Maturity effects in the Mexican interest rate futures market

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Abstract

The growing importance of the Mexican TIIE-futures, which are amongst the most actively traded future contracts worldwide, motivates the examination of their behavior. In particular, this study addresses the question of maturity effects. The analysis is done using a panel consisting of 48 series corresponding to contracts with expiration between 2003 and 2006. The analysis shows maturity effects were present in some periods, although there is no evidence of maturity effect once all contracts are considered. Moreover, these effects seem to be independent of spot behavior. The analysis also confirms the presence of maturity effect in the basis.

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1 Introduction.

Understanding the dynamics of futures price volatility is important. This study focuses on a specific aspect of futures price volatility: the relation between volatility and time to expiration. Samuelson (1965) was the first to investigate theoretically this relation, providing a model that postulates the volatility of futures prices should increase as the contract approaches expiration. This effect, more commonly known as Samuelson Hypothesis or maturity effect, occurs because price changes are larger when more information is being revealed. Early in a contract's life, little information is known about the future spot price for the underlying. Later, as the contract nears maturity, the rate of information acquisition increases, more relevant information arrives and participants are more sensitive to information arrival which affects the futures price. In consequence, price volatility increases.

The study of the behavior of volatility of futures prices near the maturity date has important implications for market participants, for derivatives pricing and for risk management. Clearinghouses set margin requirements on the basis of futures price volatility. Therefore, if there is any relation between volatility and time to maturity, the margin should be adjusted accordingly as the futures approaches its expiration date. The relation between volatility and maturity also has implication for hedging strategies. Depending on the positive or negative relation between volatility and maturity, hedgers should choose between futures contracts with different time to maturity to minimize the price volatility. For example, Low et al. (2001) propose a multiperiod hedging model that incorporates the maturity effect. Their empirical results show that the model outperforms other hedging strategies that do not account for maturity. Thirdly, volatility and time to maturity relation is also essential for speculators in the futures markets. Speculators bet on the futures price movements of the assets. If maturity effect holds then speculator may find beneficial to trade in futures contracts close to expiry as greater volatility implies greater short time profit opportunities. Finally, since volatility is central to derivatives pricing, the relation between maturity and volatility should also be taken into consideration when pricing derivatives on futures.

Numerous studies have investigated the Samuelson hypothesis empirically, yielding mixed results. In general, the maturity effect has been supported for commodities, while it has not appear to be significant for financial assets.

The aim of this article is to study the presence of maturity effects in the Mexican interest rate futures market. The study considers futures contracts whose underlying consists of 28-day deposits that produce yield at the 28-day Interbank Equilibrium Interest Rate (Tasa de Interes Interbancaria de Equilibrio, or TIIE), calculated by the Central Bank (Banco de Mexico). This benchmark serves as a measure of the average cost of funds in the Mexican interbank money market. For this purpose 48 time series are used, consisting of the settlement prices of the contract with maturities from January 2003 to December 2006. With these series a panel is constructed arranging observations not according to calendar day, but according to days to maturity. This permits to apply panel data estimation techniques in addition to the usual time series methods.

The main motivation for studying this market lies in its growing importance: the Mexican Derivatives Exchange (MexDer), reached in the first ten months of 2006 a volume of 255.99 million contracts, making it the eighth largest exchange worldwide. Its leading contract, the 28-day TIIE interest rate futures, experienced during the same period the largest increase in volume in any futures contract, becoming the third most actively traded futures contract in the world after CME's Eurodollar and Eurex' Eurobond contracts (Holz, 2007). With such impressive growth, the behavior and characteristics of this emerging market are certainly important to many participants, including non-Mexican investors.

Relative to previous literature, the contribution of this study is twofold. First, it documents the existence of maturity effects in a market for which there are almost no previous studies. This study also expands upon previous research by considering a panel where observations are arranged not according to calendar day, but according to days to maturity and applying panel data techniques that permit to assess the existence of cross-sectional individual effects.

Our findings show that maturity effects are present in 2003 and 2004, inverse maturity effect appears in 2005 and 2005, and it indicates that there is not evidence of maturity effect once all contracts are considered (2003-2006). Results are qualitatively the same when the spot volatility is included as a proxy for information flow. With respect to the basis, results show the expected maturity effect in contracts between September 2004 and March 2006, while panel analysis indicates an inverted effect in 2003 and the expected maturity effect in every year from 2004 and in the whole sample. In the final section we discuss some possible explanations of this behavior.

The rest of the article is organized as follows. The next section briefly reviews the existing literature. In section three we describe the data and the methodology employed. In section four we report the results. Concluding remarks are given in the last section.

2 Literature review

Samuelson (1965) was the first to provide a theoretical model for the relation between the futures price volatility and time to maturity. The theoretical hypotheses introduced by Samuelson, known as the Samuelson hypothesis or the maturity effect, predicts volatility of futures prices rises as maturity approaches. The intuition is that when there is a long time to the maturity date, little is known about the future spot price for the underlying. Therefore, futures prices react weakly to the arrival of new information since our view of the future will not change much with it. As time passes and we approach maturity, the futures price is forced to converge to the spot price and so it tends to respond more strongly to new information.

The example used by Samuelson to present the hypothesis relies on the assumptions that 1) futures price equals the expectation of the delivery date spot price, and 2) spot prices follow a stationary, first-order autoregressive process. This specification implies that the spot price reverts in the long run to a mean of zero. However, Rutledge (1976) argued that alternative specifications of the generation of spot prices are equally plausible and may lead to predict futures price variation decreases as maturity approaches. Later, Samuelson (1976) shows that a spot generating process that includes higher order autoregressive terms can result in temporary decreases in a generally increasing pattern of price variability. Hence a weaker result is obtained: if delivery is sufficiently distant then variance of futures prices will necessary be less than the variance very near to delivery.

Numerous studies have investigated the Samuelson hypothesis empirically, with different sets of data and different methodologies, and have obtained mixed results. In general, the effect appears to be stronger for commodities futures, while for financial futures the effect is frequently nonsignificant or non existent at all.

For commodity markets, early empirical work by Rutledge (1976) finds support for the maturity effect in silver and cocoa but not for wheat or soybean oil. Milonas (1986) derives, in line with Samuelson's arguments, a theoretical model for the maturity effect and provides empirical evidence. He calculates price variability as variances over daily price changes within a month and adjusts these variances for month, year and contract month effects. He tests for significant differences in variability among the different time to maturity groups of variances and finds general support for the maturity effect in ten out of the eleven future markets examined, which included agricultural, financial and metal commodities.

Grammatikos and Saunders (1986), investigating five currency futures, find no relation between time to maturity and volatility for currency futures prices.

Galloway and Kolb (1996) examined a set of 45 commodities futures contracts, including twelve financial contracts. Using monthly variances, they investigated the maturity effect both in an univariate setting, searching for maturity effect patterns, and performing ordinary least squares (OLS) regressions. They found strong maturity effect in agricultural and energy commodities, concluding that time to maturity is an important source of volatility in contracts with seasonal demand or supply, but they did not found the effect in commodities for which the cost-of-carry model works well (precious metals and financial). In particular, T-Bill, T-bond and Eurodollar futures showed no evidence of any significant maturity effect. A similar result for currency futures was reported in Han, Kling and Sell (1999).

Anderson and Danthine (1983) offer an alternative explanation of the time pattern of futures price volatility by incorporating time-varying rate of information flow. The hypothesis, named state variable hypothesis, states that variability of futures prices is systematically higher in those periods when relatively large amounts of supply and demand uncertainty are resolved, i.e. during periods in which the resolution of uncertainty is high. Within this context, Samuelson's hypothesis is a special case in which the resolution of uncertainty is systematically greater as the contract nears maturity. Under this perspective, the maturity effect reflects a greater rate of information flow near maturity, as more traders spend time and resources to uncover new information.

Some studies have applied the state variable hypothesis to test the existence of maturity effect. Anderson (1985) studies volatility in nine commodity futures for the period 1966 to 1980. Using both nonparametric and parametric tests he finds that on six of these markets (oats, soybean, soybean oil, live cattle and cocoa) there is strong evidence of maturity effects but no such effect for wheat, corn or silver. However, he also reports that seasonality is more important in explaining the patterns in the variance of futures price changes. Barnhill, Jordan and Seale (1987) apply the state variable hypothesis to the Treasury bond futures market during the period 1977-1984 and find evidence supportive of the maturity effect.

The effects of time to maturity have also been studied on the futures basis (defined as the futures price less the spot price). Castelino and Francis (1982), based on Samuelson's analysis of futures prices, study the effect of time to maturity on the basis over the life of commodity futures contracts. Assuming a first-order autoregressive price process, they show that the volatility of changes in the basis must decline as contract maturity approaches. The rationale behind this is that the arrival of new information is more likely to affect spot and futures prices in the same manner if it arrives closer to maturity than further away. As a corollary, it follows that hedging in a nearer contract involves less basis risk than hedging in a more distant contract. Using daily data for futures on wheat, soybeans, soybeans meal and soybean oil they provide empirical evidence of this maturity effect on the basis. Beaulieu (1998) studies the basis in two stock market equity indices. The paper utilizes GARCH model to estimate the volatility of the basis since there is heteroscedasticity and leptokurtosis present. The results indicate that the size of the variance of the basis decreases as the futures contracts approach expiration, in line with the previous results of Castelino and Francis (1982).

Chen, Duan and Hung (1999) focus on index futures and propose a bivariate GARCH model to describe the joint dynamics of the spot index and the futures basis. They use the

Nikkei-225 index spot and futures prices to examine empirically the Samuelson effect and study the hedging implications under both stochastic volatility and time-varying futures maturities. Their finding of decreasing volatility as maturity approaches contradicts the Samuelson hypothesis.

