by Geiss (1995) has pointed out that there is a danger in using non-volume weighted series in creating futures price series. While rolling over by contract highest contract volune can distort the scale of the underlying time series, in this case the distortion will be minimal. At the very least, as Geiss himself shows, changes of direction and "shape" will be preserved, both of which are more important to this study.

V.   Hypotheses

First, do the results of Lamoureux and Lastrapes hold for futures and futures options?

Hypothesis 1

H_o : Option implied variance does not help to predict conditional volatility in a GARCH frame work.

This will be tested by first deriving the option implied variance from Black's (1976) futures option model. The Black model is written as :

$$C_t^F = e^{-r(T-t)} [F_t N(d_1) - X N(d_2)] \qquad (33)$$

$$d_1 = \frac{\ln[\frac{f}{X}] + (.5\sigma^2)(T-t)}{\sigma\sqrt{T-t}} \qquad (34)$$

$$d_2 = d_1 - \sigma\sqrt{T-t} \qquad (35)$$

The implied volatility is solved for using the Newton-Ralphson method.   After it is solved for, a GARCH 1,1 model is estimated of the following form:

$$Ret_t = Lag(Ret) + \varepsilon_t \qquad (36)$$

$$h_t = a - bh_{t-1} + c\varepsilon_{t-1}^2 + d\sigma_{iv}^2 \qquad (37)$$

If the coefficient d is significant using Bollerslev-Wooldridge robust standard errors, then the null hypothesis is rejected. The adequacy of the model is measured by the Ljung-Box statistic, which is the significance of the 12th degree autocorrelation in the squared normalized residuals. Rejection of the null indicates that the model is an adequate description of the conditional voaltility. The Sign Bias Test of Engle and Ng (1993) is also performed. The rejection of the null in this case indicates that positive and negative signed innovations have different impacts on conditional volatility.

To perform the sign bias test, the normalized residual is calculated for the conditional volatility model. This normalized residual is then regressed on the model measured plus a dummy variable that takes on the value of 1 if the innovation term is negative and zero otherwise. If the t-ratio of the dummy variable coefficient is significant, then the null of no sign bias is rejected. Rejection indicates that the signs of the innovations have different effects on the conditional variance.

Keeping in mind the recent work by Enle and Ng (1993), concerning the inadequacy of GARCH models in specification of the

error structure, the model above is also estimated using a
partially non-parametric formulation so that different signed and
sized errors may have different impacts on the conditional
variance. The model is as follows:

$$h_t = a + bh_{t-1} + d\sigma_{iv_{t-1}} + gPos_1 + hPos_2 + jNeg_1 + kNeg_2 \qquad (38)$$

For this model, the Pos_1 term is equal to one times the
value of the error term if the error term is in the third
quartile of the sample distribution and equal to zero otherwise.
Pos_2 is similar, except it takes on a value if the error term is
in the fourth quartile. Similar equivalences hold for the Neg_1
and Neg_2 variables, except they are for the second and first
quartiles respectively.

Once again, the null hypothesis is rejected if the d
coefficient is significant.

While this model differs from the model used by Engle and Ng
(1993) in that it uses quartiles instead of standard deviations
to divide the innovations by size, the estimators should still be
a valid approximation of changes in the conditional variance due
to innovations, as noted by Engle and Ng. The reason for using
quartiles is that all of the distributions exhibited a marked
degree of kurtosis, leading to estimation problems if the
divisions had been based on standard deviations from the mean.

Hypothesis 2

H_0: The implied variances of option contracts of shorter
maturities than the option contract with the same expiration
month of the futures contract do not help to explain
the conditional volatility of the underlying futures
contract.

This hypothesis tests Stein's hypothesis of market
overreaction. If it is true that markets for longer term options
overeract in their prediction of future variance relative to
options of shorter duration, then the implied volatilities of
shorter maturity contracts should be significant in the
prediction of conditional volatilities. For this hypothesis, only
the curreny contracts can be used, as they are the only ones that
offer consistently shorter contracts. Typically, the options
offered expire on the month of the futures contract expiration,
and one and two months earlier. In those cases where the option
has expired, its conditional volatility has been set to zero. The
following model for the conditional volatility is then measured:

$$r_t = r^* + \varepsilon_t \qquad (39)$$

$$\varepsilon_t | \varepsilon_{t-1}, \varepsilon_{t-2}, \ldots \sim N(0, h_t), \qquad (41)$$

$$h_t = D + \alpha\varepsilon_{t-1}^2 + \beta h_{t-1} + \gamma\sigma_{t-1} + \delta\sigma_{t-1}^{Term} \qquad (40)$$

In this test, the term implied variance is listed as nearest and medium term, with nearest being the option with the nearest maturity date and medium being the middle option. Significance of the coefficient of these terms are checked using both the modified GARCH 1,1 model and the Partially Non-parametris model.

This method is actually a stronger method of testing for overreaction than Steins' method, as it allows us to test both for the significance of the coefficients and their signs. If Steins overeaction hypothesis is correct, we should find that the coefficients of the nearer maturity implied variance terms will have a negative coefficient, as their information should subtract away from the overprediction of the volatility .

Hypothesis 3

H_0 : Net volume of contracts does not help in the prediction
   of conditional volatility

This hypothesis is the first attempt to test the theoretical results of Nandi (1995) that net volume of trades will effect volatility. Nandi's results assert that in an options market that has certainty over current underlying asset price, but uncertainty over the assets future volatility, that the information asymmetries will lead to low volumes during high uncertainty and vice-versa. Again, unfortunately the availability of data only allows the testing of this hypothesis with the data from the London market.

In addition, Nandi predicts that the expected variance will be an increasing function of the net order flow. Thus, it should be found that the option market volume should have a positive coefficient in the prediction of the conditional variance, when the option implied variance is included in the model.

Hypothesis 4

H_0: The news response curves of the futures conditional

variances will be symmetrical in regard to the sign of the

innovation. That is, the slope coefficients of the signed

innovations of the conditional mean process on the

conditional variance process will have similar magnitudes

despite the sign of the innovation.

The news response curve is the plotting of the change of the

coefficient of the negative and positive sign and size variables

discussed earlier in the partially non-parametric estimation

process. In the presence of the option implied variance, the

response curves of the futures conditional variance will be

symmetrical if innovations of different signs have the same, but

different signed, magnitude of response. For example, if the

response is the same, the news response curve will look like the

following:

## Symmetric News Curve
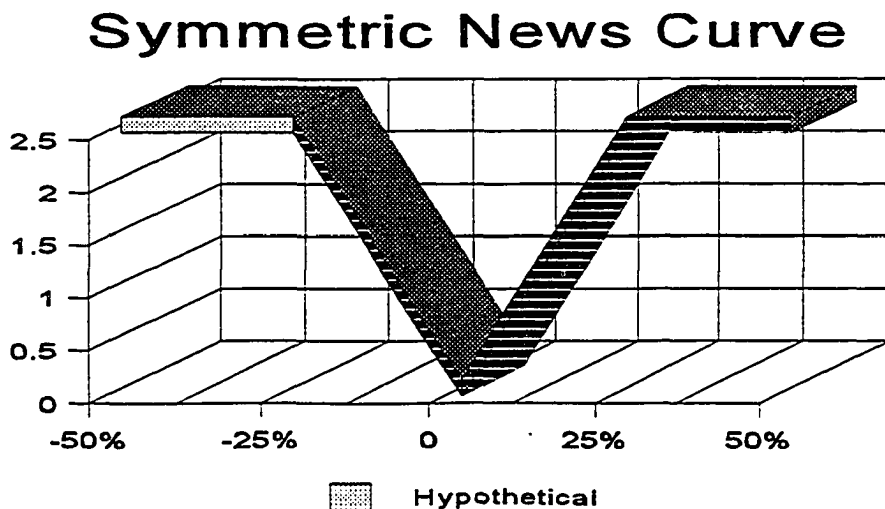
Hypothetical

If the regression coefficient is the same over the second and third quartiles (the -25% to 0 to 25%), then the curves will rise at the same slope on the news response curve. For the sample hypothetical contract, the coefficient is a positive 2.5 for the third quartile of the innovations, and -2.5 for the second quartile.

If the slope does not change over the outlying quartiles, the graph shows a flat response surface, as the y-axis denotes the change in the estimated coefficients. Thus in our sample contract, the slopes of the news response curve graph is flat as the degree of response of the conditional variance to the innovations in the conditional mean are the same for the outlying quartiles as they are for the inner quartiles of the same sign.

Hull and White (1988) and Dothan (1988) show that in the presence of priced volatility risk that the bias caused by the priced volatility risk will be asymmetric in terms of the moneyness of the option. Since for near the money options the black option price formula is linear in both the variance and option price, it follows that the price bias will be reflected in an implied option bias of the same sign and relative magnitude.

