Forecasting Accuracy and Development of a Financial Market: The Treasury Bill Futures Market

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Futures markets affect the intertemporal allocation of resources. Thus, one way to evaluate the economic benefits of futures markets is to examine their effects on the intertemporal allocation of resources. This issue was studied by DeCanio (1980) and Stein (1981, 1986) who showed that the economic benefits of futures trading can be measured by the ex-post welfare loss from misallocation of resources when futures prices are used instead of perfect foresight spot prices. In particular, the ex-post welfare losses increase proportionally to the mean squared error (MSE) of futures prices.

This article studies the relation between the forecasting accuracy of futures Treasury bill rates (relative to forward Treasury bill rates), the development of the futures market, and the changing monetary conditions. Futures contracts are traded in an open-outcry auction market on an organized exchange with a clearing association. The clearing association employs safeguards to guarantee the financial integrity of futures contracts. Forward contracts are created by buying and short-selling spot Treasury bills with different maturities in an over-the-counter dealer market with no clearing association. Kamara (1988) showed that the futures' market trading structure reduces the liquidity and default premium embedded in Treasury bill futures rates relative to forward rates.[1] The futures market trading structure reduces the cost of entry into the market and allows the participation of small traders whose credit worthiness is inadequate for using forward contracts. Yet, while the increased risk sharing reduces risk premia, it may add traders who are less informed than traders already in the spot and forward markets and can impair the ability to infer from market prices.[2]

Evidence that futures rates tend to be more accurate forecasts of future spot rates than forward rates is reported in Kamara and Lawrence (1985), Hedge and McDonald (1986),

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[1]For a detailed analysis of the trading structure of futures and forward markets and their implications on default risk, liquidity risk, and cost of trading, see Kamara (1988) and its references.

[2]Van Horne and Heaton (1983), for example, found that government security dealers have information superior to that of the market.

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and MacDonald and Hein (1989). However, an examination of subperiods is warranted for several reasons. First, the forecasting accuracy of a new capital market may change as the market develops because the strength of the reduced risk premiums effects and misinformation effects are likely to change as the futures market matures. The creation of a new market involves a costly learning process. The infancy period is a transition period where traders learn the rules of the market, institutions develop new trading systems and regulatory constraints are revised to accommodate trading. Therefore, in its infancy period, the futures market is likely to exhibit the largest adverse informational effects and the smallest increased risk-sharing effects. But as the market matures and its trading activity increases, increased risk-sharing effects are likely to increase relative to any misinformation effects. Second, as Kamara (1988) found, differences in liquidity and default premia due to different market trading structures depend on the economic characteristics of the periods examinied. Third, as Zarnowitz (1979) found, accuracy of forecasts also depends on the economic characteristics of the periods examined.

This article examines three subperiods that coincide with three different monetary regimes: June, 1976–September, 1979; October, 1979–October, 1982; and November, 1982–December, 1985. These regimes are identified in Huizinga and Mishkin (1986) and Roley (1986). The second monetary regime is characterized by substantially more volatile Treasury bill rates than the other two regimes. Also, Treasury bill futures contracts began trading in 1976 and the volume of futures transactions increased substantially (absolutely and relatively to the spot market) after October, 1979. The results show that the futures' relative forecasting accuracy has improved steadily over time. Futures rates were less accurate than forward rates during the futures market's infancy period of June, 1976–September, 1979 but more accurate afterward. The results suggest that the relative strength of the reduced risk premium and misinformation effects and hence the economic benefits of the Treasury bill futures market changed as the futures market matured.

The spectacular growth of financial futures markets and the events surrounding October 19, 1987, created a need to better understand the effects of futures trading upon the cash price volatility. Stein (1986) shows that the effects of futures trading on cash prices volatility also depend on the relative strength of reduced risk premia and misinformation effects. Hence, the results suggest that the effects of futures trading on cash prices volatility are likely also to change as the market develops.

The results also provide evidence on the roles that market trading structures and changing monetary conditions play in predicting interest rates. Most of the recent empirical evidence on the term structure of interest rates is concerned with the predictive power of implied forward rates. Thus, the results also should be of interest to students of the term structure of interest rates.[3]

EMPIRICAL RESULTS

The Data

The sample consists of near-delivery futures contracts traded during June, 1976–December, 1985, 13 weeks prior to delivery day.[4] The contract, which calls for a delivery of

[3]Hardouvelis (1988) and its references.