Bessembinder et al. (1996) present a different analysis of the economic issues underlying the maturity effect. With respect to the state variable hypothesis, they note that there is an absence of satisfactory explanations of why information should cluster towards a contract expiration date. According to their model, neither the clustering of information flow near delivery dates nor the assumption of that each futures price is an unbiased forecast of the delivery date spot price is a necessary condition for the success of the hypothesis. Instead they focus on the stationarity of prices. They show that Samuelson hypothesis is generally supported in markets where spot price changes include a predictable temporary component, a condition which is more likely to be met in markets for real assets than for financial assets. Their analysis predicts that the Samuelson hypothesis will be empirically supported in those markets that exhibit negative covariation between spot price changes and the futures term slope. Since financial assets do not provide service flows, they predict that the Samuelson hypothesis will not hold for financial futures. To test their predictions they consider data from agricultural, crude oil, metals and financial futures. Performing regressions on days to expiration, spot volatility and monthly indicators they obtain supportive evidence for their model.

Hennessy and Wahl (1996) propose an explanation of futures volatility based not on information flow or time to expiry, but on production and demand inflexibilities arising from decision making. Their results on CME commodity futures support of the maturity effect.

More recently, Aragó and Fernández (2002) study the expiration and maturity effects in the Spanish market index using a bivariate error correction GARCH model (ECM-GARCH). Their results show that during the week of expiration conditional variance increases for the spot and futures prices, according to Samuelson hypothesis.

3 Data and Methodology

3.1 The TIIE futures contract

Since March 1996, Banco de Mexico determines and publishes the short-term interest rate benchmark known as Tasa de Interés Interbancario de Equilibrio, or TIIE. There are two variants for the TIIE: 28- and 91-day. The 28-day TIIE rate is based on quotations submitted daily by full-service banks using a mechanism designed to reflect conditions in the Mexican Peso Money Market. The participating institutions submit their quotes to

Banco de Mexico by 12:00 p.m. Mexico City time. Following the receipt of the quotes, Banco de Mexico determines the TIIE in accordance with the stated procedures. Rates quoted by institutions participating in the survey are not indicative rates for informational purposes only; they are actual bids and offers by which these institutions are committed to borrow from or lend to Banco de Mexico. In case Banco de Mexico detects any collusion among participating institutions or any other irregularity, it may deviate from the stated procedure for determination of the TIIE rates.

The TIIE futures contracts are traded in the Mexican Derivatives Exchange (MexDer). Each 28-day TIIE Futures Contract covers a face value of 100,000.00 Mexican Pesos (approximately 9,100 U.S. dollars). MexDer lists and makes available for trading different series of the 28-day TIIE futures contracts on monthly basis for up to ten years. It is important to observe that, in contrast with analogous instruments like CME's Eurodollar futures or LIFFE's Short Sterling futures, TIIE futures are quoted by annualized future yields and not by prices. The relation between the quoted future yields on day t and the corresponding futures price F_t is determined by MexDer by the formula

$$F_t = \frac{100,000}{1 + Y_t(28/360)} \tag{1}$$

where Y_t is the quoted yield divided by 100.

The last trading day and the maturity date for each series of 28-day TIIE futures contracts is the bank business day after Banco de Mexico holds the primary auction of government securities in the week corresponding to the third Wednesday of the Maturity Month. Since these primary auctions are usually held every Tuesday, in general expiration day for TIIE futures corresponds to the third Wednesday of every month.

3.2 Sample Data

The study considers daily TIIE spot and futures rates between January 2003 and December 2006. The spot rate, S_t is provided by the Central Bank. Figure 1 graphs the data over the studied period. For the 2003-2006 years the highest level was reached in March 2003, declining monotonically after that and until August 2003 when it reached the historic minimum (4.745%). A period of uncertainty started after September that year and it prevailed throughout the first half of 2004 where movements of almost 150 bps within very short periods (2 weeks) were present. A stable pattern is observed in 2005 until August when the rate declined again to settle between 7.0 and 7.5 percent during the second half of 2006.

Volatility patterns are assessed using logarithm changes. For the spot rate those are defined as

$$\Delta S_t = \ln(S_{t+1}/S_t) \tag{2}$$

Futures data includes daily settlement yields and trading volume data for all 28-day TIIE futures contracts with maturities between months mentioned above. These data were obtained from the Mexican Derivatives Exchange (MexDer). Since, for the majority of contracts, open interest is low and trading volume is thin in periods long before maturity, the sample used for each futures contract includes only the thirteen months preceding its expiration. The result is a data set of 12,624 observations corresponding to 48 TIIE futures contracts with 263 daily settlement rates each. Logarithmic rate changes for futures rates are defined as

$$\Delta Y_{T\,t} = \ln(Y_{T,\,t+1}/Y_{T,\,t}) \qquad (3)$$

where $Y_{T,\,t}$ denotes the settlement yield on calendar day t for the contract with maturity T. We will refer to these logarithmic rate changes $\Delta Y_{T\,t}$ simply as rate changes.

As for the expiration month itself, it will be excluded from the analysis, considering that trading volume decreases as the contract enters the expiration month inducing abnormal price variability. Hence, we have a set of 48 series of logarithmic rate changes, corresponding to contracts with expiration dates ranging from January 2003 to December 2006, and with 242 observations each.

Table 1 presents summary statistics for the rate changes $\Delta Y_{T\,t}$. Mean rate changes are predominantly negative with the exception of contracts that matured between September 2004 and October 2005. However, few of these mean estimates are significantly different from zero. Most contracts are leptokurtic (kurtosis greater than 3) and positively skewed, although these departures from normality tend to diminish for more recent contracts. Standard deviation also diminishes over time, with contracts expiring in 2006 being the less volatile. With the exception of contracts maturing in 2005, in all cases Bera-Jarque statistic rejects the hypothesis of normality. The table includes the results for the Engle (1982) LM-test for an autoregressive conditional heteroscedasticity (ARCH) effect. In most of the series, ARCH effects are not significant.

The basis at time t for a contract i with maturity in T will be measured by the log-basis, that is, by the difference between the futures log-rate and the spot log-rate,

$$B_{T\,t} = \ln Y_{T,\,t} - \ln S_t.$$

Figure 2 shows the average log basis for each contract in the sample. From the highest point in the graph for the contract that matured in May 2004, average log basis declined progressively until it became negative in contracts with expiration between November 2005 and September 2006. Furthermore Table 3 presents the monthly average log basis across contracts grouped by semesters according to their expiration date. For contracts that expired in the first semester of 2005 negative basis appeared 7 months before expiration. Negative basis are also present from 11 months before expiration in first semester of 2006 contracts and from 13 to 9 months before maturity in contracts of the second semester of 2006. This effect seems to be related with the declining patterns of the TIIE after the second half of 2005.

The log-basis change between t and $t+1$ is

$$\begin{aligned}\Delta B_{Tt} &= [\ln Y_{T,t+1} - \ln S_{t+1}] - [\ln Y_{T,t} - \ln S_t] \\ &= \Delta Y_{Tt} - \Delta S_t\end{aligned}$$

Table 2 presents summary statistics for the basis changes ΔB_{Tt} of each contract. Most of the means are negative and tend to increase over time, although none of them is statistically different from zero. For the majority of contracts basis changes are leptokurtic. Standard deviation of these changes diminish over time, with contracts expiring in 2006 having the less volatile basis. With the exception of two, in all cases Bera-Jarque statistic rejects the hypothesis of normality of the basis changes. The results for the LM-test show that, in most of the series, the hypothesis of no ARCH effects cannot be rejected.

With respect to trading volume, taking the 48 series that matures from January 2003 until June 2006, daily volume is tracked since the day the contract first appeared. Then the average traded volume across the 48 contracts and relatively to the days to expiration is obtained. Since 2005, contracts with maturity up to 10 years are available; however trading volume is almost negligible for contracts with expiration longer than 3 years. Figure 3 presents the number of contracts traded according to months before expiration. The results show that the traded volume increases monotonically as the contract approaches expiration. As in other futures market, contracts with the shortest maturity are far more liquid than contracts with maturities longer than three months. the plot indicates that the peak in trading volume is reached around four to ten weeks before expiration while in the last four weeks volume declines. This justifies the decision of considering for the analysis only the thirteen months previous to the expiration of the contract.

Finally, Figure 4 reports the number of TIIE futures contracts traded every month from January 2003 to December 2006. It is noticeable the significant drop in volume during 2005 as compared to previous years. This fact is explained by some tax issues that induced participants to switch their hedge positions to swaps traded over the counter.

4 Methodology

Different studies have employed different approaches to test Samuelson Hypothesis. Some studies calculate price variability as variances over daily price changes within a month, record the number of months left to maturity of the contract and then perform OLS regressions using these monthly variances, like in Milonas (1986) or Galloway and Kolb

(1996). In Bessembinder et al. (1996) daily volatility is estimated as the absolute value of future returns and regressions are performed on days to expiration, spot volatility and monthly indicators. Other studies build long term future series by rolling over contracts and apply different GARCH models with time to maturity as an exogenous variable.

In this study, the focus is on extending the usual OLS regressions by applying panel estimation techniques. Hence, from the 48 series of rate changes a panel data set is constructed by aligning the data by days to expiration instead of calendar day. This implies rearranging subindexes to express the cross-sectional and time dimensions.