Thus a lack of symmetry in the response curves in the presence of the option implied variance could be an indication of a volatility risk premium. An example of what we could expect to see in a news response curve in the presence of a volatility risk premium is :
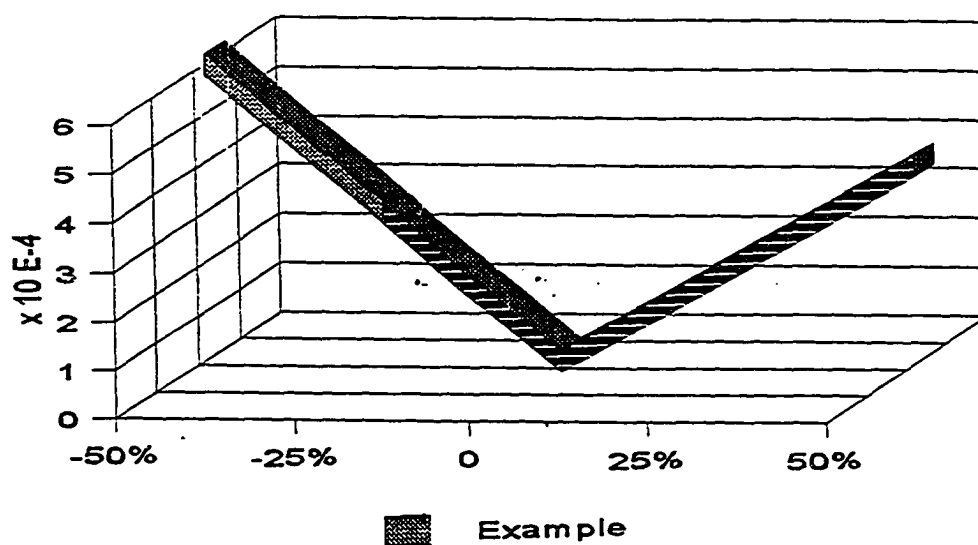
We can test for significance of the difference by using the Baillie-Bollerslev adjusted standard errors to perform a t-test to test for the significance of the sign bias test as detailed above.

Hypothesis 5

H_0: There is no difference in the shape or magnitude of the news response curves based on contracts or the markets in which the contracts are traded.

This is a qualitative evaluation based on graphs of the news response curves and on the relative magnitude of the slope coefficients between the contracts and the different markets. If the curves seem to have different shapes and magnitudes based on observation, we then will hold that the hypothesis is rejected. There is no test of significance in this case.

VI. Empirical Results

Hypothesis 1

Table I shows the results of the estimation of the GARCH 1,1 model with the option implied variance used as a predictor of the conditional variance. Whereas Lamoureux and Lastrapes found several instances of where the option implied variance was a significant predictor of the conditional variance, here only three contracts, the LIFFE Euromark , the IMM Swiss Franc and the CBOT 5-Year Treasury Note contract show significant coefficients on the option implied variance. For all contracts, the Ljung-Box test rejects the null hypothesis at least at the 10% level. However, for all but the LIFFE Long Gilt, Bund and the IMM Japanese Yen, the Sign Bias Test suggests that the models do not adequately describe the conditional variance process, as the results of the Sign Bias Test suggests that for the majority of the contracts, there are very differing responses to innovation, based on the signs of the innovations

Tables III, IV, and V repeat the test using the partially non-parametric estimation process. In Table III, the currency contracts are tested. For all of the contracts, except the Japanese Yen, the implied option variance is significant at the 1% level. Relative to the size of the lagged conditional variance, the implied option

variance is rather small. This seems to indicate that in futures markets there is a great tendency to "ignore" implied volatility.

Table IV shows the results for the LIFFE interest rate contracts. In this case, only the Long Gilt and the Bund contracts exhibit significant coefficients on the implied option variance. It is interesting to note, that in this case none of the sign coefficients are significant on the Eurodollar and Euromark contracts, even though the sign bias test indicated there was a significant difference between the response of the conditional variance to different signed innovations. Considering the reported robustness of the Sign Bias Test, by Engle and Ng, this is rather surprising.

The results for the American market interest rate contracts in Table V are more reassuring. The coefficients on the option implied variance for the 5-Year Treasury Notes contract is significant under the Partially Non-parametric (PNP) estimation process, as it was under the $GARCH(1,1)$ process. Additionally, the IMM Eurodollar also exhibits a significant reaction to the option implied variance.

As with Lamoureux and Lastrapes results, there is a plethora of differing reactions to the implied variance, based on different contracts. In general, it seems that when the conditional volatility is modeled correctly as per the Ljung-Box and the Sign Bias tests, there does seem to be a tendency for the implied volatility to be a useful predictor of future volatility for the

majority of contracts. However, it does not replace the lagged
conditional volatility in the prediction of the volatility process,
nor does it play a large part in the volatility process in relation
to the lagged conditional volatility.

There is, as noted above, three possible explanations for the
lack of successful explanation of the volatility process by the
option implied variance. First, there could be the effect of market
overreaction. Second, there could be liquidity effect. And third,
it could be due to the presence of a volatility risk premium.

Hypothesis 2

As seen in Table II, Stein's hypothesis of market overreaction receives little support from the GARCH$(1,1)$ model. The only significant effect from an option implied volatility is for the longest to maturity option contract on the IMM Deutsche Mark futures contract. Once again, the Ljung-Box test attests to the model adequacy, while the Sign-Bias test attests otherwise, except in the case of the Japanese Yen contract.

For the Partially Non-parametric estimation process results in Table III, we see that there may be some support for Stein's hypothesis. In the case of the Canadian Dollar, the Deutsche Mark and the Pound Sterling, the coefficients of the implied options variance of the different maturity contracts are significant, among these being, the shortest maturity contract.

Additionally, as is consistent with Stein's market overreaction hypothesis, the significant coefficients on the shortest maturity options are typically negative. This would be consistent with the idea that markets overreact to information over the longer term.

However, the lack of significance of the medium term options is troubling. Why should only the longest and shortest term option implied variances be significant? While there is some evidence here for the overreaction hypothesis, the inconsistency across the contracts tested keeps it from being conclusive. It is interesting

to note that the significance, or lack thereof, can not be directly tied to contract volume. The highest volume contracts, the Japanese Yen and the Deutsche Mark, are polar opposites in terms of the reaction to the implied option variances.

Japanese Yen
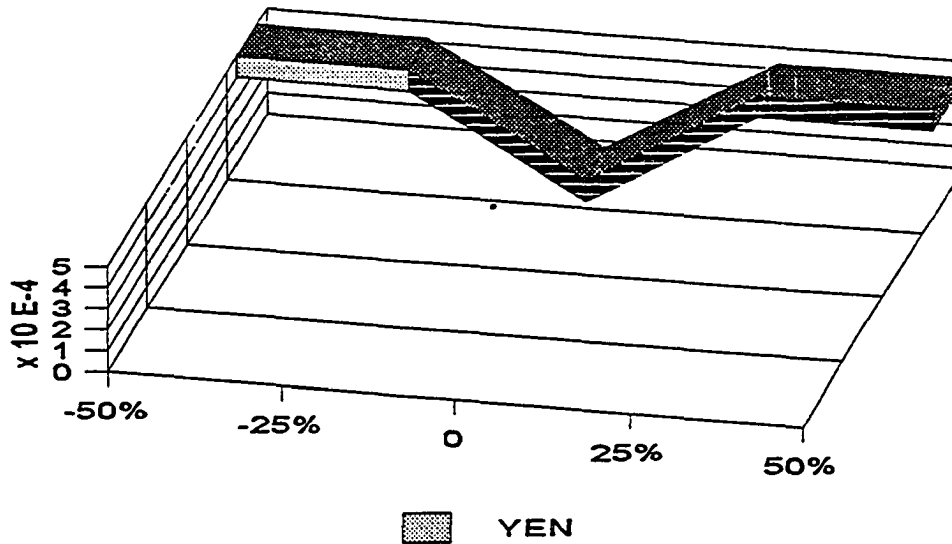
The Japanese Yen futures contract is the enigma of the contracts studied here. It exhibits no significant coefficient on its option implied variance in the conditional volatility estimation under any of the models tried here. It's news response curve is perfectly symmetric according to the Sign Bias test, so for the slope coefficients, we use the coefficient of the squared innovation term in Table I.

These results are not consistent with the overreaction hypothesis of Stein. It may be consistent with the hypothesis of the volatility risk premium, in that the implied option volatility does not help to explain the conditional volatility. It's lack of

asymmetric response curves however do not lead to conclusive

evidence in favor of the hypothesis of volatility risk premiums.