[4]Futures and forward rates with 4 weeks to delivery were compared also. The results are similar to those reported. Studying longer forecasting horizons is impossible because bills issued with longer than six months to maturity were almost never deliverable against futures contracts prior to the June 1983 futures contract.

13-week Treasury bills with one million dollars face value, expires on a quarterly cycle (March, June, etc.). The settlement discount rates on these contracts are from the *International Monetary Market Yearbook*. The spot rates being predicted are bid discount rates of the deliverable Treasury bill on the futures contracts' delivery days. Forward discount rates are calculated [based on Stigum (1981, pp. 54–57)] from bid discount rates on 26-week and 13-week spot Treasury bills.[5] The spot rates are from the Federal Reserve Board.[6] Spot rates are observed up to an hour after the closing of the futures market. This gives forward rates an advantage over futures rates.

Forecasting Accuracy Tests

Comparing the forecasting accuracy of futures rates and forward rates, over the entire sample period of June, 1976–December, 1985, Table I shows that futures rates have a lower MSE than implied forward rates. Using futures rates rather than implied forward rates would have reduced MSE and increased ex-post social welfare by 10%. The comparison reveals that, over the entire sample period, the reduced risk premiums effects dominated the misinformation effects.[7]

During 1976–1985, there are apparently three monetary regimes [Huizinga and Mishkin (1986) and Roley (1986)]:[8]

Regime 1: June, 1976–September, 1979,

Regime 2: October, 1979–October, 1982,

Regime 3: November, 1982–December, 1985.

These regimes represent subperiods that vary substantially in terms of both the volatility of Treasury bill rates and the liquidity of the futures market.

Table I also shows that the futures' bias is smaller than the forwards' bias (in absolute value) in all three subperiods. The variance of the futures forecast error is larger than the variance of the forward forecast error in the first regime, but smaller than in the second but lower afterwards. Using futures rates rather than implied forward rates would have reduced ex-post social welfare by 10% during June, 1976–September, 1979, but would have increased ex-post social welfare by 10%–27% after October 1979.

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[5]Forward contracts always involve short-selling Treasury bills. Arbitrageurs often borrow bills at a term repo rate that exceeds the Treasury bill rate. Treasury bill rates are used for consistency with Kamara and Lawrence (1985), Hedge and McDonald (1986), and MacDonald and Hein (1989), and with virtually the entire literature on the predictive power of the term structure of interest rates. Using term repo rates yields two different forward rates depending on which bill is being financed, and the implied forward rate lies betwen them.

[6]Bid rates are used in this study. The rates are unweighted averages of at least five government security dealers. It was apparent from an examination of the quote sheets of a major financial intermediary that the bid-ask spread over the sample period was almost a constant and is too small and invariant to affect the results of this study. Moreover, Capozza, and Cornell (1979) argued, "bid prices [but not ask prices] more accurately reflect true market prices" (fn. 5).

[7]Comparing futures and forward rates cannot reveal whether futures trading had adverse informational effects on forward prices. However, studying the predictive power of implied forward rates during the recent monetary regimes, Hardouvelis (1988) found that implied forward rates are better predictors of changes in spot rates than autoregressive and vector autoregressive models.

[8]These regimes correspond to the following futures contracts: September, 1976–September, 1979; December, 1979–December, 1982; March, 1983–December, 1985.

Table I
RELATIVE FORECASTING ACCURACY, INTEREST RATE VOLATILITY, AND LIQUIDITY VARIABLES OVER ENTIRE SAMPLE AND ACROSS SUBPERIODS

	June 1976–December 1985	June 1976–September 1979	October 1979–October 1982	November 1982–December 1985
$\frac{\text{MSE (forward)}}{\text{MSE (futures)}}$	1.10	0.89	1.10	1.27
Difference between squared biases of forward and futures rates, in percents.	0.24	0.04	0.49	0.20
$\frac{\text{Variance (forward error)}}{\text{Variance (futures error)}}$	1.06	0.82	1.07	1.11
Average monthly standard deviations of daily changes in 13-week Treasury bills (percent)	0.13	0.06	0.26	0.08
Average daily volume of trading in the near-maturity futures contract	8,458	793	14,214	10,527
Mean of the ratios of futures-spot average daily trading volumes	0.78	0.40	1.37	0.55
Number of observations	38	13	13	12

and third regimes. This is consistent with Stein (1986, Ch. 3) who argues that the increased risk sharing from introducing futures trading leads to lower risk premia, but the entry of small traders, who are less informed relative to commercial traders already in the markets, increases the variance of the futures' forecast error.