Specifically, if the contracts are labelled with the variable i ($i = 1, ..., 48$), $T(i)$ is the maturity date defining the i-th contract, and $\tau = T(i) - t$ is the number of days to maturity, then all data can be defined in terms of the pair (i, τ) instead of the previous (T, t). For example, in terms of time to maturity, rate changes for contract i are expressed as

$$\Delta Y_{i\tau} = \ln(Y_{i,\tau}/Y_{i,\tau+1}) \tag{4}$$

Recall that the expiration month has been excluded from the analysis. Hence, the time variable τ ranges from the 20-th day before the contract expires ($\tau = 20$) to 262 days before expiration ($\tau = 262$).

For each futures series i there is a corresponding series of contemporaneous spot rates, which will be denoted $S_{i,t}$. To maintain coherence with the panel data structure, each of these series is subsequently aligned in terms of the days to maturity τ defined by contract i. Then, as with the future series, the study considers the logarithmic returns

$$\Delta S_{i\tau} = \ln(S_{i,\tau}/S_{i,\tau+1}) \tag{5}$$

where, for the i-th contract, $S_{i,\tau}$ is the value S_t of the TIIE spot rate on calendar day $t = T(i) - \tau$.

Finally, in terms of time to expiration, the basis for contract i at time t is

$$\Delta B_{i\tau} = \Delta Y_{i\tau} - \Delta S_{i\,\tau}. \tag{6}$$

As in Rutledge (1976) or Bessembinder et al. (1996), daily variability will be measured by the absolute value of the logarithmic rate changes. That is,

$$\sigma(Y)_{i\tau} = |\ln(Y_{i,\tau}/Y_{i,\tau+1})| \tag{7}$$

for the case of futures variability. Analogous expressions hold for spot changes volatility $\sigma(S)$ and basis changes volatility $\sigma(B)$.

The maturity effect will first be investigated by performing individual OLS regressions for each contract. This amounts to considering the unrestricted model,

$$\sigma(Y)_{i\tau} = \alpha_i + \beta_i \tau + u_{i\tau} \tag{8}$$

corresponding to linear regressions the futures volatility on time to expiration. The hypothesis is that if maturity effect is present, the coefficient β_i should be negative.

Next, imposing the restrictions

$$\alpha_i = \alpha, \qquad \beta_i = \beta \qquad \forall i = 1, ..., N$$

yields the restricted model

$$\sigma(Y)_{i\tau} = \alpha + \beta\tau + u_{i\tau} \tag{9}$$

After estimating coefficients, analysis of variance tests of the residuals will give information on the presence of individual effects, time effects or both. To perform a panel data analysis, the two-way error component regression model disturbances are decomposed as

$$u_{i\tau} = \mu_i + \lambda_\tau + \eta_{i\tau} \tag{10}$$

where μ_i denotes the unobservable individual effect, λ_τ the unobservable time effect, and $\eta_{i\tau}$ is the remainder stochastic disturbance term. λ_τ is individual invariant and accounts for any time specific effect that is not included in the regression.

In the last stage of the analysis, consists of panel regressions both with fixed and random effects. The fixed and random effects estimators are designed to handle the systematic tendency of $u_{i\tau}$ to be higher for some individuals that for others (individual effects) and possibly higher for some periods than for others (time effects). The fixed effects estimator does this by (in effect) using a separate intercept for each individual or time period. When considering a fixed-effects model, μ_i and λ_τ are treated as constants and are swept out. Under a random effects model, they are treated as part of the error term and β is estimated by GLS.

There are advantages and disadvantages to each treatment of the individual effects. A fixed effects model cannot estimate a coefficient on any time-invariant regressor since the individual intercepts are free to take any value. By contrast, the individual effect in a random effects model is part of the error term, so it must be uncorrelated with the regressors.

On the flip side, because the random effects model treats the individual effect as part of the error term, it suffers from the possibility of bias due to a correlation between it and regressors

In order to test for the effects of information flow, the above analysis is performed including spot volatility as a regressor. Finally, to test the hypothesis of decreasing volatility of the basis as maturity approaches, the same analysis is performed with basis volatility as dependent variable.

All the coefficient estimates were obtained using Rats v.5.0 software package.

5 Empirical Results

5.1 Estimates of time-to-maturity effects on volatility

Table 4 reports results of individual regressions of the daily volatility estimates on the number of days until the contract expires[1]. Estimated coefficients on the time to expiration variable are negative, as predicted by Samuelson hypothesis, but only for contracts that matured in 2003 and 2004. In 2005 all coefficients are positive and significant, contrary to Samuelson hypothesis. In 2006 all the coefficients are still positive, although only a few are significant. This particular behavior of contracts maturing in 2005 is also evident in the estimated mean coefficients. In contrast with all the other periods, in 2005 no mean coefficient is significantly different from zero.

The last two columns of Table 4 report the adjusted R^2 and the Durbin-Watson statistics. The adjusted R^2 values show the model has little explanatory power. On the other hand, Durbin-Watson test results indicate there is no significant first order autocorrelation of the residuals.

The results of the test for individual and time effects in volatility series are presented in Table 5. The first columns depict the results of the restricted model regression

$$\sigma(Y)_{i\tau} = \alpha + \beta\tau + u_{i\tau}$$

The estimated regression coefficients are negative and significant for contracts expiring in 2003 and 2004 but is positive and significant for contracts expiring in 2005 and 2006. Moreover, when the whole period is considered, β is not significantly different of zero. These results indicate a maturity effect was present but disappeared in contracts expiring from 2005 onwards. The analysis for the presence of individual effects, time effects or both shows the presence of individual effects in contracts expiring in 2005 and in the whole set of contracts.

Table 6 reports the results of panel regression of daily volatility on days to expiration. Estimation is done either by fixed effects or by random effects. The results support Samuleson hypothesis for contracts with expiration in 2003 and 2004. However, the results for contracts with expiration in 2005 and 2006 is against the hypothesis. In fact, for these contracts volatility appears to decrease as maturity approaches. When the whole set of contracts is considered, the β coefficient is not significant, indicating there is no evidence of relation between volatility and time to maturity.

[1]Similar regressions were performed considering, instead of days to maturity, the squared root of days to maturity. The results obtained are qualitatively the same.

5.2 Effect of controlling for variation in information flow

As mentioned earlier, recent studies on the Samuelson hypothesis suggest that increased volatility prior to a contract expiring is directly due to the rate of information flow into the futures market. The significance of information effects is therefore investigated by following the testing procedure used in Bessembinder et al. (1996) which involves including spot price variability as an independent variable in the regression outlined above. If spot price stationarity is the most significant determinant of the Samuelson hypothesis, the coefficient on the days to expiry variable should remain negative and significant despite the inclusion of the spot volatility variable.

Table 7 reports results of individual regressions of the daily volatility estimates on the number of days until the contract expires and on spot volatility. Compared with the results obtained previously, the inclusion of the spot volatility does not appear to have any significant effect. The TIIE spot volatility is only statistically significant in very few cases, showing in general, futures volatility is not being affected by spot volatility.

The last two columns of Table 7 report the adjusted R^2 and the Durbin-Watson statistics. The negative value of the adjusted R^2 values for some of the series reveal a poor fit. On the other hand, Durbin-Watson test results indicate there is no significant first order autocorrelation of the residuals.

When the spot volatility is introduced in the restricted regression as a control variable to account for the effects of information flow, the main change is that the maturity effect during the whole set of contracts becomes statistically significant, as we can see in Table 8. The first columns depict the results of the restricted model regression

$$\sigma(Y)_{i\tau} = \alpha + \beta\tau + \gamma\sigma(S)_\tau + u_{i\tau}$$

where $VS_{i\tau}$ is the spot rate volatility. Spot volatility is significant except in 2005 and 2006 contracts. The estimated β coefficients are negative and significant for 2003 and 2004 contracts and positive and significant for contracts expiring in 2005 and 2006. However for the whole set of contracts it appears to be negative.

These results indicate that, when we account for the information flow effects, the maturity effect is present during the whole period, although it is not observable in the last two years. The analysis for the presence of individual effects, time effects or both shows the presence of individual effects is qualitatively the same as obtained without the spot volatility as regressor. Table 9 reports the results of panel regression of daily volatility on days to expiration and spot volatility. Estimation is done either by fixed effects or by random effects. With the exception of 2006 contracts, the spot volatility appears to be significant. Again, 2005 seems to have a particular behavior, with the spot volatility coefficient being negative. As before, the results support Samuelson hypothesis for contracts with expiration in 2003 and 2004, while the results for contracts with expiration in

2005 and 2006 is against the hypothesis. In fact, for these contracts volatility appears to decrease as maturity approaches. However, when the whole set of contracts is considered, the β coefficient becomes significant at 5%, indicating that, when we consider the effects of information flow, there is evidence of relation between volatility and time to maturity.

5.3 Estimation of maturity effect on the basis.

Table 10 shows the results of the regression of the basis volatility on time to maturity. The coefficients β are positive and significant for contracts with expiration between September 2004 and March 2006, indicating that basis volatility decreased as maturity approached. This is in agreement with the results of Castelino and Francis (1982) or Beaulieu (1998). However, for the rest of the contracts the results show some evidence against this effect, either because β is negative and significant, not significant at all or with very poor fittings (negative $\bar{R}^2$).

Table **??** presents annual panel regressions for basis changes volatilities. Once again, 2003 coefficient for time to maturity is negative and significant, while coefficients are significant and positive from 2004 to 2006 and for the whole sample. Except for 2003, panel results indicate that as distance to maturity increases the volatility in the basis changes augment.

6 Conclusions

The growing importance of the Mexican derivatives market, now ranking among leading derivatives markets in the world, motivates a detailed examination of its behavior. Specifically, this study analyzes the volatility of TIIE futures contracts in relation with their maturity, i.e. the existence of maturity effect, and complements previous research using panel data techniques that permits the analysis across calendar time. In fact, descriptive statistics show that volatility has been consistently diminishing over time, indicating changes in return patterns and a possible reduction in information asymmetry in the Mexican futures markets.