Canadian Dollar
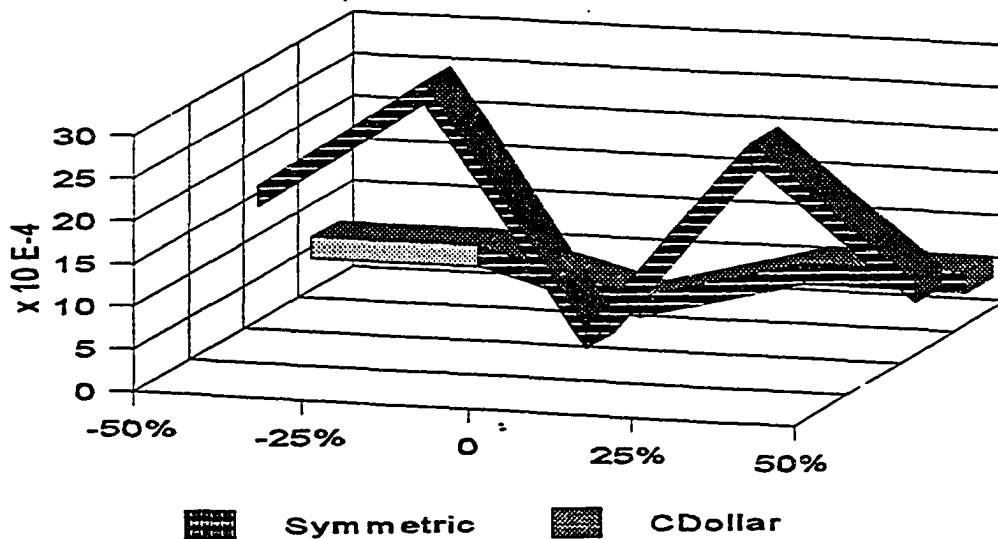
The Canadian Dollar Futures contract exhibits a significant

Sign Bias statistic, and shows an extreme departure from symmetry

in its news response curve as opposed to the symmetric curve of its

GARCH 1,1 model. The contracts volatility seems to be more

responsive to negative innovations than positive ones and shows a

greater response to smaller innovations than to larger ones. This

would be strongly consistent with the hypothesis of there being

volatility risk. The news response curve above is estimated

including the option implied variance of the shorter term contract

as per TABLE III. Thus, even taking into account the possibility of
market overreaction, the evidence seems to be
consistent with the presence of a volatility risk premium.

Deutsche Mark
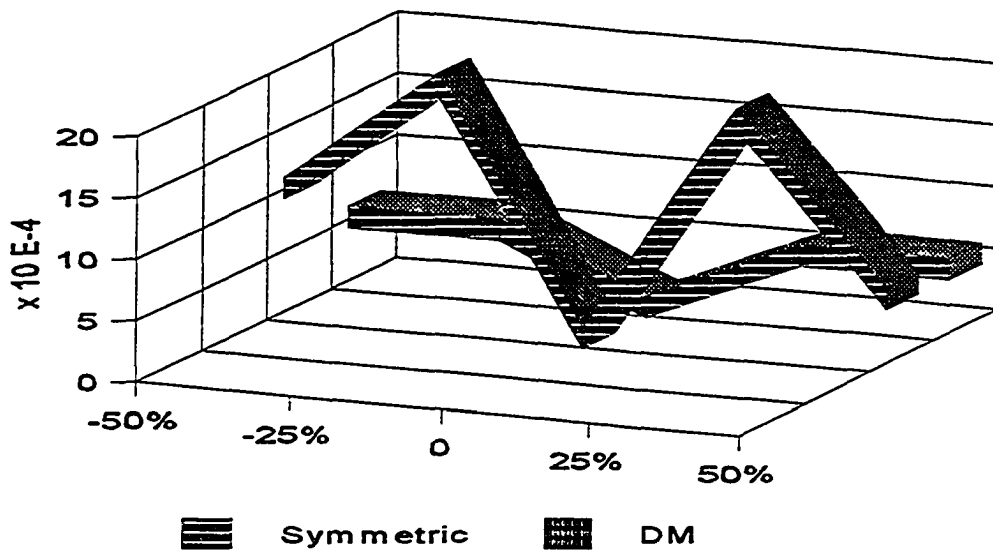
The response curve of the Deutsche Mark contract seems similar
to that of the Canadian Dollar contract. However, the difference
between the responses to the negative and positive innovations is
largest for the largest innovations, not those nearest to the
middle. The Deutsche Mark contract exhibits the strongest
consistency with Stein's overreaction hypothesis. We conclude that
there may be support here for the risk premium hypothesis.

Pound Sterling
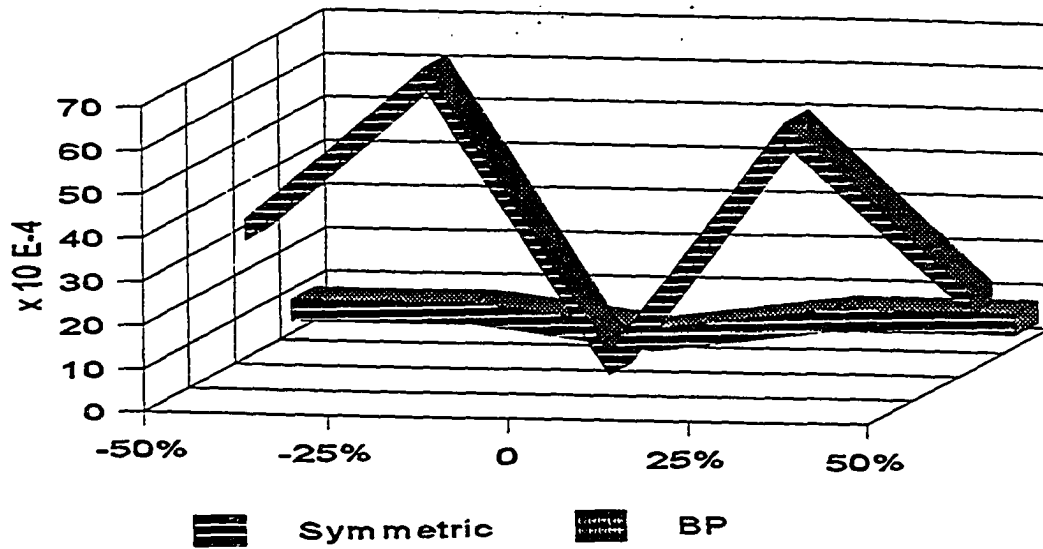
The British Pound Sterling futures contract has a significant sign bias statistic, and the news response curve shows that the negative innovations have a larger response than the positive innovations of similar magnitude. This would seem to give some support to the possibility of a volatility risk premium.

Swiss Franc
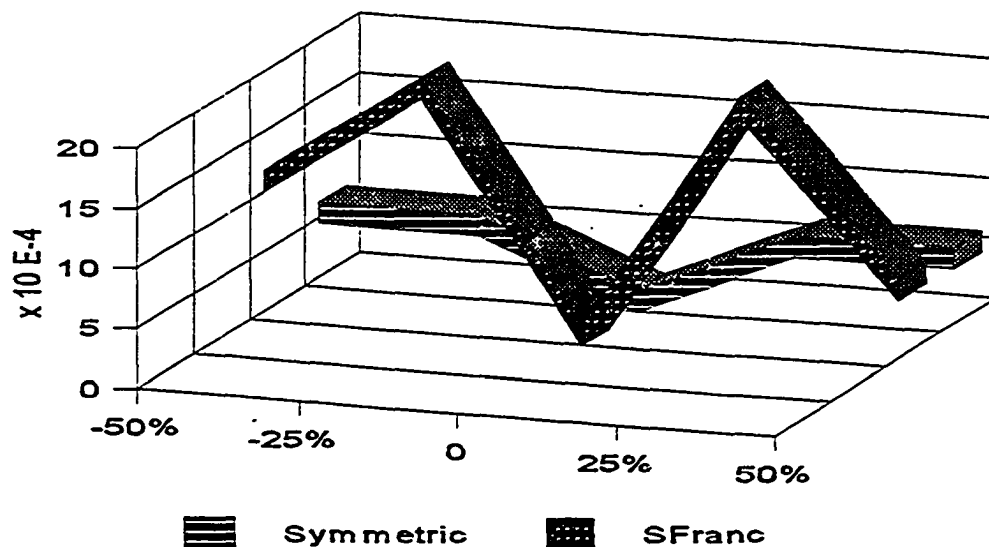
The sign bias test indicates that there is significant sign bias, but the news response curve does not seem to show a difference in responsiveness based on sign, but rather on magnitude. The larger innovations tend to have more muted responses relative to their size compared to smaller innovations. This result seems not to support the hypothesis of a volatility risk premium.

IMM Interest Rate Futures

Eurodollar
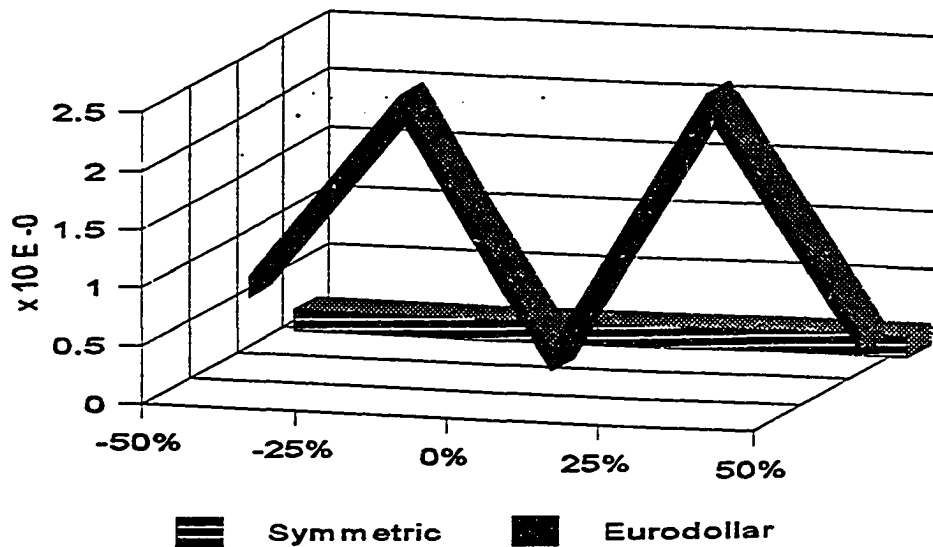
The Sign Bias test statistic is significant, but the news response curve shows little difference between the response based on sign, but again a difference based on the magnitude of the innovation. We conclude there is little support here for the volatility risk premium hypothesis.

