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***ESTIMATING THE TERM STRUCTURE OF VOLATILITY
AND FIXED INCOME DERIVATIVE PRICING***

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Estimating the Term Structure of Volatility and Fixed Income Derivative Pricing*

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Abstract

Estimating the parameters of the instantaneous spot interest rate process is of crucial importance for pricing fixed income derivative securities. This paper presents an estimation for the parameters of the Gaussian interest rate model for pricing fixed income derivatives based on the term structure of volatility. We estimate the term structure of volatility for US treasury rates for the period 1983 - 1995, based on a history of yield curves. We estimate both conditional and first differences term structures of volatility and subsequently estimate the implied parameters of the Gaussian model with non-linear least squares estimation. Results for bond options illustrate the effects of differing parameters in pricing.

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1. Introduction

The accuracy of valuation and risk of fixed-income derivatives are very dependent on the quality of the parameters involved in the modelling of the underlying interest rate dynamics. One way for estimating these parameters is through the theoretical and observed term structure of volatility (TSV) of interest rates. The theoretical TSV is determined based on a term structure model that relates analytical zero coupon bond prices to time to maturity.

Several interest rate models have been developed in the last fifteen years: Vasicek (1977), Cox, Ingersoll and Ross (1985), Hull and White (1990), Jamshidian (1991), Heath, Jarrow and Morton (1992) and more recently Duffie and Kan (1995). Either by arbitrage methods or general equilibrium conditions, all these models derive valuation equations for zero coupon bonds, that is, the term structure of interest rates, and for derivative securities dependent upon these analytical term structures.

In this paper the theoretical TSV is from the Gaussian interest rate model. This model was developed independently by Hull and White (1990) and Jamshidian (1991) and is an extension of the Vasicek (1977) model. It is an arbitrage model, and is the most tractable analytically and very widely used in practical financial applications. For this model there is available in closed form an expression for the TSV that should hold under a condition of no arbitrage in a bond market. With this formula and an estimate of the TSV for US treasury rates, using Non-Linear Least-Squares (NLS), we estimate the parameters of the instantaneous spot rate, its volatility and mean reversion speed. We discuss how this can be accomplished without knowledge of the TSV itself, but by using an unbiased estimate of it. Our estimate of the TSV for US treasury rates is based on quarterly data from a history of yield curves from the 2nd quarter of 1983 to the 1st quarter of 1995.

We illustrate the effects on fixed income derivative pricing with an application of options on bonds using the estimated parameters from a conditional and first differences TSV.

Koenigsberg, Showers, Streit(1991) also study the TSV and its effects on bond option valuation. Their interest is more in "calibrating" a model to some TSV rather than estimating fundamental parameters out of an observable TSV to be used in an analytical model. In our approach, the TSV that the model will imply will match the observable TSV by construction. There will be no need for model calibration.

In principle, calibration methods simply choose fundamental parameters setting them

to some pre-specified value. In this sense, the variance of these "estimates" is zero. This may be sub-optimal, since usually their mean-squared error is very high due to a large bias term. Estimation methods, on the other hand, may be chosen so that mean-squared error itself is minimized. Thus, unless one is certain to pick the right parameter values in calibration methods, estimation methods should be preferred, since the loss in bias may outweigh the reduction in variance for the former.

There is an additional reason to consider estimation instead of calibration. In some instances, the latter may be unfeasible. For example, the parameters of a newly created derivative security cannot be determined by calibration, since there are no similar securities traded in that market. This will be particularly important for emerging market derivatives.

Amin and Morton (1993) estimate implied volatility functions and parameters for several interest rate models based on Eurodollar futures and futures options. Therefore, their approach is also one of calibrating constant parameters of a model to what current options prices imply rather than estimating these constant parameters from historical data that will be optimal in some statistical sense. The derivative prices given by Amin and Morton (1993) parameters will price well over short horizons and specific securities and not over any derivative that have as underlying the bond market in question. Backus, Foresi and Zin (1994) presents an analysis and critique of calibrating interest rate models parameters. They show that arbitrage opportunities may occur leading to mispricing of derivatives.

Aït-Sahalia (1995) presents a testing procedure based on nonparametric methods for the specification of the parameters, drift and volatility, of the instantaneous spot interest rate. He rejects most specifications for the short rate including the Gaussian case. The specification for the instantaneous rate that passes his test is a quite general parametric specification but no analytical results are yet available for zero coupon bonds and derivatives pricing. Thus, it is yet to be studied the effects on pricing that his model will imply.