Results show that the common maturity effect in TIIE futures was present until 2004. Unexpectedly, volatility seems to be decreasing as time to maturity decreases in contracts expiring in 2005 and 2006, contrary to Samuelson hypothesis. Considering the performance of the spot TIIE during the analyzed period results for 2005 and some of the 2006 contracts may be reasonable. Particularly, the volatility of the spot rate registered during 2004 should be reflected between 13 to 7 trading months before expiration in contracts maturing in 2005. The TIIE reached its highest value around May 2005 and it was more or less stable until August, when it started to decrease. That is why volatility in 2005 contracts is higher in dates distant from maturity and lower when they approached to expiration. Panel analysis delivers the same conclusions, maturity effects are present in 2003 and 2004, inverse maturity effect appears in 2005 and 2005, and it indicates that there is not evidence of maturity effect once all contracts are considered (2003-2006).

For individual series, results are qualitatively the same when the spot volatility is included as a proxy for information flow. In general, spot volatility does not explain futures volatility but only in 2005 contracts where there is an inverse relation. On the contrary, when panel data techniques are applied spot volatility explain futures volatility except for 2006 contracts and the maturity effect becomes statistically significant using the whole set of contracts That is, panel analysis show that if information flow is controlled, evidence about the relation between volatility and maturity appears and results are contrary to Anderson and Danthine (1983).

Finally, individual contract analysis of changes in the basis shows the expected maturity effect in contracts between September 2004 and March 2006, while panel analysis indicates an inverted effect in 2003 and the expected maturity effect in every year from 2004 and in the whole sample. In general it can be said that the volatility of the changes is decreasing as contracts approach to expiration.

The study of the behavior of volatility of futures prices near the maturity date has important implications for market participants, for derivatives pricing and for risk management. Hedging strategies that consider the effects of maturity normally outperform the strategies that do not. Clearinghouses set margin requirements on the basis of futures price volatility, in general, implying that the higher the volatility the higher the margin. Therefore, if there is any relation between volatility and time to maturity, the margin should be adjusted accordingly as the futures contract approaches its expiration date. Matching margins with price variability in an efficient way is the aim of an adequate margin policy. Although exchanges monitor price variability for different assets they do not usually consider differences among different contracts over the same underlying.

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Figure 1: TIIE spot rate during the period 2003-2006

Daily TIIE spot rate from January 2003 to December 2006.

Table 1: Descriptive statistics for TIIE futures contracts daily logarithmic changes

Contract	Mean	t-stat	Standard Deviaton	Skewness	Kurtosis	BJ	p-value	ARCH (LM)	p-value
Jan03	-0.2720	−0.86	0.3109	1.99	15.85	1824.63*	0.0000	2.59	0.7621
Feb03	-0.0052	−0.02	0.3210	1.86	15.50	1714.39*	0.0000	0.80	0.9770
Mar03	-0.0510	−0.16	0.3070	1.61	12.94	1100.25*	0.0000	0.74	0.9810
Apr03	-0.0216	−0.07	0.3114	0.95	10.02	532.22*	0.0000	2.89	0.7163
May03	-0.1014	−0.34	0.2929	1.34	13.86	1261.49*	0.0000	3.40	0.6379
June03	-0.2991	−1.02	0.2880	0.05	7.01	161.84*	0.0000	14.21*	0.0143
July03	-0.4714	−1.63	0.2839	0.44	6.96	165.52*	0.0000	13.61*	0.0183
Aug03	-0.5384	−1.87	0.2829	0.20	6.04	95.04*	0.0000	18.63*	0.0023
Sept03	-0.5568	−2.04*	0.2687	0.41	6.17	108.22*	0.0000	6.01	0.3054
Oct03	-0.7011	−3.12*	0.2212	0.32	4.03	14.91*	0.0006	3.53	0.6195
Nov03	-0.5935	−2.62*	0.2227	0.40	3.83	13.40*	0.0012	8.71	0.1212
Dec03	-0.6151	−2.58*	0.2345	0.36	4.15	18.65*	0.0001	2.69	0.7478
Jan04	-0.3708	−1.52	0.2399	1.00	8.47	342.19*	0.0000	2.74	0.7400
Feb04	-0.6025	−2.45*	0.2415	0.47	4.83	42.66*	0.0000	8.8	0.1173
Mar04	-0.5225	−2.08*	0.2472	0.39	5.15	52.82*	0.0000	11.25*	0.0467
Apr04	-0.3620	−1.39	0.2572	0.39	4.64	33.02*	0.0000	16.04*	0.0067
May04	-0.2959	−1.16	0.2514	0.12	3.72	5.83	0.0541	9.27	0.0986
June04	-0.0930	−0.37	0.2443	0.39	6.39	121.91*	0.0000	5.67	0.3400
July04	-0.0294	−0.13	0.2304	-0.02	5.42	59.08*	0.0000	18.35*	0.0025
Aug04	-0.0091	−0.04	0.2126	0.18	4.27	17.44*	0.0002	9.29	0.0981
Sept04	0.0337	0.16	0.2106	0.11	3.88	8.34*	0.0154	6.01	0.3056
Oct04	0.0916	0.43	0.2115	0.33	4.30	21.40*	0.0000	6.67	0.2462
Nov04	0.1948	0.91	0.2118	0.35	4.28	21.56*	0.0000	8.71	0.1211
Dec04	0.2563	1.29	0.1958	0.32	4.05	15.20*	0.0005	14.81*	0.0112
Jan05	0.2616	1.45	0.1772	0.25	4.13	15.32*	0.0005	12.99*	0.0235
Feb05	0.2416	1.38	0.1721	0.28	4.35	21.56*	0.0000	14.71*	0.0117
Mar05	0.3104	1.83	0.1673	0.29	4.27	19.70*	0.0001	12.39*	0.0298
Apr05	0.3393	2.04*	0.1634	0.34	4.44	25.42*	0.0000	16.58*	0.0054
May05	0.1717	1.16	0.1451	-0.17	3.31	2.17	0.3386	23.54*	0.0003
June05	0.1145	0.82	0.1372	-0.08	3.48	2.51	0.2849	27.35*	0.0000
July05	0.1426	1.21	0.1164	-0.03	3.24	0.62	0.7344	8.97	0.1103
Aug05	0.0732	0.68	0.1067	0.02	3.39	1.57	0.4563	4.32	0.5049
Sept05	0.0783	0.77	0.1003	0.07	3.67	4.76	0.0928	8.29	0.1410
Oct05	0.0376	0.39	0.0962	0.10	3.83	7.32*	0.0258	9.93	0.0771
Nov05	-0.0634	−0.66	0.0940	-0.11	3.84	7.48*	0.0237	9.58	0.0882
Dec05	-0.0734	−0.80	0.0906	-0.05	4.34	18.19*	0.0001	11.55*	0.0414
Jan06	-0.0687	−0.73	0.0924	0.00	4.03	10.70*	0.0047	3.99	0.5505
Feb06	-0.1602	−1.79	0.0880	0.09	3.93	9.03*	0.0110	4.13	0.5308
Mar06	-0.2365	−2.62*	0.0887	-0.11	4.04	11.32*	0.0035	5.70	0.3368
Apr06	-0.3270	−3.67*	0.0877	-0.27	4.15	16.29*	0.0003	8.43	0.1341
May06	-0.3231	−3.65*	0.0871	-0.38	4.57	30.55*	0.0000	3.07	0.6898
June06	-0.2917	−3.21*	0.0895	-0.30	4.25	19.40*	0.0001	5.74	0.3323
July06	-0.2496	−2.77*	0.0887	-0.15	4.36	19.64*	0.0001	6.25	0.2828
Aug06	-0.2722	−2.83*	0.0948	0.01	3.90	8.23*	0.0163	8.25	0.1432
Sept06	-0.2243	−2.37*	0.0931	0.24	4.42	22.56*	0.0000	10.10	0.0724
Oct06	-0.2221	−2.27*	0.0963	0.57	6.28	121.44*	0.0000	15.62*	0.0080
Nov06	-0.2058	−1.91	0.1060	0.36	6.40	121.75*	0.0000	21.59*	0.0006
Dec06	-0.1574	−1.42	0.1090	0.79	10.63	613.09*	0.0000	17.30*	0.0040

This table reports the statistics of the daily logarithmic changes of each of the futures contracts along 242 days before expiration month. BJ is the Bera-Jarque statistic for testing the null hypothesis of normal distribution. The ARCH-LM is the LM-statistic of autoregressive conditional heteroscedasticity effect with 5 lags. * indicates 5% significance.