Table I also reports the standard deviation of daily changes in 3-month Treasury bill spot rates, the average daily volume of trading near-maturity futures contracts and the ratio of the average (over the month) daily trading volumes in futures and spot Treasury bill markets.[9] The standard deviation of daily changes in the 3-month Treasury bill rates in the second subperiod is substantially higher than in the first and third subperiods. The trading volume on the near-maturity futures contract and the futures-spot volumes ratios indicate that the liquidity of the Treasury bill futures market increased (absolutely and relatively to the spot market) substantially after September, 1979. The improvement in the relative forecasting accuracy of futures rates in the second subperiod is associated with increases in the volatility of spot interest rates, the trading volume of futures contracts and the futures article-spot trading volumes ratio.

This article estimates the following relation between futures-spot volume ratio and $\hat{\sigma}$, the sample standard deviation of daily changes in 3-month Treasury bill rates[10]

$$\frac{\text{Futures trading volume}}{\text{Spot trading volume}} = 0.24 + 2.89\hat{\sigma}$$

$$(t=) \qquad\qquad (4.39) \quad (5.92)$$

The regression suggests that changes in the liquidity of the futures market relative to the spot market are positively related to changes in the volatility of underlying rates. This provides further support to Kamara (1988) who found that the value of the transaction advantages of futures contracts over forward contracts are related to the volatility of underlying rates.

The differences between an infant and a mature futures market are particularly evident from a comparison of the first and third subperiods because the standard deviations of daily changes in 3-month Treasury bill rates in the two regimes are similar. The ratio of forward-futures MSEs, the ratios of the forward-futures forecast error variances and the difference in the forward-futures squared biases are all much higher in the third regime than in the first regime. The evidence suggests that in a infant futures market, the adverse informational effect dominated the increased risk-sharing effect. Because of the costly learning process in the infancy period the misinformation effect is at its peak while the increased risk-sharing effect is relatively small. But in a mature futures market, the increased risk-sharing effects dominate any misinformation effects.

The finding that the reduction in the squared biases is highest in the second regime, is consistent with Kamara (1988) who found that the differences between the liquidity and

[9]Daily rates on 3-month Treasury bills were provided by the Federal Reserve Board. Average daily volumes of trading near-maturity futures contract were calculated, over ten preceding business days, from the *International Monetary Market Yearbook*. Ratios of futures-spot average daily trading volumes were calculated for each data point in the following way: Monthly average daily volume of trading in futures market were calculated from the *International Monetary Market Yearbook*. Each futures contract is on Treasury bills with one million dollars face value. Monthly averages of daily transactions by U.S. government security dealers in the secondary spot Treasury bill market (of up to one year bills, in one million dollars of face value) are reported in the *Federal Reserve Bulletin* of the Board of Governors of the Federal Reserve System.

[10]The regression's R^2 value is 0.50. The observations in the regression were corrected for a first-order serial correlation (using $\hat{\rho} = 0.41$). The hypothesis that the errors are homoskedastic was tested and not rejected at conventional levels using White's (1980) test.

default premia in forward and futures rates increase with interest rate volatility and with the ratio of futures-spot volume of trading.

A test proposed by Ashley, Granger, and Schmalensee (1980) and Brandt and Bessler (1983), which allows futures and forward forecast errors to be correlated, is used to test the statistical significance of the difference between the MSE's. The difference between two MSEs can be written as

$$MSE(e_1) - MSE(e_2) = [S(e_1)^2 - S(e_2)^2] + [m(e_1)^2 - m(e_2)^2]$$
$$= \left[\text{Cov}\left(\Delta, \sum\right)\right] + [m(e_1)^2 - m(e_2)^2].$$

where e_i $(i = 1, 2)$ is a vector of out-of-sample errors from the i^{th} forecasting method, $S(e_i)$ and $M(e_i)$ are the sample mean and standard deviation, Cov is the sample covariance, $\Delta_t = e_{1t} - e_{2t}$, $\Sigma_t = e_{1t} + e_{2t}$ and $\overline{\Sigma}$ is the mean of Σ. The null hypothesis is that both terms on the right-hand side equal zero. The test is, therefore, performed using the least squares regression

$$\Delta_t = a + b\left[\sum_t - \overline{\sum}\right] + u_t$$

where $a = m(e_1) - m(e_2)$; $b = \text{Cov}(\Sigma, \Delta)/\text{Var}[\Sigma_t - \overline{\Sigma}]$; and u_t is a white noise disturbance.