The paper is organized as follows. Section 2 presents the estimation of the TSV based on a history of US treasuries yield curves, for the unconditional, conditional and first difference cases. Section 3 presents the Gaussian model results and the NLS estimation procedure and estimates for the parameters, mean reversion speed and volatility, of the instantaneous interest rate process. Section 4 presents derivative pricing based on the estimated parameters and parameter values available in the literature. Section 5 concludes the paper.

2. Term Structure of Volatility

We estimate two TSVs : the conditional and the unconditional. Usually the conditional TSV is estimated by computing the variance of the first difference of spot interest rates that define the term structure. However, we can also compute the conditional variance directly exploiting the dependency that exist in a history of yield curves.

This is because one of the basic properties of economic and financial time series is dependence, i.e., current data depend on the sigma-field generated by their past observations. In economics and finance there is a long tradition of using this property in either univariate or multivariate time-series models, e.g., AutoRegressive Integrated Moving Average (ARIMA) models and Vector AutoRegression (VAR) models for the conditional mean and Generalized AutoRegressive Conditional Heteroskedasticity (GARCH) models for the conditional variance.

We will make use of these methodologies for estimating the conditional TSV. The reason for this widespread use of “conditional models” is the belief that, by conditioning on a relevant information set, agents can estimate parameters of interest as well as forecast future events more precisely. This general principle applies to Π -order Markov processes, where only a subset of the sigma-field generated by the past is needed to forecast the future. Of utmost importance is the forecasting improvement that conditional models deliver. To illustrate this point, we use here the simplest example possible, that of a weakly-stationary AR(1) process, Y_t :

$$Y_t = \rho Y_{t-1} + e_t \quad (1)$$

where $|\rho| < 1$ and e_t is white noise. The conditional expectation of Y_{t+k} , denoted $E(Y_{t+k} | I_t)$, is given by $\rho^k Y_t$. Thus, the conditional forecast error is:

$$f_t^k = Y_t - E(Y_{t+k} | I_t) = e_{t+k} + \rho e_{t+k-1} + \dots + \rho^{k-1} e_{t+1} \quad (2)$$

And, its mean-squared-error is simply:

$$(1 + \rho^2 + \dots + \rho^{2(k-1)})\sigma_E^2 = \frac{\sigma_E^2(1 - \rho^{2k})}{(1 - \rho^2)} \quad (3)$$

The unconditional mean-squared-error of forecasting Y_t , is its own unconditional second moment, given by $\frac{\sigma_E^2}{(1-\rho^2)}$. Notice that, by using the conditional model, the forecast error is reduced, since $(1 - \rho^{2k}) < 1$ for k finite. Thus, on average, using the conditional model allows for a reduction of the forecast error.

GARCH models, introduced by Bollerslev(1986) as an extension of Engle(1982), represent another class of models for which there is a decrease in the variance forecast error by conditioning on the past. To illustrate this result, consider $\Delta X_t = u_t$, where $u_t | I_{t-1} \sim N(0, h_t)$, and:

$$h_t = \alpha_0 + \alpha_1 u_{t-1} + \beta h_{t-1} \quad (4)$$

i.e., ΔX_t is a GARCH(1,1) process, where we impose $\alpha_1 + \beta < 1$. Using the Law of Iterated Expectations, it can be shown that:

$$E(h_{t+k} | I_{t-1}) = \frac{\alpha_0}{(1 - \alpha_1 - \beta)} (1 - (\alpha_1 + \beta)^k) + h_t (\alpha_1 + \beta)^k \quad (5)$$

thus, as k increases, the conditional expectation converges to the unconditional expectation of ΔX_t , given by $\frac{\alpha_0}{(1-\alpha_1-\beta)}$.

We estimate the TSV from a history of US yield curves available at the Bloomberg Financial Markets. The data set, based on quarterly observations, covers the period from the 2nd quarter of 1983 to the 1st quarter of 1995. The interest rates used are the continuously compounded spot rates for the following maturities: 6 months, 1 year, 2 years, 3 years, 5 years, 10 years and 30 years. The frequency of observation was chosen to be quarterly since our interest is on the estimation of constant parameters. Figure 1 presents a plot of these rates.