Figure 2: Average log-basis

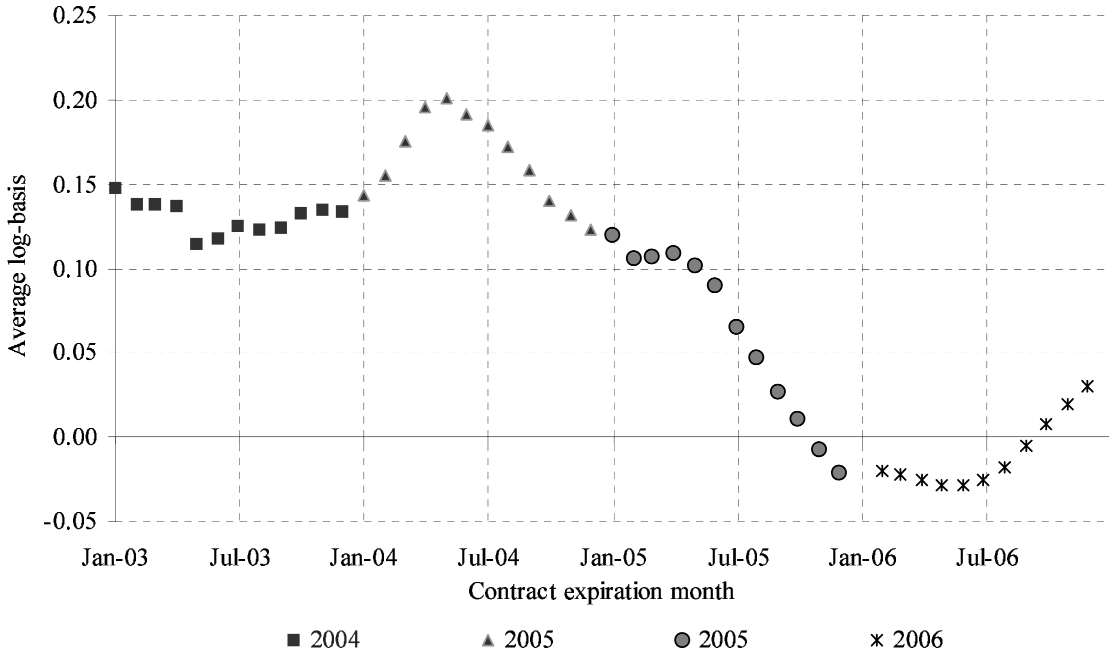
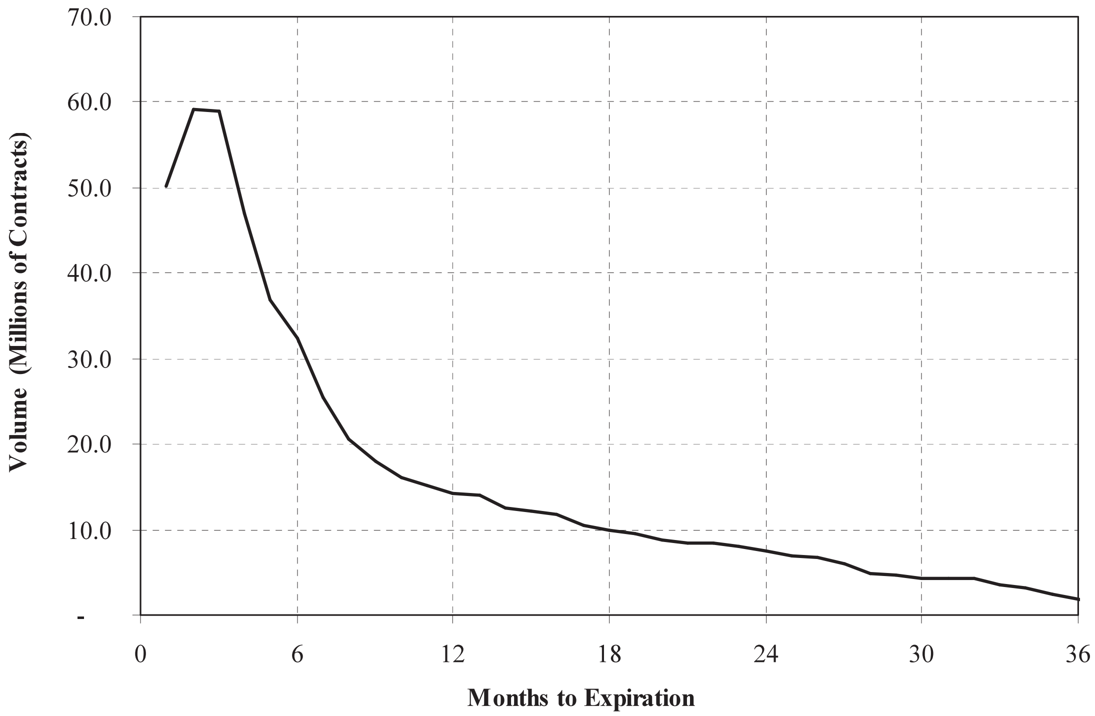
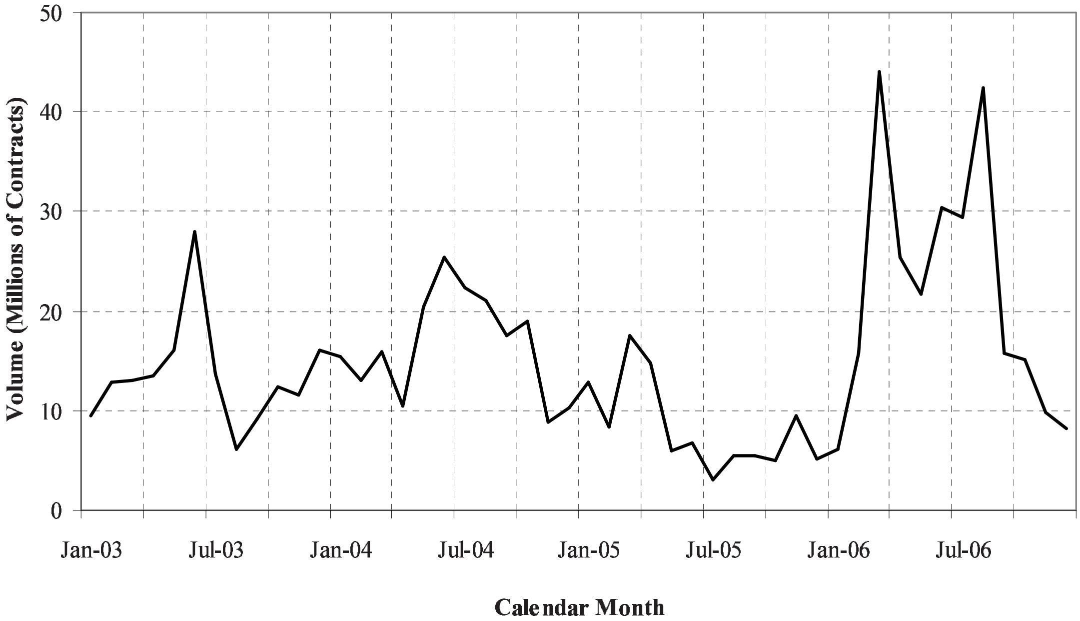


Figure 3: Number of TIIE Futures contracts traded per month relative to contract expiration



Numbers are millions of contracts traded during each month before the expiration date.

Figure 4: Volume of TIIE Futures contracts traded during the whole period



Numbers are millions of contracts traded monthly during the period.

Table 2: Descriptive statistics for daily basis changes

Contract	Mean	tstat	Standard Deviation	Skewness	Kurtosis	BJ	p-value	ARCH (LM)	p-value
Jan03	-0.3243	-0.65	0.4949	-0.11	8.33	286.50*	0.0000	34.68*	0.0000
Feb03	0.0175	0.04	0.4993	-0.24	8.65	324.53*	0.0000	32.53*	0.0000
Mar03	-0.1981	-0.40	0.4845	-0.04	7.94	246.00*	0.0000	30.75*	0.0000
Apr03	-0.3283	-0.69	0.4663	-0.28	8.12	267.68*	0.0000	36.03*	0.0000
May03	-0.2093	-0.46	0.4495	-0.30	10.45	563.42*	0.0000	42.69*	0.0000
June03	0.0011	0.00	0.4662	-0.71	8.49	324.00*	0.0000	18.32*	0.0026
July03	0.0475	0.10	0.4502	-1.03	7.60	256.04*	0.0000	14.95*	0.0106
Aug03	-0.0899	-0.19	0.4603	-0.77	5.79	102.73*	0.0000	14.77*	0.0114
Sept03	-0.0907	-0.20	0.4564	-0.75	5.84	103.48*	0.0000	12.39*	0.0298
Oct03	-0.0636	-0.15	0.4173	-0.69	5.12	64.21*	0.0000	15.85*	0.0073
Nov03	-0.2081	-0.49	0.4171	-0.66	4.56	42.01*	0.0000	17.62*	0.0035
Dec03	-0.1844	-0.43	0.4226	-0.72	4.88	56.40*	0.0000	17.01*	0.0045
Jan04	-0.0498	-0.12	0.4265	-0.59	4.22	28.92*	0.0000	9.26	0.0992
Feb04	0.0659	0.15	0.4237	-0.49	3.94	18.42*	0.0001	16.64*	0.0052
Mar04	0.0340	0.08	0.4396	-0.64	4.02	27.10*	0.0000	16.76*	0.0050
Apr04	-0.0090	-0.02	0.4632	-0.61	3.88	22.66*	0.0000	15.87*	0.0072
May04	-0.2548	-0.56	0.4510	-0.43	3.76	13.29*	0.0013	21.25*	0.0007
June04	-0.3877	-0.90	0.4253	-0.39	4.00	16.29*	0.0003	10.72	0.0572
July04	-0.2788	-0.71	0.3859	-0.32	3.68	8.74*	0.0127	10.44	0.0637
Aug04	-0.3407	-0.90	0.3726	-0.51	4.20	25.15*	0.0000	9.42	0.0934
Sept04	-0.3126	-0.84	0.3656	-0.50	4.14	23.05*	0.0000	10.12	0.0720
Oct04	-0.2403	-0.67	0.3533	-0.56	4.38	31.68*	0.0000	10.67	0.0582
Nov04	-0.3221	-0.93	0.3400	-0.57	4.58	38.30*	0.0000	14.07*	0.0152
Dec04	-0.0205	-0.06	0.3150	-0.55	5.35	67.91*	0.0000	17.58*	0.0035
Jan05	-0.3033	-1.02	0.2928	-0.69	6.02	110.97*	0.0000	22.07*	0.0005
Feb05	-0.2163	-0.80	0.2656	-0.58	6.73	153.79*	0.0000	29.23*	0.0000
Mar05	-0.1229	-0.50	0.2441	-0.39	7.39	200.36*	0.0000	58.42*	0.0000
Apr05	-0.1433	-0.61	0.2317	-0.40	8.71	334.68*	0.0000	69.86*	0.0000
May05	-0.1745	-0.90	0.1899	-0.13	3.19	1.06	0.5897	20.17*	0.0012
June05	-0.2499	-1.40	0.1757	-0.18	3.19	1.72	0.4226	26.15*	0.0001
July05	-0.2282	-1.48	0.1514	-0.40	3.34	7.56*	0.0228	13.69*	0.0177
Aug05	-0.2284	-1.62	0.1385	-0.47	3.73	14.07*	0.0009	34.14*	0.0000
Sept05	-0.1837	-1.41	0.1280	-0.58	4.43	34.10*	0.0000	41.56*	0.0000
Oct05	-0.1583	-1.29	0.1204	-0.56	4.98	52.04*	0.0000	49.96*	0.0000
Nov05	-0.1686	-1.40	0.1181	-0.56	5.06	55.36*	0.0000	56.20*	0.0000
Dec05	-0.0928	-0.82	0.1108	-0.34	4.85	39.13*	0.0000	39.80*	0.0000
Jan06	-0.0304	-0.27	0.1090	0.08	3.90	8.39*	0.0151	27.16*	0.0001
Feb06	-0.0505	-0.49	0.1004	0.27	3.71	8.11*	0.0174	12.27*	0.0312
Mar06	-0.0248	-0.23	0.1042	0.31	4.48	26.09*	0.0000	21.80*	0.0006
Apr06	-0.0524	-0.50	0.1038	0.28	4.78	34.93*	0.0000	16.68*	0.0052
May06	-0.0127	-0.12	0.1022	0.32	5.26	55.89*	0.0000	12.04*	0.0342
June06	0.0300	0.29	0.1037	0.19	4.79	33.87*	0.0000	17.09*	0.0043
July06	0.0718	0.69	0.1026	0.29	4.93	41.10*	0.0000	19.88*	0.0013
Aug06	0.0521	0.48	0.1069	0.30	4.35	21.94*	0.0000	12.07*	0.0338
Sept06	0.0752	0.70	0.1063	0.58	5.05	56.13*	0.0000	11.35*	0.0449
Oct06	0.0461	0.42	0.1072	0.74	6.00	112.70*	0.0000	12.14*	0.0329
Nov06	0.0404	0.34	0.1160	0.45	6.10	105.28*	0.0000	18.24*	0.0027
Dec06	0.0572	0.48	0.1176	0.80	9.10	401.23*	0.0000	18.16*	0.0028