IMM Treasury Bill

2.5
2
1.5
1
0.5
0

x 10 E-1

-50%   -25%   0   25%   50%

■■■ Symmetric   ■■ T-Bill
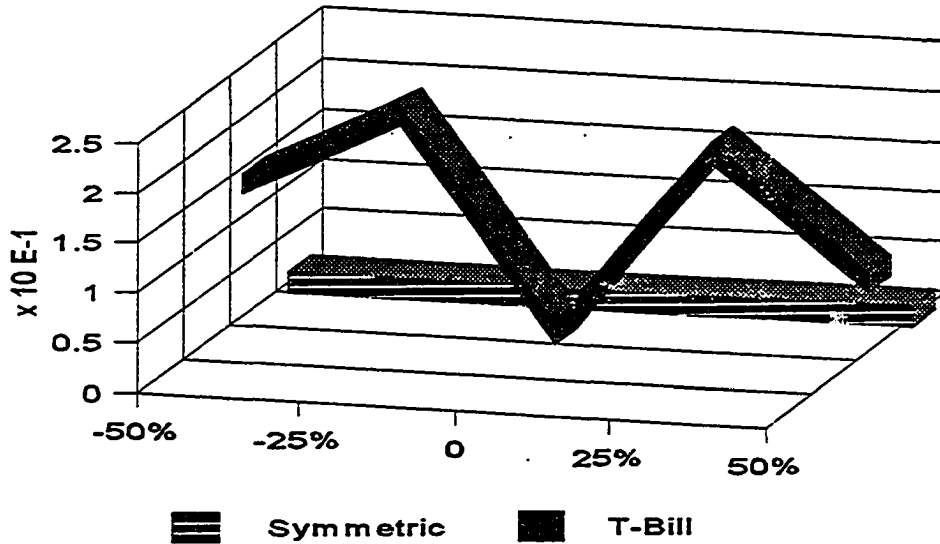
The Sign Bias test statistic is significant at the 5% level.
The news response curve seems to show that larger negative
innovations get a greater response than similar sized positive
innovations. We conclude that there is some support for the
volatility risk premium hypothesis.

CBOT Interest Rate Futures

10-Year Treasury Note
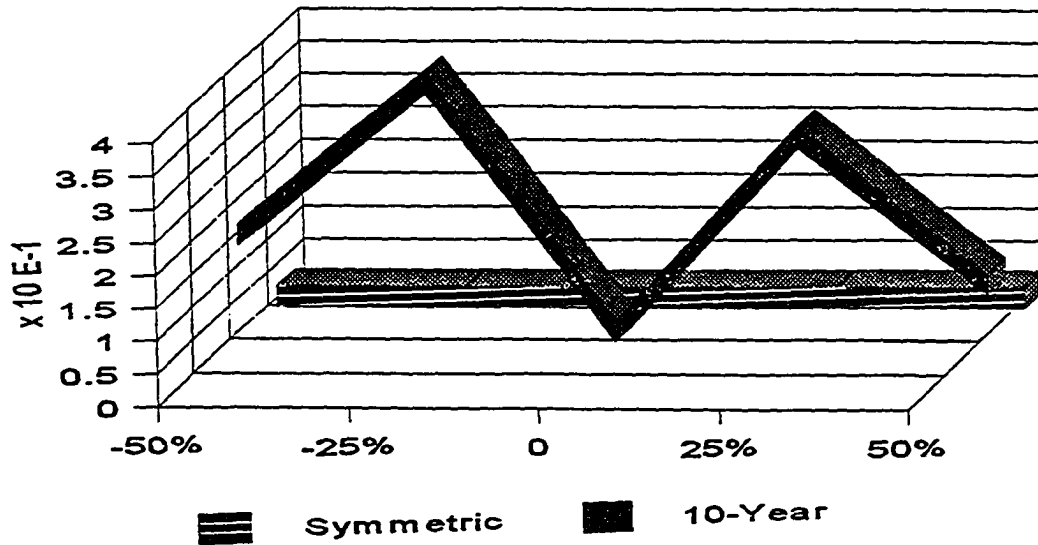
The Sign Bias test statistic for the 10-Year Treasury Note contract is significant at the 1 % level. The news response curve shows a marked difference in the response to the sign of the innovations. We conclude that there is support for the hypothesis of a volatility risk premium.

5-Year Treasury Note
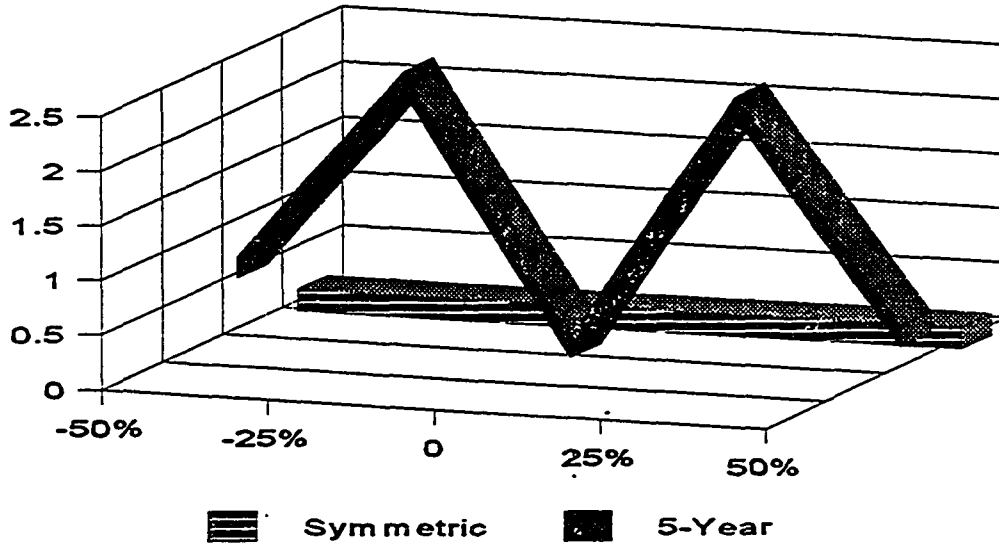
The Sign Bias test statistic for the 5-Year Treasury note contract is significant at the 1% level. The news response curve seems to be symmetrical, with innovations of greater magnitude leading to a relatively more shallow response than innovations that are smaller in magnitude. We conclude there is little support for the presence of a volatility risk premium here.

LIFFE Interest Rate Contracts

<u>*Eurodollar*</u>
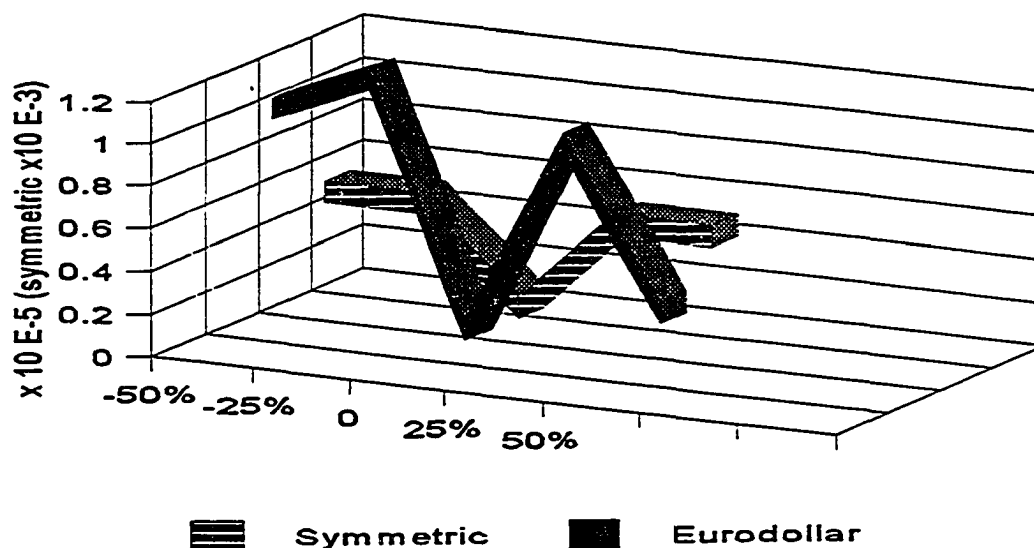
The Sign Bias test statistic for the Eurodollar futures contract is significant at the 1% level. The news response curve shows a marked lack of symmetry and a much greater response to negative innovations than to positive ones. The news response curves for the LIFFE contracts include volume as an explanatory variable. Thus we conclude that there is support here for a volatility risk premium.