Three TSV are estimated. For the conditional, which is estimated with a VAR model, unconditional and first differences case. Table 1 below presents the estimated values.

Table 1: Annual Spot Interest Rate Volatility in %

Maturity, Years	Conditional	Unconditional	First Differences
0.5	1.37	4.18	1.43
1.0	1.54	4.28	1.55
2.0	1.50	4.16	1.48
3.0	1.49	4.05	1.47
5.0	1.44	3.98	1.41
10.0	1.35	3.80	1.32
30.0	1.24	3.19	1.24

The unconditional values are shown here for illustration purposes. We will use the theoretical conditional TSV of the Gaussian model for parameter estimation.

3. The Gaussian Model and Parameter Estimation

Below some major steps and results of the Gaussian interest rate model are presented. For the complete derivation reference is made to Vasicek (1977), Hull and White (1990) and Jamshidian (1991).

In the Gaussian interest rate model the dynamics of the instantaneous spot rate is given by the stochastic differential equation:

$$dr = (\theta(t) - ar)dt + \sigma dZ \quad (6)$$

Where r is the instantaneous spot interest rate, $\theta(t)$ is a time dependent long term rate, that is, the mean rate that the instantaneous rate is converging to, a is the speed of mean reversion, σ the volatility parameter and dZ is a Brownian motion. The last two parameters are the objective of our estimation.

From a non-arbitrage condition for bonds with distinct maturities, theoretical zero coupon bond prices at time t maturing at time T ($t \leq T$), are derived as:

$$P(t, T) = A(t, T)e^{-B(t, T)r} \quad (7)$$

Where:

$$B(t, T) = \frac{1 - e^{-a(T-t)}}{a} \quad (8)$$

$$\text{Log } A(t, T) = \text{Log} \frac{P(0, T)}{P(0, t)} - B(t, T) \frac{\partial \text{Log } P(0, t)}{\partial t} - \frac{1}{4a^3} \sigma^2 (e^{-aT} - e^{-at})^2 (e^{2at} - 1) \quad (9)$$

The price at time t of a call option maturing at time T on a pure discount bond maturing at time s ($t \leq T \leq s$) is given by:

$$P(t, s)N(h) - XP(t, T)N(h - \sigma_P) \quad (10)$$

And the respective put option price:

$$XP(t, T)N(-h + \sigma_P) - P(t, s)N(-h) \quad (11)$$

Where:

$N(.)$: Cumulative normal distribution.

$$\sigma_P = \nu(t, T)B(T, s) \quad (12)$$

$$h = \frac{1}{\sigma_P} \log \frac{P(t, s)}{P(t, T)X} + \frac{\sigma_P}{2} \quad (13)$$

$$\nu(t, T)^2 = \frac{\sigma^2(1 - e^{-2a(T-t)})}{2a} \quad (14)$$

The conditional volatility at time t , for a bond maturing at time T :

$$\sigma_B(t, T) = \frac{\sigma}{a}(1 - e^{-a(T-t)}) \quad (15)$$

And the conditional volatility of a spot rate at time t maturing at time T :

$$\sigma_s(t, T) = \frac{\sigma}{a(T-t)}(1 - e^{-a(T-t)}) \quad (16)$$

Estimation of the speed of mean reversion a and the short rate volatility σ of the instantaneous rate given by (6) can be performed using NLS. We start by assuming that the TSV can be written as:

$$TSV(t, T) = f(a, \sigma, (T-t)) + u_{(T-t)} \quad (17)$$

Where $f(a, \sigma, (T-t))$ is the conditional theoretical TSV for spot rates given by (16) above and $u_{(T-t)}$ represents an i.i.d. measurement error, which can assume different values depending on the spot rate with time to maturity $(T-t)$. If $u_{(T-t)}$ is i.i.d., a and σ could be estimated directly from (1) by NLS. However, we do not observe $TSV(t, T)$, but we can construct an unbiased estimator for it as follows:

$$TSV(t, T) = \widehat{TSV}(t, T) + v_{(T-t)} \quad (18)$$

Where $v_{(T-t)}$ is a zero mean error, uncorrelated with $(T-t)$ and $\widehat{TSV}(t, T)$ is an unbiased estimate of $TSV(t, T)$. Combining (17) and (18), we can write:

$$\widehat{TSV}(t, T) = f(a, \sigma, T-t) + u_{(T-t)} - v_{(T-t)} \quad (19)$$

From (19) we can finally estimate a and σ using NLS, since $u_{(T-t)} - v_{(T-t)}$ are uncorrelated with $(T-t)$. These estimates will be consistent if (17) is the true Data Generating Process for TSV. Moreover, with enough restrictions on $u_{(T-t)} - v_{(T-t)}$, they will also be the Maximum Likelihood (ML) estimates of a and σ , with all the desirable properties of the ML class of estimators.