This table reports the statistics of the daily basis changes along 242 days before expiration month. BJ is the Bera-Jarque statistic for testing the null hypothesis of normal distribution. The ARCH-LM is the LM-statistic of autoregressive conditional heteroscedasticity effect with 5 lags. * indicates 5% significance.

Table 3: Average log-basis by month to expiration

Months to Expiration	Contracts expiring in semester,							
	S1'2003	S2'2003	S1'2004	S2'2004	S1'2005	S2'2005	S1'2006	S2'2006
2	0.0258	0.1158	0.0228	0.0713	0.0063	-0.0235	-0.0132	0.0240
3	0.0305	0.1660	0.0430	0.0892	0.0146	-0.0278	-0.0223	0.0375
4	0.0608	0.1759	0.0904	0.0970	0.0227	-0.0256	-0.0303	0.0489
5	0.1005	0.1490	0.1511	0.0921	0.0403	-0.0172	-0.0410	0.0572
6	0.1442	0.0991	0.2064	0.0964	0.0694	-0.0116	-0.0478	0.0571
7	0.1691	0.0813	0.2497	0.1199	0.1048	-0.0031	-0.0471	0.0395
8	0.1770	0.0801	0.2831	0.1190	0.1427	0.0051	-0.0454	0.0162
9	0.1679	0.0635	0.3020	0.1409	0.1556	0.0234	-0.0387	-0.0031
10	0.1815	0.0953	0.2847	0.1720	0.1731	0.0384	-0.0267	-0.0171
11	0.1790	0.1378	0.2225	0.2352	0.1716	0.0567	-0.0091	-0.0329
12	0.1618	0.1761	0.1569	0.2770	0.1694	0.0924	0.0043	-0.0409
13	0.1835	0.2032	0.1118	0.3034	0.1916	0.1290	0.0152	-0.0379

Table 4: Regression of daily volatility on days to expiration

Contract (i)	α_i	t-stats	β_i	t-stats	$\bar{R}^2$	D-W
Jan03	0.01636	7.58*	-0.00003	−2.61*	0.014	1.73
Feb03	0.01725	8.40*	-0.00004	−3.08*	0.019	1.84
Mar03	0.01617	8.87*	-0.00003	−2.40*	0.011	1.89
Apr03	0.01497	7.96*	-0.00001	−1.29	0.001	1.92
May03	0.01200	7.38*	-0.00001	−0.51	-0.003	1.89
June03	0.01522	6.89*	-0.00002	−1.67	0.010	1.74
July03	0.01647	7.80*	-0.00003	−2.38*	0.022	1.69
Aug03	0.01760	8.99*	-0.00003	−2.94*	0.033	1.78
Sept03	0.01400	7.95*	-0.00001	−1.08	0.001	1.97
Oct03	0.01080	8.98*	0.00000	−0.08	-0.004	1.81
Nov03	0.01152	8.83*	0.00000	−0.59	-0.003	1.64
Dec03	0.01195	9.03*	-0.00001	−0.69	-0.002	1.83
Jan04	0.01400	7.39*	-0.00002	−2.04*	0.018	1.59
Feb04	0.01463	8.17*	-0.00003	−2.41*	0.023	1.75
Mar04	0.01531	8.72*	-0.00003	−2.71*	0.028	1.63
Apr04	0.01588	9.36*	-0.00003	−2.82*	0.027	1.53
May04	0.01362	8.96*	-0.00001	−1.29	0.002	1.68
June04	0.01451	8.18*	-0.00003	−2.38*	0.022	1.75
July04	0.01359	9.09*	-0.00002	−2.11*	0.018	1.62
Aug04	0.01352	10.11*	-0.00003	−3.28*	0.035	1.84
Sept04	0.01260	9.51*	-0.00002	−2.41*	0.018	1.92
Oct04	0.01038	8.40*	0.00000	−0.39	-0.004	1.82
Nov04	0.00828	7.29*	0.00001	1.63	0.005	1.99
Dec04	0.00751	7.72*	0.00001	1.99*	0.007	2.02
Jan05	0.00654	8.28*	0.00001	2.45*	0.012	2.01
Feb05	0.00512	6.67*	0.00002	3.48*	0.035	1.90
Mar05	0.00450	5.64*	0.00002	3.75*	0.054	2.01
Apr05	0.00256	3.11*	0.00004	5.29*	0.125	2.07
May05	0.00303	4.81*	0.00003	5.71*	0.117	2.17
June05	0.00240	4.05*	0.00003	5.99*	0.136	2.17
July05	0.00209	4.44*	0.00003	6.52*	0.129	2.12
Aug05	0.00240	5.44*	0.00002	5.24*	0.092	2.08
Sept05	0.00174	4.49*	0.00002	6.25*	0.117	1.93
Oct05	0.00145	3.18*	0.00002	5.73*	0.127	1.81
Nov05	0.00179	3.69*	0.00002	4.70*	0.089	1.87
Dec05	0.00184	3.73*	0.00002	4.19*	0.080	1.90
Jan06	0.00378	6.56*	0.00001	1.41	0.005	1.90
Feb06	0.00305	6.07*	0.00001	2.49*	0.021	1.90
Mar06	0.00299	5.73*	0.00001	2.62*	0.022	1.92
Apr06	0.00328	6.50*	0.00001	2.05*	0.013	1.93
May06	0.00363	6.94*	0.00000	1.16	0.002	1.97
June06	0.00368	6.64*	0.00000	1.24	0.002	1.81
July06	0.00386	7.12*	0.00000	0.67	-0.003	1.80
Aug06	0.00435	7.08*	0.00000	0.26	-0.004	1.77
Sept06	0.00364	6.32*	0.00000	1.32	0.002	1.68
Oct06	0.00353	5.72*	0.00001	1.37	0.002	1.62
Nov06	0.00429	6.95*	0.00000	0.87	-0.002	1.60
Dec06	0.00358	6.41*	0.00001	2.44*	0.009	1.65

The table reports the estimates of the regression model

$$\sigma(Y)_{i\tau} = \alpha_i + \beta_i \tau + \varepsilon_{i\tau}$$

where τ represents days to maturity. $\bar{R}^2$ is the adjusted R^2. DW is the Durbin-Watson test for first-order serial correlation of the residuals. There are 242 observations. * indicates significance at 5%. Estimation with Heteroscedasticity-consistent standard errors.