Euromark
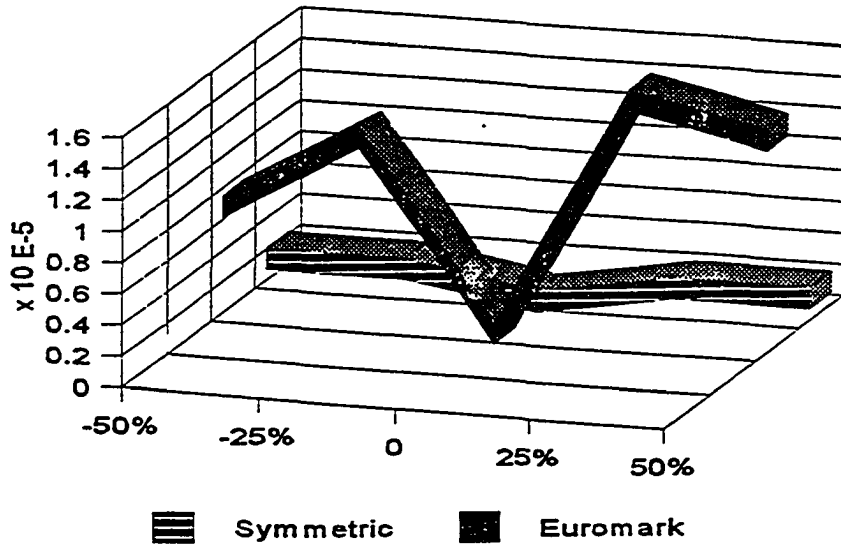
The Sign Bias test statistic for the Euromark contract is significant at the 1% level. The response curve shows a response curve that exhibits a preference for positive innovations over negative ones. We thereby conclude that the volatility risk premium hypothesis is to be rejected.

Long Gilt and Bund

The Sign Bias Test statistic for both of these contracts are insignificant. The news response curves are both symmetric, with larger magnitude innovations leading to relatively shallower responses than for innovations of smaller magnitude. We conclude, as in the case of the Japanese Yen, there is no support for the volatility risk premium hypothesis.

Hypothesis 5
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There are obviously marked differences in the news response

curves between the types of contracts. The response curves of the

Long Gilt, Bund, and Japanese Yen futures contracts tend towards

being symmetry, having their conditional volatility processes

adequately described by a GARCH 1,1 process. The Long Gilt and Bund

however, differ from the Japanese Yen contract, in that their

volatility processes seem to be, in part, predicted by their option

implied variances. The LIFFE Euromark differs from all other

contracts in that it shows a volatility process that is more

responsive to positive innovations than to negative ones. The

remaining contracts tend to show a greater responsiveness to

negative innovations, particularly the relatively smaller in

magnitude negative innovations.

There is one noteworthy difference between markets. The

coefficients of the response curves for the American markets'

interest rate contracts tend to be about 1000+ times larger than

the response curves for the remaining contracts in other markets.

While it is tempting to attribute this to the tighter regulation

market activity in the American markets, again the issue is far

from clear cut. While the contracts for the treasury notes have

daily and absolute price movement limits, the IMM Eurodollar and

the Treasury Bill contract only have such limits for the first 30

minutes of trading on the trading day. Obviously, the presence of a

price movement limit can not be the sole explanation. However, the coefficients on the Treasury Note contracts are about 10 times larger than on the other American market interest rate futures. It would seem then, that the presence of price limits do tend to make market volatility to be more reactive to innovations than they would be otherwise.

VII. Summation of the Empirical Results

Unlike the results for stocks and stock options, the testing of the sufficiency of implied volatility as a description of the underlying assets volatility process for futures and futures options requires that the specific direction of innovations to the conditional mean be taken into account. Without the allowance for the effects that different sized and signed innovations have, one can make incorrect conclusions about the adequacy of the model used. It would be very interesting to repeat the results of Lamoureux and Lastrapes (1993) and Stein (1989) using an EGARCH or Partially Non-parametric GARCH model instead of the more traditional models.

Taking into account the differing effects of innovations of different signs, we find that for most contracts, the option implied volatility is at best a marginal predictor of conditional volatility. This result is consistent with either of the three following hypothesis: that the market overreacts to innovations, that there is a priced volatility risk premium, or that there is bias due to the degree of liquidity in the options market.

The effect of volume on the prediction of conditional volatility leads to some interesting results. Volume does seem to be a significant predictor of volatility, but this effect does not seem to be uniform across all contracts. This would seem to be contradictory to the prediction of Nandi's model.

The examination of the news response curves shows that the support of a volatility risk premium is mild in general. While the Sign Bias Test indicates there are definite size biases in the majority of the contracts conditional volatility structure, the news response curves generally show that this test result may be due to the fact that innovations of greater magnitude generally lead to relatively less powerful responses than innovations of the same sign, but smaller magnitude. Except for Canadian Dollar, The Deutsche Mark, Pound Sterling, IMM Treasury Bill and the LIFFE Eurodollar contracts, there is no definite support for the volatility risk premium hypothesis amongst the news response curves. If there is any chance of validating the volatility risk hypothesis, it would seem to be with these contracts.

Comparison amongst the types of contracts and the markets reveals that in general, interest rate futures contracts traded in American markets exhibit a stronger response to innovations in their conditional volatility structure than do those interest rate futures traded in the London market. A comparison of these effect show that some of this greater responsiveness may be due to the price limits that are imposed on some of the American markets, but that other factors may also play a part.

In general, we conclude that there does not seem to be one overriding reason as to why biases exists in option pricing in these markets. The results for all of three hypotheses are rather

underwhelming. Clearly, volume has some effect in some markets, but for one of the markets tested, it had no effect.

Stein's overreaction hypothesis receives some support from the results of Table III. Three of the five tested contracts exhibit situations where the implied volatility of shorter-term option contracts help to predict conditional volatility. They generally also have the expected negative sign on their coefficients, with the exception of the shortest-term option contract on the Deutsche Mark futures. But as noted previously, these results could also come from the presence of a priced volatility risk premium.

In our opinion, the most overwhelming proof would be to see if participants in contracts in which we feel there is the strongest evidence of a volatility risk premium are exposed to such a risk. We propose next to test this using a standard risk exposure model, looking in particular for the exposure of participants to contracts that we feel may harbor a priced volatility risk premium. The contracts we suspect may harbor a priced volatility risk premium are as follows: the CME Canadien Dollar, the CME Deutsche Mark, the CME British Pound, the IMM Treasury Bill the CBOT 10-Year Treasury Note and the LIFFE Eurodollar. It will be interesting to see if these are the contracts that commercial banks show an exposure to a volatility risk premium. This is tested in the following sections.

VIII.   Volatility Risk Premiums of Futures and Commercial Banks

Large commercial banks make up the bulk of the trading in

market for both exchange traded and over-the-counter derivatives.

Banks not only deal with derivatives to handle their own exposures .

to a variety of risks, but also sell risk management services to

clients and indulge in speculation.

For example, survey data released by the U.S. Office of the

Comptroller of the Currency (1995) shows that the portfolios of

commercial banks in the United States had a total notional amount

of $17.99 trillion for the end of the first quarter of 1995. Nine

commercial banks accounted for 93% of the total notional amount of

derivatives in the U.S. banking system.[4]

Altogether, 663 banks at year end of 1994 reported holding

derivatives. This concentration of the largest of U.S. commercial

banks as holders of what are viewed in some context as highly risky

assets has alarmed some regulators. Particularly alarming to bank

regulators in the United States has been the explosive growth of

bank use of what are off balance sheets activities (OBSA's). Until

recently, commercial banks did not report any useful information of

their activities in derivatives. Indeed, until recently, there has

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4.   These banks were Chemical Bank, Citibank, Morgan Guaranty,
Bankers Trust, Bank of America NT&SA, Chase Manhattan, First
National Bank of Chicago, NationsBank and Republic National Bank
of New York.

been no generally agreed upon principles about how derivatives should be accounted for, either in terms of banks exposure to risk, net cashflows from trading derivatives or what amount they should be assessed at.

These regulatory and accounting uncertainties have not been the only alarming news to regulatory authorities and investors. In recent years large users of derivatives have reported major losses due to their dealings in them. The names of Metallgesellschaft, Barings, and Nomura have already passed into the general public's consciousness as warnings of the riskiness of derivative dealings.

The concern of regulators is that derivative dealings could lead to major bank failure by one of four ways. First, many banks use derivatives for the purpose of speculation, so as to enhance bank profitability. A bank could be brought to the brink of bankruptcy on the basis of a "big wrong bet" due to its trading (Barings PLC being the prime example). A second area of possible bank failure is that the bank uses derivatives to hedge its and its customers exposure to various risks, but employs a flawed hedging model. This is as not as far fetched as it sounds. Turnover amongst staffs of trading desks are reportedly quite huge and the pricing of many derivatives are still imperfectly understood.

A third possibility is that of a liquidity drought coupled with one of the previous two scenarios. A lack of interest in the particular derivatives contract a bank is holding at any one time could be disastrous.

The fourth possibility is that of counterparty default, where in the case of over-the-counter derivatives, the counterparty to the claim fails to meet its obligations.

By far the most alarming scenario is what is termed systematic risk. Systematic risk is the risk that a disruption at a bank or market could cause a systematic failure of banks. It is held by some that derivatives have led to a greater interconnectedness of markets.

In context of this study, there is suspicion that users of derivatives are exposed to an additional risk that may or may not have been priced by markets. Volatility risk, if it has systematic components, should be priced by rational asset markets if banks are exposed to it.

The pricing of volatility risk by markets would mean that the exposure of banks to this risk should be taken into account in the banks asset exposures and the exposure of the deposit insurance fund.