A crucial step on the estimation procedure is obtaining unbiased estimates of $TSV(t, T)$. This can be accomplished in several ways, but we opted to do it using a VAR, where spot rates for different maturities are stacked into a vector (X_t) , which has its dynamics explained by a truncation of its own past plus a vector white noise measurement error; see Sims(1980). Under this framework, the conditional variance of X_t is given by the unconditional variance of the measurement error. Its unbiased estimate, which is corrected for degrees of freedom, is readily available in standard econometric software.

Table 2 below presents the estimated results.

Table 2: N L S Parameter Estimation

Conditional TSV	First Differences TSV
$a=0.0125$	$a=0.0139$
$\sigma=0.0148$	$\sigma=0.0148$
t-stat $a=3.08$	t-stat $a=3.99$
t-stat $\sigma=48.27$	t-stat $\sigma=57.48$
Adj. $R^2=0.63$	Adj. $R^2=0.75$

Both sets of parameters are statistically significant with good adjusted R^2 values. Figures 2 and 3 present plots of the estimated and theoretical Gaussian TSV for the conditional and first difference parameter estimation, respectively.

Hull (1993) (page 407) uses the values of $\sigma=0.014$ and $a=0.1$ as parameters for the Gaussian model. However, he does not specify how these parameters were estimated¹. His volatility parameter is close to ours but the speed of mean reversion is about ten times greater. Next section we show the effects on derivative prices that these parameters generate.

4. Effects on Derivative Pricing

We apply the above parameters in the pricing of at-the-money European options on pure discount bonds given above for the Gaussian model (equations (10) and (11)). We consider 1 year, 2 years and 3 years options on 10 and 20 years pure discount bonds for August 16, 1995.

The pure discount bonds prices are computed with the US term structure model developed by Duarte and Werlang (1995). Spot interest rates and bond prices are given at table 3 below.

¹Apparently, similar numbers are use in practical financial applications.

Table 3: Spot Interest Rates and Bond Prices for US Market

Maturity in years	Spot Interest Rate in %/year (semi-annual compounded)	Bond Price in US\$ (par=100)
1	5.80	94.443
2	6.05	88.762
3	6.26	83.117
10	6.66	51.936
20	7.27	23.974

Below option prices are computed using the conditional, first differences and Hull (1993) parameters. Substantial differences, ranging from 5 to 580 %, in call and put option prices and ranging from 40 to 110 % in underlying bond volatility are observed between ours and Hull's parameter values. Notice that the main reason for these observed differences is the estimate of the mean-reversion coefficient a . Ours is about a tenth of Hull's, although volatility estimates are very similar.

Call and put options prices are given at table 4 below.

Table 4: Bond Option Prices², US\$

Bond Option Call or Put	Conditional $a=0.0125,$ $\sigma=0.0148$	First Differences $a=0.0139,$ $\sigma=0.0148$	Hull (1993) $a=0.1,$ $\sigma=0.014$	Difference Conditional-Hull in %
1C10B	4.225	4.210	3.436	22.96
2C10B	6.836	6.821	6.107	11.94
3C10B	9.322	9.310	8.851	5.32
1P10B	1.337	1.322	0.548	143.98
2P10B	0.998	0.983	0.269	271.00
3P10B	0.553	0.541	0.081	582.72
1C20B	3.036	3.006	1.851	64.02
2C20B	4.531	4.495	3.105	45.93
3C20B	5.753	5.714	4.317	33.26
1P20B	1.703	1.674	0.518	228.76
2P20B	1.837	1.800	0.411	346.96
3P20B	1.706	1.667	0.270	531.85

²The notation is: first digit, time to maturity of the option in years; first letter, whether call C or put P; next two digits, maturity of bond; last letter B, means bond. Thus "1C10B" means: 1 year call option on a 10 years bond.