Table 5: Test for individual and time effects in futures volatility series

Year		Regression coefficients			Analysis of variance			Equality of variances	
		estimate	t-stat	p-value	Source	F-test	p-value	χ^2	p-value
2003	α	0.014500	26.42	0.0000	Individual	0.7458	0.6949	185.93	0.0000
	β	-0.000019	-5.35	0.0000	Time	0.8826	0.8967	(df=11)	
					Joint	0.8766	0.9132		
2004	α	0.012800	31.04	0.0000	Individual	1.7542	0.0566	71.57	0.0000
	β	-0.000015	-5.85	0.0000	Time	0.9520	0.6868	(df=11)	
					Joint	0.9870	0.5455		
2005	α	0.002955	12.56	0.3144	Individual	21.6631	0.0000	609.11	0.0000
	β	0.000023	15.28	0.0000	Time	0.9869	0.5443	(df=11)	
					Joint	1.8895	0.0000		
2006	α	0.003637	21.34	0.0000	Individual	0.5384	0.8782	71.58	0.0000
	β	0.000005	4.76	0.0000	Time	1.0488	0.2980	(df=11)	
					Joint	1.0265	0.3794		
All	α	0.008484	42.64	0.0000	Individual	31.953	0.0000	6430.03	0.0000
	β	-0.000002	-1.20	0.2313	Time	0.7779	0.9952	(df=47)	
					Joint	5.8655	0.0000		

This table reports the coefficients of the restricted regression

$$\sigma(Y)_{i\tau} = \alpha + \beta\tau + u_{i\tau}$$

where α and β are assumed to be constant across contracts and τ represents days to maturity. Analysis of variance is an analysis of variance test for common means, across individuals, across time, or both. The last two columns report the results of a likelihood ratio test for equal variances across cross-sections. *df* = degrees of freedom.

Table 6: Panel regression of daily volatility on time to expiration

Year	Regression coefficients				
		estimate	**t-stat**	**p-value**	$\bar{R}^2$
2003	Intercept	0.014500	27.08	0.00000	0.00727
	β	-0.000019	-5.35	0.00000	
	Panel Regression - Estimation by Random Effects				
2004	Intercept	0.012800	28.98	0.00000	0.01578
	β	-0.000015	-5.86	0.00000	
	Panel Regression - Estimation by Random Effects				
2005	Intercept	0.002955	5.77	0.00000	0.14452
	β	0.002955	15.87	0.00000	
	Panel Regression - Estimation by Fixed Effects				
2006	Intercept	0.003637	22.37	0.00000	0.00239
	β	0.000005	4.75	0.00000	
	Panel Regression - Estimation by Random Effects				
All	Intercept	0.008484	16.90	0.00000	0.11530
	β	-0.000002	-1.27	0.20404	
	Panel Regression - Estimation by Fixed Effects				

This table reports the coefficients of the panel regression over absolute returns

$$\sigma(Y)_{i\tau} = \alpha + \beta\tau + u_{i\tau}$$

where τ is the variable for days to maturity. The error component descomposes as $u_{i\tau} = \mu_i + \lambda_\tau + \eta_{i\tau}$, allowing for individual or time effects.

Table 7: Regression of daily volatility on days to expiration and spot volatility

Contract	α	t-stats	β	t-stats	γ	t-stats	$\bar{R}^2$	DW
Jan03	0.015655	7.32*	-0.000032	−2.71*	0.056243	0.91*	0.0148	1.778
Feb03	0.016236	7.89*	-0.000040	−3.50*	0.108008	1.68*	0.0297	1.932
Mar03	0.014954	7.82*	-0.000030	−2.85*	0.119048	1.72*	0.0266	1.998
Apr03	0.014357	6.94*	-0.000017	−1.46	0.057322	0.81	0.0007	1.976
May03	0.010627	5.45*	-0.000009	−0.90	0.136344	1.59	0.0141	2.033
June03	0.013193	5.70*	-0.000023	−1.72	0.130879	1.99	0.0349	1.929
July03	0.014004	5.31*	-0.000025	−1.78	0.105744	1.66	0.0336	1.816
Aug03	0.015863	6.35*	-0.000031	−2.39*	0.072071	1.20*	0.0370	1.865
Sept03	0.012400	5.52*	-0.000010	−0.81	0.074178	1.32	0.0077	2.055
Oct03	0.009167	5.95*	0.000003	0.38	0.072022	1.80	0.0036	1.868
Nov03	0.010914	6.83*	-0.000004	−0.45	0.028368	0.79	-0.0050	1.658
Dec03	0.010945	6.74*	-0.000005	−0.53	0.048332	1.17	-0.0017	1.868
Jan04	0.013356	6.96*	-0.000022	−2.02*	0.030458	0.66*	0.0161	1.610
Feb04	0.014505	8.03*	-0.000025	−2.41*	0.006559	0.17*	0.0191	1.751
Mar04	0.014779	8.50*	-0.000028	−2.72*	0.029454	0.73*	0.0259	1.664
Apr04	0.014596	8.45*	-0.000031	−3.04*	0.084387	1.84*	0.0373	1.628
May04	0.013152	8.45*	-0.000014	−1.45	0.040226	0.93	0.0014	1.716
June04	0.014311	7.74*	-0.000026	−2.37*	0.013954	0.28*	0.0187	1.760
July04	0.013400	9.10*	-0.000021	−2.05*	0.015833	0.34*	0.0142	1.624
Aug04	0.012597	9.11*	-0.000030	−3.74*	0.102748	2.05*	0.0526	1.934
Sept04	0.011968	8.68*	-0.000024	−3.06*	0.096045	2.16*	0.0327	1.994
Oct04	0.010237	8.11*	-0.000006	−0.77	0.042906	0.99	-0.0046	1.861
Nov04	0.008230	7.17*	0.000010	1.25	0.030395	0.64	0.0025	2.012
Dec04	0.007487	7.65*	0.000011	1.59	0.021118	0.43	0.0039	2.036
Jan05	0.006551	8.28*	0.000015	2.32*	-0.01412	−0.30*	0.0086	2.001
Feb05	0.005167	6.71*	0.000022	3.5*	-0.0339	−0.71*	0.0326	1.879
Mar05	0.004623	5.74*	0.000027	4.06*	-0.07455	−1.42*	0.0573	1.947
Apr05	0.002688	3.22*	0.000040	5.72*	-0.09213	−1.65*	0.1308	1.996
May05	0.003469	5.42*	0.000032	6.07*	-0.16581	−2.57*	0.1335	2.071
June05	0.002809	4.54*	0.000033	6.53*	-0.1733	−2.42*	0.1523	2.087
July05	0.002326	4.92*	0.000028	6.71*	-0.15774	−2.27*	0.1438	2.061
Aug05	0.002513	5.70*	0.000021	5.17*	-0.09868	−1.37*	0.0959	2.043
Sept05	0.001763	4.55*	0.000022	5.59*	-0.05191	−0.63*	0.1150	1.915
Oct05	0.001481	3.23*	0.000022	5.34*	-0.03118	−0.39*	0.1242	1.791
Nov05	0.001795	3.71*	0.000018	4.19*	-0.02017	−0.22*	0.0859	1.860
Dec05	0.001847	3.69*	0.000017	3.89*	-0.00844	−0.08*	0.0757	1.898
Jan06	0.003808	6.62*	0.000005	1.39	-0.0189	−0.24	0.0011	1.890
Feb06	0.002895	5.70*	0.000008	2.37*	0.080446	0.61*	0.0211	1.924
Mar06	0.002986	5.39*	0.000009	2.62*	0.001298	0.02*	0.0181	1.916
Apr06	0.003186	5.82*	0.000007	2.06*	0.034588	0.51*	0.0093	1.946
May06	0.003503	6.44*	0.000004	1.20	0.048664	0.74	-0.0013	1.994
June06	0.003437	5.88*	0.000005	1.33	0.095035	1.26	0.0032	1.816
July06	0.003868	6.89*	0.000002	0.67	-0.00539	−0.09	-0.0067	1.794
Aug06	0.004366	7.00*	0.000001	0.27	-0.01072	−0.14	-0.0080	1.766
Sept06	0.003651	6.33*	0.000005	1.32	-0.0159	−0.20	-0.0016	1.670
Oct06	0.003543	5.73*	0.000006	1.44	-0.03956	−0.47	-0.0010	1.613
Nov06	0.004282	6.96*	0.000003	0.92	-0.0227	−0.29	-0.0063	1.594
Dec06	0.003552	6.42*	0.000009	2.44*	-0.0372	−0.45*	0.0048	1.639

The table reports the estimates of the unrestricted regression model

$$\sigma(Y)_{i\tau} = \alpha_i + \beta_i \tau + \gamma_i\, \sigma(S)_{i\tau} + u_{i\tau}$$

where τ represents days to maturity and $\sigma(S)_{i\tau}$ is the spot volatility. $\bar{R}^2$ is the adjusted R^2. There are 242 observations. Expiration month is excluded. * indicates significance at 5%.

Table 8: Test for individual and time effects in futures volatility series with TIIE spot variance as control variable

Year	**Regression coefficients**				**Analysis of variance**			**Equality of variances**	
		estimate	t-stat	p-value	Source	F-test	p-value	χ^2	p-value
2003	α	0.013100	21.91	0.00000	Individual	0.8003	0.6400	182.48	0.0000
	β	-0.000018	-5.17	0.00000	Time	0.9299	0.7673		
	γ	0.081700	5.57	0.00000	Joint	0.9242	0.7912		
2004	α	0.012200	27.94	0.00000	Individual	1.1770	0.2974	67.13	0.0000
	β	-0.000017	-6.56	0.00000	Time	0.9513	0.6894		
	γ	0.057900	4.47	0.00001	Joint	0.9612	0.6542		
2005	α	0.002928	12.40	0.00000	Individual	20.3612	0.0000	597.19	0.0000
	β	0.000022	14.19	0.00000	Time	0.9885	0.5376		
	γ	0.021571	1.32	0.18805	Joint	1.8342	0.0000		
2006	α	0.003638	20.90	0.00000	Individual	0.5380	0.8786	71.57	0.0000
	β	0.000005	4.73	0.00000	Time	1.0488	0.2981		
	γ	-0.000466	-0.02	0.98541	Joint	1.0265	0.3795		
All	α	0.007230	36.10	0.00000	Individual	15.0028	0.0000	5590.21	0.0000
	β	-0.000004	-3.24	0.00118	Time	0.8311	0.9727		
	γ	0.164300	24.94	0.00000	Joint	3.1439	0.0000		

This table reports the coefficients of the restricted regression over the residuals of excess returns

$$\sigma(Y)_{i\tau} = \alpha + \beta\tau + \gamma\sigma(S)_{i\tau} + u_{i\tau}$$

where α and β are assumed to be constant across contracts, τ is the variable for days to maturity and $\sigma(S)_{i\tau}$ is spot volatility. Analysis of variance is an analysis of variance test for common means, across individuals, across time, or both. The last two columns report the results of a likelihood ratio test for equal variances across cross-sections.