Reasons for use of Derivative contracts by Commercial Banks

There are three primary reasons for commercial banks to be involved in derivatives. First, to enhance the value of the bank to it's shareholders by hedging the interest rate and currency risks the bank faces through it's activities as a depositor and lender. Second, to make use of superior information and technical facilities to speculate in derivatives markets, thus adding to the profitability of the firm. Third, to offer risk management services to firms that may not find it convenient to handle their own risk management.

Diamond's (1984) theory of banks as delegated monitors holds that banks act as insiders to financial markets that allow depositors to lend money to borrowers without having to directly bear the costs of monitoring the financial conditions of borrowers.

Therefore, it follows that banks involved in derivatives should be doing so as a means of primarily reducing the risk of the bank and of borrowers. Banks using derivatives do so because they are inherently riskier, and use derivatives as means of risk sharing, and/or banks "force" borrowers to hedge so as to limit the risk exposure of the banks depositors and shareholders.

However, the recent Call Report Schedule RC-R issued by the Office of the Comptroller of the Currency for first quarter of 1995 shows that for the largest 9 banks, only 5% of the derivatives held were for the banks' own risk management needs. That is, out of

approximately $16 trillion of notional amount held, only$ 0.8

trillion is being used to hedge approximately $1 trillion in assets

held as of the end of the period. The remaining was reportedly held

for trading purposes, with no break-down between bank and customer

transactions. The remaining 612 banks below the top 9 reportedly

held 58% percent for the purpose of risk management. This evidence ·

seems to be somewhat contradictory to the theory of banks as

delegated monitors if the use for trading purposes for banks

themselves makes up a large proportion of the derivatives retained

for trading purposes.

The Qualitative Asset Transformation (QAT) theory holds that

bankers act to provide brokerage and qualitative asset

transformation services. Banks seek to transform claims with

respect to credit risk, liquidity, duration, and divisibility. In

the case of derivatives, banks again use derivatives to hedge and

diversify risks for itself and for customers of its risk management

services, which seeks to transform the claims of customers with

respect to market risk, credit risk, and counterparty risk.

The concentration of almost all of commercial bank activities

in the hands of 9 large banks seems to imply that considerable

scale economies exist in derivatives use. Based on 1993 data Sinkey

and Carter (1995), it is estimated that the critical mass of assets

needed for a bank to become a dealer/trader bank in derivatives is

roughly $12 billion in assets or $1 billion in equity capital.

The offering of risk-management services of this nature

obviously requires considerable investment in intellectual capital and computational facilities. Additionally, the intellectual capital seems to be of the nature that it takes some time to build up. Turnover in derivatives management is reportedly high, with rival firms often hiring away trained traders and managers.

A recent paper by Berger, Hunter, and Timme (1993) suggests that scale economies and bank efficiencies at meeting plans may also be a rational explanation of bank use of derivatives and their concentrated use by the largest of banks. Berger et al note that the empirical banking literature shows that scale inefficiencies occur for banks with less than $500 million in assets, with full scale efficiency accomplished in the $500 million to $10 billion in asset range, with constant average costs after $10 billion. Considering Sinkey and Carter's rough estimate of the critical asset size needed to become a trader/dealer bank, these empirical observations suggest that large commercial banks, no longer being able to benefit from scale economies to increase profits, seek to exploit the niche that their size leaves to them : derivatives.

Berger, Hanweck and Humphrey (1993) measure the efficiencies of banks in making the correct level and mix of output as well as the cost efficiency of banks. They find that output efficiencies are on average larger that the cost inefficiencies. That is, banks are deficient in producing revenues through the inappropriate choice of and levels of output in services rather than in controlling costs. A surprising part of this finding is that larger

banks seem to be less inefficient in this regard than smaller banks. Thus it may be that derivatives allow larger banks to offset their scale inefficiencies by allowing them to achieve relatively highly valued bundles of services , perhaps in the form of risk-management through the use of derivatives.

There exists considerable agency problems in the use of derivatives by banks. The first is that between bank management and shareholders. While derivative use may reduce the exposure of shareholders to certain risks, speculation in derivatives on the parts of banks provides free cash flow to management that is not directly monitored as it is an off-balance-sheet item. Thus there may exist considerable temptation on the part of management to take a riskier position in derivatives than their shareholder might desire.

The second agency problem is that with banks having deposit insurance, there exists considerable temptation for banks to take risky investments, using the deposit insurance as a means of guaranteeing a loss limit to depositors, or what is referred to as the "moral hazard" problem. This moral hazard problem may be countered however by regulatory discipline or market discipline. Risk-based capital standards price banks ABSCESS explicitly by requiring them to be backed by bank capital. However, the risk based capital standards are relatively new requirements for banks. Only since the passage of Federal Deposit Insurance Corporation Improvement Act (FDICIA) (effective June 19, 1993) have banks been

required to account for their credit exposure due to derivatives.

Obviously then, there are some reasons to suspect the regulatory discipline of banks is a moral hazard problem. Until perhaps the middle of 1993 then, we should expect that there may be a moral hazard effect that may affect the exposure of banks to risks. But this will only be empirically observable if the discipline of the markets has been in effect before the regulatory guidelines.

The third agency problem existing in the bank use of derivatives is that of employee versus the firm. Since much of the intellectual capital that is built up by banks is difficult to transfer and often traders are compensated either directly or indirectly based on the profits they generate for the bank in speculation, there exists considerable temptation for traders to hedge or trade to their ultimate advantage, not the banks. Again, considering the high turnover amongst derivative traders in banks, traders will be sorely tried to maximize the long range benefits of derivatives for the banks and their customers and not just maximize their own short-term gains.

The final major agency problem in the banks use of derivatives is based on the banks relationship with its customers in its risk-management services. Banks derive their risk-management income based primarily on the amount of services used, not on the success of the risk management service in reducing the customers risks. As a result, banks have the opportunity to use risk management

customers desire and naivete to their own advantage. A customer wanting risk reduction for its foreign currency exposure could end up with a much larger, or different type, of hedge than desired, all to the benefit of the bank in terms of the fees generated. Banks may also be tempted to use relatively cash flush customers as counterparties to speculative derivatives positions of the bank's (or again other customers) that have gone bad. Again as a part of it's risk management services. In fact as alleged by the 1995 suit of Bankers Trust by Proctor and Gamble, this may be a considerable problem.[5]

Thus there would seem to have been considerable incentives until recently for commercial banks to have "overindulged" in their use of derivatives.

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[5] :The Bankers" <u>Business Week</u> October 16, 1995, ppg: 106-111.

Off Balance Sheet Activities and Their Effects on Commercial Banks

The effects of Off-balance sheet activities on commercial bank value has only recently become investigated. Lynge and Lee (1987) found that off-balance sheet banking activities are negatively related to total risk. But they found no relationship between ABSCESS and market risk.

Kane and Unal (1990) developed a model for estimating "hidden capital". Hidden capital is made up of the misvaluation of on-balance sheet items and the value of off-balance sheet items. Their model also allows for the separation of bookable and unbookable sources of value. Using the sample period of 1975 - 1985 and 147 banks and bank holding companies, Kane and Unal find that off-balance sheet items were a significant drain on bank capital before 1980, but become insignificant thereafter. They also find that off-balance sheet items seem to hedge market variation only before 1978. After this, they lose their significant and negative sensitivities to market variation.

Levonian (1991) investigated the effects of large commercial banks burgeoning activities in derivatives and ABSCESS over the period of 1985-1989 using a portfolio consisting of BankAmerica, Bankers Trust, Chase Manhattan, Chemical, Citicorp, First Chicago, J.P. Morgan, Manufacturers Hanover, and Security Pacific. Using

implied volatilities from an Option Pricing model of bank assets and Deposit Insurance liability, Levonian finds that the riskiness of bank assets and activities did increase at the sample banks during the period studied. However, market capital-asset ratios generally rose, leaving the burden on the deposit insurance fund unchanged.

Neuberger (1992) conducted an empirical analysis of the behavior of Bank Holding Company (BHC) stock returns with goal of identifying the effect of bank portfolio composition on the risks embodied in the stock returns. Using an aggregated sample of quarterly data from 1988 to 1990, Neuberger uses a modified APT model that takes in both direct effect of priced factors and the indirect effects of the risk factors via the stock market risk factor. Neuberger finds that bank use of currency and interest rate contracts significantly increases the market risk of the sample companies, while not reducing extra-market risk.

In contrast, Hassan, Karels, and Peterson (1994) find that the use of futures, forwards, and options led to decreased volatility of banking assets. Hassan et al construct two measures of bank asset risk. The first measure calculates implied asset variance using a contingent claims model of equity and deposit insurance similar to that used by Levonian (1991), The second measure used is the implied asset variance from a subordinated debt option pricing model. Using a sample of 30 Commercial Banks and Bank Holding Companies. Usually, the derivative use variables are significant at

the 10% level and negative, indicating that derivative use decreases the risk of banks. This evidence supports the notion that banks primarily use derivatives to reduce their and their customers, and shareholders risk.