The underlying bonds theoretical volatility are given in table 5 below.

Table 5: Underlying Bond Volatility Annual %

Bond Volatility for $P(t,T)$	Conditional $a=0.0125,$ $\sigma=0.0148$	First Differences $a=0.0139,$ $\sigma=0.0148$	Hull (1993) $a=0.1,$ $\sigma=0.014$	Difference Conditional-Hull in %
$\sigma_B(1, 10)$	12.614	12.536	8.308	51.83
$\sigma_B(2, 10)$	11.281	11.219	7.709	46.34
$\sigma_B(3, 10)$	9.932	9.884	7.048	40.92
$\sigma_B(1, 20)$	25.062	24.749	11.906	110.50
$\sigma_B(2, 20)$	23.886	23.603	11.686	104.40
$\sigma_B(3, 20)$	22.695	22.440	11.442	98.35

5. Concluding Remarks

Most of the literature in applied finance uses calibration as an intermediate step for derivative pricing. These methods have well-known shortcomings. First, they are likely to be sub-optimal in the mean-squared error sense due to a large bias term. Second, they may be unfeasible, since it requires the existence of a liquid market for similar securities. The latter is especially the case in emerging markets.

Using the Gaussian interest rate model with estimated parameters, we illustrate the fact that derivative security prices are greatly dependent on underlying model parameters values. NLS estimates for the interest rate model are obtained from the conditional observed and theoretical term structure of volatility. They are unbiased, and the resulting theoretical TSV will match, by construction, the observed TSV for the US treasury bond market. This is of particular importance for market makers when pricing novel over-the-counter fixed income derivatives since there will be no traded security in the “neighborhood” (in effect, the market maker is “completing the market”) for “calibrating” the model.

Estimates are given for parameters implied by conditional and first differences variances. They are very similar in value and no substantial price differences in call and put options

on bonds are observed. However, when comparing to parameters known in the literature, substantial differences in option prices and underlying bond volatility are found. This illustrates how critical interest rate parameters estimation is for pricing.

In future research we will estimate TSVs with higher frequency data; monthly and weekly and the respective Gaussian parameters values. The possibility of applying GARCH models will also be considered.

6. References

1. Aït-Sahalia, Yacine (1995), "Testing Continuous-Time Models of the Spot Interest Rate". Working paper, Graduate School of Business, The University of Chicago, June.
2. Amin, Kaushik I. and Andrew J. Morton (1993), "Implied Volatility Functions in Arbitrage Free Term Structure Models". Working paper, School of Business Administration, The University of Michigan, April.
3. Backus, David K., Silverio Foresi and Stanley E. Zin (1994), "Arbitrage Opportunities in Arbitrage-Free Models of Bond Pricing". Working paper, Stern School of Business, New York University, October.
4. Bollerslev, Tim (1986), "Generalized Autoregressive Conditional Heteroskedasticity". *Journal of Econometrics* 31.
5. Duarte Júnior, Antonio Marcos and Sérgio Ribeiro da Costa Werlang (1995), "A Model to Estimate the U.S. Term Structure of Interest Rates". Working paper, Banco da Bahia Investimentos, August.
6. Engle, Robert (1982), "Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of U.K. Inflation". *Econometrica* 50.
7. Duffie, Darrell and Rui Kan (1995), "A Yield-Factor Model of Interest Rates". Working paper, Graduate School of Business, Stanford University, January.

8. Heath, David, Robert Jarrow and Andrew Morton (1992), "Bond Pricing and the Term Structure of Interest Rates: A New Methodology for Contingent Claims Valuation", *Econometrica* 60.
9. Hull, John C. and Alan White (1990), "Pricing Interest Rate Derivative Securities". *Review of Financial Studies* Vol. 3, n. 4.
10. Hull, John C. (1993), *Options, Futures, and other Derivative Securities*, 2nd. Edition. Prentice-Hall.
11. Jamshidian, Farshid (1991), "Bond and Option Evaluation in the Gaussian Interest Rate Model and Implementation " *Research in Finance* 9.
12. Koenigsberg, Mark, Janet Showers and James Streit (1991), "The Term Structure of Volatility and Bond Option Valuation". *Journal of Fixed Income*, September.
13. Sims, C. A. (1980), "Macroeconomics and Reality". *Econometrica* 48.
14. Vasicek, Oldrich (1977), "An Equilibrium Characterization of the Term Structure". *Journal of Financial Economics* 5.