The null hypothesis that the difference between the *MSEs* equals zero is that $a = 0$ and $b = 0$. The alternative hypothesis, that $MSE(e_1)$ is greater than $MSE(e_2)$, is that a and b are both nonnegative and at least one is strictly positive (assuming that both mean forecast errors are positive.)[11] The null hypothesis cannot be rejected if either estimate is significantly negative. If one estimate is negative but not significant, a one-tailed t-test on the other estimate can be used. If both estimates are positive but not significant, an F-test can be performed. However, because the usual F-test is four-tailed, it does not take into account the sign of the coefficients. Under independence of a and b (which is true in this case), the probability of obtaining an F-statistic greater than F_0 and having both estimates positive is equal to one-fourth the significance level of F_0.

Table II reports the results of tests.[12] Futures rates are significantly more accurate than forward rates over the entire sample. Both coefficients are positive and the intercept is significant at a 0.01% level. An examination of the subperiods reveals that the differences between futures and forward rates in the first and second subperiod were insignificant. None of the coefficients of the second and third regressions in Table II is significantly positive at 5%. However, futures rates were significantly more accurate than forward rates in the last subperiod. Both coefficients of the last regression are positive and the intercept is significantly positive at a 0.1% level.

CONCLUSIONS

This article examines the relationship of the relative forecasting accuracy of futures Treasury bill rates, the development of the futures market, and the changing monetary conditions. The results show that trading structures and forecasting accuracy of a market

[11]When a mean forecast error is negative, all errors from that forecast are multiplied by minus one, and the regression and hypothesis test are performed in an analogous manner.

[12]The hypothesis that the errors of the regression over the entire sample are homoskedastic was tested and not rejected at a 5% level using White's (1980) test.

Table II
TESTS OF DIFFERENCES BETWEEN FUTURES AND FORWARD MSES
$\Delta_t = \hat{a} + \hat{b}(\Sigma_t - \overline{\Sigma})$

	$\hat{a}$	$\hat{b}$	R^2	Durbin Watson	Number of Observations
A. June 1976–December 1985:[a]	0.25	0.01	0.04	2.10	37
	(4.49)	(1.28)			
B. June 1976–September 1979:[b]	−0.15	3.18	0.16	1.69	13
	(−0.39)	(1.46)			
C. October 1979–October 1982:[a]	0.66	6.48	0.10	2.54	13
	(0.30)	(1.13)			
D. November 1982–December 1985:[a]	0.19	0.03	0.12	1.40	12
	(4.35)	(1.14)			

The term Δ_t is the forecast error differential. The term Σ_t is the sum of the forecast errors. $\overline{\Sigma}$ is the mean of Σ_t. For each regression, whenever the sample mean of a forecast error was negative its observations in that regression were multiplied by minus one. The *t*-statistics are in parentheses below the coefficients. The observations in the futures vs. forward regression in part A were corrected for a first-order serial correlation (using $\hat{\rho} = 0.39$). The Durbin-Watson values of the other regressions are insignificant at conventional levels. The hypothesis that the errors of the regression in part A are homoskedastic was tested and not rejected at a 5% level using White's (1980) test.

[a] H_0: MSE (forward) = MSE (futures). H_1: MSE (forward) > MSE (futures).

[b] H_0: MSE (forward) = MSE (futures). H_1: MSE (futures) > MSE (forward).

are interrelated. Futures rates are less accurate than forward rates in the futures' early years but significantly more accurate afterward. The improvements in the futures' relative accuracy are associated with the futures market liquidity relative to the spot market and with the volatility of the underlying spot rates. Furthermore, the growth in the liquidity of the future market relative to the spot market is positively related to the volatility of underlying rates.

The results suggest that the relative strength of the reduced risk premium and misinformation effects and, hence the economic benefits of the Treasury bill futures market, change as the futures market matures. The inception of a futures market allows new traders, who tend to be less informed than traders already in the spot and forward markets, to enter the markets system. Moreover, all traders face a costly learning process. Consequently, in the infancy period of the futures market, adverse informational effects dominate reduced risk premiums. But when the market matures, reduced risk premiums dominate any misinformation effects.

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