Sharpe, Vance and McDermott (1994) use information from three individual Australian banks. They find that the banks could have substantially reduced their risk by using mean-variance portfolio theory. In fact, the available risk reduction was higher than for U.S. commercial banks as measured by Grammatikos et al (1986). Sinkey and Carter (1995) use a sample of 670 commercial banks and bank holding companies. Splitting the sample into groups which contain banks that use derivatives and those that do not. User banks have substantially different capital structures from non-users of derivatives. Users have a substantially greater ratio of notes, debentures and preferred stock in their capital structure. User banks also exhibit significantly lessor equity capital ratios, net interest margins and loan quality. User banks also seem to have large short term maturity gaps they need to hedge, while they have much smaller long-term maturity gaps. Large commercial banks are found to use derivatives primarily to increase net interest income. Sinkey and Carter also find that barriers to entry and cost economies are the primary determinants of dealer activity in derivatives.

Gorton and Rosen (1995) Estimate the market values and interest-rate sensitivities of the interest-rate swap positions of

volatility risk premium proxy. The volatility risk premium proxy will be constructed following the idea of Amin and Ng (1993). The implied option variance for each contract will be substituted for the lagged conditional volatility in a GARCH 1,1 model. Using this estimated GARCH 1,1 model, the futures price will be forecasted using the implied option variance. The forecasted futures prices will then be subtracted from the actual futures price. This difference will then be taken as the volatility risk premium proxy.

Given this, the following model will be estimated for the portfolio of banks identified as being the biggest dealers in derivatives:

$$\varepsilon_t = \beta_0 + \sum_{i=1}^{13} \beta_i Premium_i + \xi_t \qquad (43)$$

Where the premium proxies of all thirteen contracts from the previous section are used. This model will be estimated by the method of Seemingly Unrelated Regression (SUR), so as to minimize effects between the returns of different banks. If any of the coefficients of the risk premiums are significant, we can conclude that there seems to be an exposure to our portfolio of banks that can be tied to volatility risk.

<u>Data</u>

The sample of banks consists of the 25 largest derivative
using banks as determined by the 1995 first quarter report of the
Office of the Comptroller of Currency is also used. Ideally, for
contrast, a sample of comparable non-user banks would be used.
However, user banks are overwhelming larger than non-user banks.
The samples are detailed in Appendix B. The daily returns of the
sample banks are estimated from the most recent set of CRSP Tapes.

Results

The results are reported in Table VII. Our portfolio of banks show a significant amount of exposure to volatility risk associated with the IMM Eurodollar contract, the Japanese Yen contract and the Canadian Dollar contract.

The tests were also run, using each explanatory variable separately in a series of OLS regressions. While there was some slight changes in the value of the coefficients, the significance of the variables were unchanged. The OLS results supported the SUR results reported in Table VII. As a result, the OLS results were deemed redundant, and are not reported here.

These results seem very strange in light of what we know from the earlier tests for volatility risks. While the Canadian Dollar contract seems to exhibit the sort of behavior that theoretically would be associated with the existence of a volatility risk premium, the Japanese Yen does not. The IMM Eurodollar contract gives marginal support at best to the volatility risk premium hypothesis.

In the context of the presence of a volatility risk hypothesis, there are a number of possible explanations. First, that banks being interested in speculation, speculate in terms of the direction of some futures contracts over the long term and that what has been captured in Table VII is the long run speculative exposure of these banks to the contracts that they felt

were likely to appreciate or depreciate over the long run.

It is also possible that the exposures revealed are the long run net exposure that these firms undertook on the behalf of customers for risk management purposes. However, if true, these exposures should be hedged. The fact that it does not seem that they all are may indicate two possible scenarios.

First it could be the case that the banks are unable to properly hedge their exposure due to lack of liquidity of the markets. However, the futures and option markets for all of the three significant contracts are very liquid, in fact the Japanese Yen and the Eurodollar contracts see the heaviest trading activity of any futures and options in the world. Their trading volume regularly exceeds that of many financial markets in the world.

Second, it could be the case that they are not interested in the hedging of these contracts fully. They may be more interested in the fees generated by risk management services than in the actual service of risk management.

Both of these point out that there may be a need for more active monitoring of these off-balance sheet items by regulatory authorities. The current method of assessing the risk of these items requires banks to carry a percentage of assets based on the risk class of the instrument used. In this case, all of the contracts studied here would be in the same risk class. But they show very different risks to the banks in terms of the exposure of the banks to volatility risk premiums. This suggests that not only

should risk class be dependent on the type of contract, but also on the volatility of the individual contract.

IX. Final Summation

The purpose of this work was to test explanations of pricing biases in futures and futures options markets. The results have been surprising to say the least.

In light of all of the available information, There seems to be some support for the presence of a priced volatility risk premium in the futures contracts of the CME Canadian Dollar and in the IMM Eurodollar. However, the evidence for each contract is not overwhelming. It would be interesting to see, with better data on volume, how our results would change if we added the net volume of option contracts as an explanatory variable. But in light of the effect this variable had in the testing of the LIFFE contracts, it may be likely that our overall conclusion of there being support for a volatility risk premium for these two contracts would be unchanged.

If there are priced volatility risk premiums, why are the results strongest for these two contracts? There is no obvious factor that connects these two contracts. The IMM Eurodollar is one of the most heavily traded futures contract in the world, as is it's options. The Canadian Dollar contract is, at best, a minor contract of relatively little interest.

What is most striking about the results reported here is how individual these contracts seem to be. Some have volatility

structures that exhibit overreaction to market news, others do not. Some exhibit volume effects that support Nandi's asymmetric market information hypothesis, others do not. Clearly, the type of market rules in effect, as shown by our results in testing hypothesis 5, seem to have some effect. But what is very striking about all of this is that the data do not give overwhelming support to any one hypothesis that attempts to explain market behavior.

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APPENDIX A
SYMBOLS USED REPEATEDLY AND THEIR DEFINITIONS

This appendix lists the frequently used symbols in this work and their definitions.

c -   Price of an European call option.
C -   Price of an American call option.
X -   Exercise price of a call option.
t -   current period
T -   Maturity period of option.
r -   prevailing market rate of an United States Government T-Bill.
r_m -   prevailing rate of return on market portfolio.
I -   set of available information
dw, dz -   Brownian Motion Processes.
e -   unexpected "news", innovation.
σ -   implied volatility (model measure of ex ante volatility expectations).
h -   conditional volatility (from GARCH)
V -   volatility process (theorized)
V^* -   long run level of theorized volatility process. Mean of market expected variance.

Appendix B

The "Big 6"

Bankers TC NY	Chemical Bank NY
Morgan Guaranty TC NY	Chase Manhattan Bk NY
Citibank NA NY	Bank of America CA

Top 25 as of 1st Q. 1995 Call Report Schedule RC-R

Chemical Bank	Citibank NA
Morgan Guaranty	Bankers Trust
Bank of America NT&SA	Chase Manhattan Bank NA
First NB of Chicago	NationsBank NA Carolinas
Republic NB of NY	First NB of Boston
Bank of NY	Natwest Bank NA
First Union NB NC	State Street B&TC
Bank of America IL	Mellon Bank NA
Seattle-First NB	PNC Bank NA
Wells Fargo Bank NA	Bank One Columbus NA
Boston Safe Deposit & TC	Harris Trust & Savings
Marine Midland Bank	National City Bank
CoreStates Bank NA	

Table I
GARCH Estimation with opion implied variance.

$$h_t = a + bh_{t-1} + c\xi_{t-1}^2 + d\sigma_{iv_t}$$

h_t is the volatility at time t conditional on the available information,
ξ_t^2 is the squared innovation of the conditional mean,
and σ_{iv} is the Black (1977) futures option formula implied variance.

LIFFE	a	b	c	d	Ljung-Box	Bias
Euro-dollar	3.56 E-9	0.9997 ***	4.3 E-4***	-4.8 E-8	119.11 ***	-4.83***
Euromark	-8.83 E-9***	0.998***	3.4 E-4***	1.4 E-6***	186.28 ***	8.5***
Long Gilt	1.4 E-7***	0.987***	1.7 E-3***	-1.4 E-6	30.91***	1.51
Bund	4.2 E-6	0.996***	6.97 E-5	-3.25 E-4	243.07 ***	0.189
CME						
Euro-dollar	0.255*	0.991***	0.0015 ***	-141.79	19.37*	-6.4***
Treasury Bill	0.059*	0.998***	0.00046 ***	-0.7459	71.23***	-2.04**
Canadian Dollar	4.2 E-7*	0.9959 ***	0.00049 ***	-0.00123	39.96***	-12.4***
Deustche Mark	1.9 E-6*	0.997***	0.00052 ***	-6.8 E-5	34.36***	-18.9***
Japanese Yen	4.8 E-7***	0.982***	0.00045 **	9.36 E-8	17.36*	-0.691
Pound Sterling	1.9 E-5**	0.997***	0.00052 ***	-0.001	35.52***	-15.5***
Swiss Franc	3 E-6***	0.997***	0.00054 ***	1.3 E-4*	26.11***	-18.3***
CBOT						
10-Year Treasury Note	0.0461	0.998***	0.00052 ***	-0.00057	137.91 ***	-2.6***
5-Year Treasury Note	0.405	0.995***	0.0019 ***	20.58*	71.88***	-5.2***

- Denotes significance at the 10% level
* - Denotes significance at the 5% level
** - Denotes significance at the 1% level

Table II
GARCH Estimation with option implied volatilities frpm options with different maturities

$$h_t = a + bh_{t-1} + c\xi_{t-1} + d\hat{\sigma}_{iv,f_{t-1}} + e\hat{\sigma}_{iv,m} + f\hat{\sigma}_{iv,n}$$

h_t is the volatility at time t conditional on the available information,
ξ^2_t is the squared innovation of the conditional mean,
d σ_{iv} is the Black (1977) futures option formula implied variance. f denotes the option with the same month of maturity as the underlying future, n the option with the shortest maturity date, and m, the intermediate option.