Table 9: Panel regression of daily volatility on time to expiration and spot rate volatility

Year	Regression coefficients				
		Estimate	t-stat	p-value	$\bar{R}^2$
2003	α	0.013200	22.28	0.00000	0.01796
	β	-0.000018	-5.17	0.00000	
	γ	0.081500	5.56	0.00000	
	Panel Regression - Estimation by Random Effects				
2004	α	0.012200	27.37	0.00000	0.01938
	β	-0.000017	-6.55	0.00000	
	γ	0.056200	4.32	0.00002	
	Panel Regression - Estimation by Random Effects				
2005	α	0.000000			0.14555
	β	0.000025	16.31	0.00000	
	γ	-0.064700	-3.87	0.00011	
	Panel Regression - Estimation by Fixed Effects				
2006	α	0.003642	21.90	0.00000	0.00215
	β	0.000005	4.74	0.00000	
	γ	-0.003401	-0.13	0.89328	
	Panel Regression - Estimation by Random Effects				
All	α	0.000000			0.11707
	β	-0.000002	-2.05	0.04072	
	γ	0.061100	8.36	0.00000	
	Panel Regression - Estimation by Fixed Effects				

This table reports the estimated coefficients of the panel regression

$$\sigma(Y)_{i\tau} = \alpha + \beta\tau + \gamma\sigma(S)_{i\tau} + u_{i\tau}$$

where τ is the variable for time to maturity and $\sigma(S)_{i\tau}$ is the spot rate volatility.

Table 10: Regression of basis changes volatility on days to expiration

Contract	α	t-stats	β	t-stats	$\bar{R}^2$	DW
Jan03	0.01988	6.82*	0.00001	0.54	-0.003	1.49
Feb03	0.01949	6.84*	0.00001	0.54	-0.003	1.65
Mar03	0.01918	7.30*	0.00001	0.62	-0.003	1.56
Apr03	0.02052	8.10*	0.00000	−0.16	-0.004	1.53
May03	0.01503	6.59*	0.00002	1.25	0.002	1.52
June03	0.01976	5.56*	0.00000	−0.11	-0.004	1.53
July03	0.02606	7.81*	-0.00005	−2.27*	0.020	1.63
Aug03	0.02942	9.62*	-0.00006	−3.29*	0.041	1.67
Sept03	0.02500	8.26*	-0.00003	−1.61	0.008	1.72
Oct03	0.02451	10.08*	-0.00004	−2.66*	0.017	1.63
Nov03	0.02257	10.42*	-0.00002	−1.43	0.002	1.67
Dec03	0.02147	11.11*	-0.00001	−0.72	-0.003	1.57
Jan04	0.02349	10.34*	-0.00002	−1.19	0.001	1.66
Feb04	0.02095	9.56*	0.00000	−0.03	-0.004	1.68
Mar04	0.02210	8.79*	0.00000	−0.25	-0.004	1.97
Apr04	0.01984	7.44*	0.00002	1.06	0.001	2.05
May04	0.01467	5.86*	0.00005	2.90*	0.036	2.08
June04	0.01749	6.32*	0.00002	1.32	0.005	2.00
July04	0.01715	7.60*	0.00001	0.89	-0.001	2.04
Aug04	0.01602	7.87*	0.00001	0.94	-0.001	2.04
Sept04	0.01394	7.35*	0.00003	2.10*	0.010	1.97
Oct04	0.01071	6.76*	0.00004	3.76*	0.037	1.98
Nov04	0.00826	5.87*	0.00006	5.00*	0.069	2.03
Dec04	0.00711	5.43*	0.00005	4.73*	0.067	1.94
Jan05	0.00521	4.08*	0.00006	5.02*	0.095	2.05
Feb05	0.00558	4.74*	0.00005	4.36*	0.080	1.88
Mar05	0.00474	4.34*	0.00005	4.72*	0.098	1.73
Apr05	0.00320	2.70*	0.00005	4.90*	0.133	1.74
May05	0.00368	4.55*	0.00004	6.13*	0.143	1.78
June05	0.00285	4.05*	0.00004	7.02*	0.176	1.77
July05	0.00250	4.23*	0.00003	6.93*	0.156	1.82
Aug05	0.00214	4.08*	0.00003	7.10*	0.151	1.63
Sept05	0.00155	3.11*	0.00003	6.90*	0.158	1.57
Oct05	0.00178	3.14*	0.00003	5.65*	0.132	1.57
Nov05	0.00170	2.80*	0.00003	5.44*	0.133	1.50
Dec05	0.00156	2.55*	0.00003	5.29*	0.130	1.54
Jan06	0.00426	5.97*	0.00001	1.59	0.009	1.60
Feb06	0.00341	6.02*	0.00001	2.68*	0.024	1.71
Mar06	0.00361	5.43*	0.00001	2.14*	0.015	1.59
Apr06	0.00372	5.96*	0.00001	1.92	0.010	1.65
May06	0.00427	6.97*	0.00000	0.84	-0.002	1.72
June06	0.00421	6.73*	0.00000	0.98	-0.001	1.64
July06	0.00431	7.23*	0.00000	0.71	-0.002	1.64
Aug06	0.00451	6.91*	0.00000	0.64	-0.002	1.69
Sept06	0.00373	6.10*	0.00001	1.83	0.008	1.64
Oct06	0.00366	5.80*	0.00001	1.70	0.006	1.61
Nov06	0.00435	6.72*	0.00000	1.17	0.000	1.59
Dec06	0.00332	5.58*	0.00001	2.93*	0.019	1.58

The table reports the estimates of the unrestricted regression model

$$\sigma(B)_{i\tau} = \alpha_i + \beta_i \tau + u_{i\tau}$$

where τ represents days to maturity and $VB_{i\tau}$ is the basis volatility. $\bar{R}^2$ is the adjusted R^2. There are 242 observations. Expiration month is excluded. * indicates significance at 5%.

Table 11: Test for individual and time effects in basis changes volatility series.

Year	**Regression coefficients**				**Analysis of variance**			**Equality of variances**	
		Estimate	t-stat	p-value	Source	F-test	p-value	χ^2	p-value
2003	α	0.021900	25.30	0.000	Individual	0.361	0.971	66.5	0.000
	β	-0.000013	-2.35	0.019	Time	0.833	0.967	($df = 11$)	
					Joint	0.813	0.984		
2004	α	0.015977	23.46	0.000	Individual	6.509	0.000	127.8	0.000
	β	0.000023	5.22	0.000	Time	1.043	0.321	($df = 11$)	
					Joint	1.281	0.003		
2005	α	0.003041	9.01	0.000	Individual	34.490	0.000	1077.4	0.000
	β	0.000039	18.06	0.000	Time	0.988	0.541	($df = 11$)	
					Joint	2.450	0.000		
2006	α	0.003946	20.30	0.000	Individual	0.345	0.975	42.0	0.000
	β	0.000006	5.20	0.000	Time	0.956	0.671	($df = 11$)	
					Joint	0.929	0.774		
All	α	0.011218	34.61	0.000	Individual	59.694	0.000	9930.0	0.000
	β	0.000014	6.66	0.000	Time	0.826	0.976	($df = 47$)	
					Joint	10.433	0.000		

This table reports the coefficients of the restricted regression over the residuals of excess returns

$$\sigma(B)_{i\tau} = \alpha + \beta\tau + \gamma + u_{i\tau}$$

where α and β are assumed to be constant across contracts, τ is the variable for days to maturity and $\sigma(B)_{i\tau}$ is basis changes volatility. Analysis of variance is an analysis of variance test for common means, across individuals, across time, or both. The last two columns report the results of a likelihood ratio test for equal variances across cross-sections. df = degrees of freedom.

Table 12: Panel regression of basis changes volatility on time to expiration

Year	**Regression coefficients**				
		Estimate	t-stat	p-value	$\bar{R}^2$
2003	α	0.021900	27.03	0.00000	-0.00741
	β	-0.000013	-2.35	0.01886	
	Panel Regression - Estimation by Random Effects				
2004	α	0.015977	16.41	0.00000	0.03227
	β	0.000023	5.28	0.00000	
	Panel Regression - Estimation by Random Effects				
2005	α	0.003041	3.46	0.00054	0.20505
	β	0.003041	19.18	0.00000	
	Panel Regression - Estimation by Fixed Effects				
2006	α	0.003946	21.74	0.00000	-0.00070
	β	0.000006	5.19	0.00000	
	Panel Regression - Estimation by Random Effects				
All	α	0.011218	10.82	0.00000	0.19870
	β	0.000014	7.41	0.00000	
	Panel Regression - Estimation by Fixed Effects				

This table reports the estimated coefficients of the panel regression

$$\sigma(B)_{i\tau} = \alpha + \beta\tau + u_{i\tau}$$

where τ is the variable for time to maturity and τ is time to maturity.