LIFFE Contract	Canadian Dollar	Deustche Mark	Japanese Yen	Pound Sterling	Swiss Franc
	4.3 E-6*	3.3 E-6***	4.82 E-7***	2.15 E-5**	3.06 E-6**
	0.996***	0.997***	0.983***	0.997***	0.997***
	49 E-4***	5.2 E-4***	4.54 E-4**	5.16 E-4***	5.4 E-4***
	-1.23 E-3	-2.3 E-4**	1.08 E-8	1.02 E-3	1.5 E-4
	-2.17 E-7	9.1 E-5	7.7 E-7	9.7 E-4	4.25 E-5
	-4.9 E-4	8.4 E-5	1.4 E-6	2.5 E-4	1.33 E-5
Jung-Box	39.96***	34.38***	17.35 *	35.5***	26.09***
Bias	5.85***	9.19***	1.05	8.385***	8.159***

- Denotes significance at the 10% level
* - Denotes significance at the 5% level
** - Denotes significance at the 1% level

TABLE III
GARCH Estimation with option implied volatilities from options with different maturities

$$h_t = a + bh_{t-1} + d\hat{\sigma}_{iv,f} + e\hat{\sigma}_{iv,m} + f\hat{\sigma}_{iv,n} + gPos1 + hPos2 + jNeg1 + kNeg2$$

h_t is the volatility at time t conditional on the available information and σ_{iv} is the Black (1977) futures option formula implied variance. Where f denotes the option with the same month of maturity as the underlying future, n the option with the shortest maturity date, and m, the intermediate option. Pos1 is the innovations in the conditional mean when the error term is between the median of the error and it's third quartile, Pos2 is error terms of the fourth quartile, Neg1 is the error terms from the second quartile to the median, and Neg2 the error terms from the first quartile.

IFFE contract	Canadian Dollar	Deustche Mark	Japanese Yen	Pound Sterling	Swiss Franc
	-7.05 E-6***	-9.39 E6***	4.5 E-7**	7.3 E-5***	1.35 E-5***
	0.998***	0.9985***	0.981***	0.999***	0.9985***
	-2.36 E-3***	-9.2 E-5***	-1.6 E-7	-8.53 E-4***	-7.97 E-5***
	1.14 E-7	-4.2 E-5*	6.01 E-7	-1.6 E-4	2.04 E-5
	-1.5 E-3***	8.67.E-5***	1 E-5	-1.57 E-3***	3.07 E-5
	2.27 E-3***	1.886 E-3***	3.75 E-5	5.37 E-3***	1.99 E-3***
	7.36 E-4***	5.27 E-4***	3.58 E-5	1.53 E-3***	5.61 E-4***
	-2.78 E-3***	-1.96 E-3***	-2.15 E-5	-6.5 E-3***	-1.96 E-3***
	-1.46 E-3***	-1.01 E-3***	4.02 E-7	-2.93 E-3***	-1.09 E-3***
Ljung-Box	39.96***	34.38***	17.35*	35.5***	26.09***

* - Denotes significance at the 10% level
** - Denotes significance at the 5% level
*** - Denotes significance at the 1% level

Table IV
Partially Non-parametric GARCH estimation with option implied variance

$$h_t = = a + bh_{t-1} + d\hat{\sigma}_{iv} + gPos1 + hPos2 + jNeg1 + kNeg2$$

h_t is the volatility at time t conditional on the available information
and σ_{iv} is the Black (1977) futures option formula implied variance. Pos1 is the innovations in the conditional mean when the error term is between the median of the error and it's third quartile, Pos2 is error terms of the fourth quartile, Neg1 is the error terms from the second quartile to the median, and Neg2 the error terms from the first quartile.

	Eurodollar	Euromark	Long Gilt	Bund
a	2.33 E-8***	-6.21 E-9	1.03 E-7	-8.4 E-6***
b	0.986***	0.997***	0.9845***	0.997***
d	1.3 E-7	3.56 E-8	-4.3 E-6**	-3.9E-4***
g	9.256 E-6***	1.56 E-5***	7.32 E-5**	3.2 E-3***
h	1.865 E-6	1.38 E-5***	4.97 E-5*	1.53 E-3***
j	-1.13 E-5***	-1.17 E-5***	-8.14 E-5**	-3.72 E-3***
k	-9.34 E-6***	-1.06 E-5***	-5.55 E-5*	-1.28 E-3***
Ljung-Box	119.96***	185.94***	30.96***	243.07***

Denotes significance at the 10% level
- Denotes significance at the 5% level
*- Denotes significanceat the 1% level

Table V
Partially Non-parametric GARCH estimation with option implied variance

$$h_t = =a + bh_{t-1} + d\hat{\sigma}_{iv} + gPos1 + hPos2 + jNeg1 + kNeg2$$

h_t is the volatility at time t conditional on the available information and σ_{iv} is the Black (1977) futures option formula implied variance. Pos1 is the innovations in the conditional mean when the error term is between the median of the error and it's third quartile, Pos2 is error terms of the fourth quartile, Neg1 is the error terms from the second quartile to the median, and Neg2 the error terms from the first quartile.

Contract	IMM-Eurodollar	IMM-Treasury Bill	CBOT- 10-Year Treasury Note	CBOT- 5-Year Treasury Note
a	-0.731***	-0.137**	-0.197**	-0.48***
b	0.996***	0.998***	0.998***	0.996***
d	-82.32***	-0.384	1.65 E-4	-4.3***
g	2.25**	0.191*	0.296*	2.28**
h	0.26	0.068	0.0733	0.27
j	-2.12**	-0.211*	-0.376*	-2.34**
k	0.510	-0.134*	-0.147	0.55063
Ljung-Box	19.37*	71.23***	137.95	74.82

Denotes significance at the 10% level
- Denotes significance at the 5% level
* - Denotes significance at the 1% level

Table VI

Partially Non-parametric GARCH estimation with option implied variance and net volume

$$h_t = =a + bh_{t-1} + d\sigma_{iv} + gPos1 + hPos2 + jNeg1 + kNeg2 + m\ Vol_{t-1}$$

h $_t$ is the volatility at time t conditional on the available information
and σ_{iv} is the Black (1977) futures option formula implied variance. Pos1 is the innovations in the conditional mean when the error term is between the median of the error and it's third quartile, Pos2 is error terms of the fourth quartile, Neg1 is the error terms from the second quartile to the median, and Neg2 the error terms from the first quartile. Vol is the net trade volume on the options contract.

LIFFE	Eurodollar	Euromark	Long Gilt	Bund
a	1 E-8	1.96 E-7*	1.65 E-6**	-8.2 E-6***
b	0.993***	0.995***	0.9765***	0.997***
d	1.84 E-7*	2.6 E-8	-1.68 E-7	-3.31 E-4**
g	9.35 E-6**	1.556 E-5***	7 E-5*	3.16 E-3***
h	1.58 E-5***	1.3636 E-5**	4.5 E-5*	1.53E-3**
j	-1.08 E-5**	-1.19 E-5***	-7.6 E-5*	-3.64 E-3***
k	-8.82 E-6**	6.8 E-6	-5.345 E-5*	-1.28 E-3**
m	6.34 E-12**	2.1 E-7	-1.64 E-8**	-4.9 E-12 **
Ljung-Box	119.96***	186.26***	30.91***	243.07***

* Denotes significance at the 10% level
** Denotes significance at the 5% level
*** Denotes significanceat the 1% level

Table VII
Exposure of Banks to volatility risk premiums

$$\varepsilon_t = \beta_0 + \sum_{i=1}^{13} \beta_i Premium_i + \xi_t$$

$\hat{\varepsilon}$ is the residual from the regression of the value weighted market portfolio on the value weighted returns of the portfolio of 26 banks listed in Appendix B. Premium is the volatility risk premium of the ith type of contract as listed below.

	Coefficient	Standard Error	t-ratio
ntercept	0.00925	0.0005706	1.621
reasury Bill	−0.000329	0.0002536	−1.2957
0-Year T-Note	0.0005184	0.0003385	1.5314
,-Year T-Note	−0.000181	0.0001743	−1.0414
MM Eurodollar	0.004156	0.0018806	2.2099**
'ound Sterling	0.03883	0.05969	0.6506
:anadian Dollar	−0.40709	0.20537	−1.9822**
)eustche Mark	−0.19698	0.21533	−0.9148
Japanese Yen	−0.2333	0.10861	−2.148**
;wiss Franc	−0.03736	0.11143	−0.3353
.IFFE Eurodollar	0.1648	0.4251	0.3877
.ong Gilt	−0.3539	0.23725	−1.4915
3und	−0.039	0.036	−1.093
:uromark	0.00323	0.3194	0.0101

- significant at the 10% level
* - significant at the 5% level
** - significant at the 1% level