Figure 1

Quarterly US Interest Rates 1983 - 1995

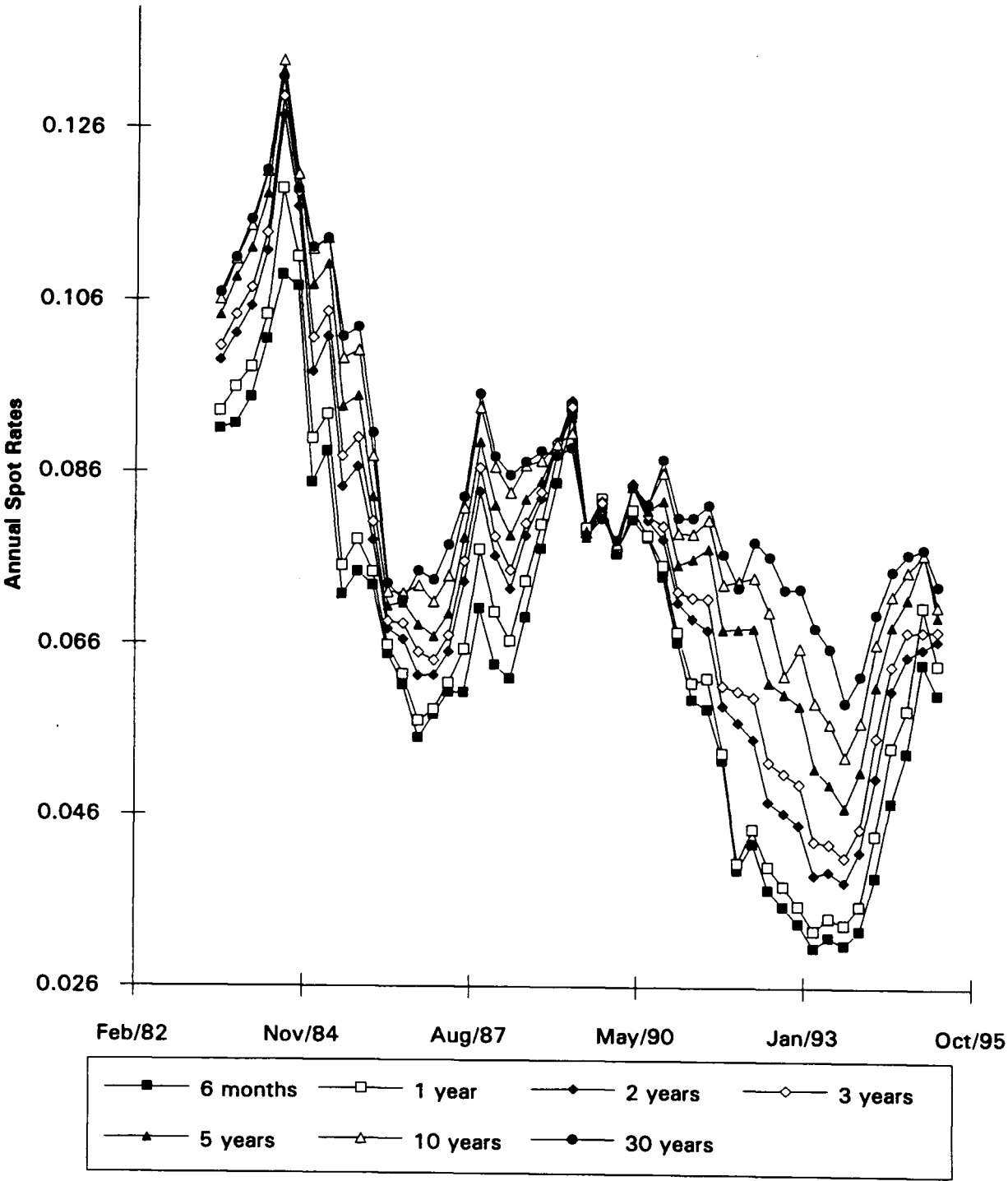


Figure 2

Term Structure of Conditional Volatilities U.S. Treasury Rates

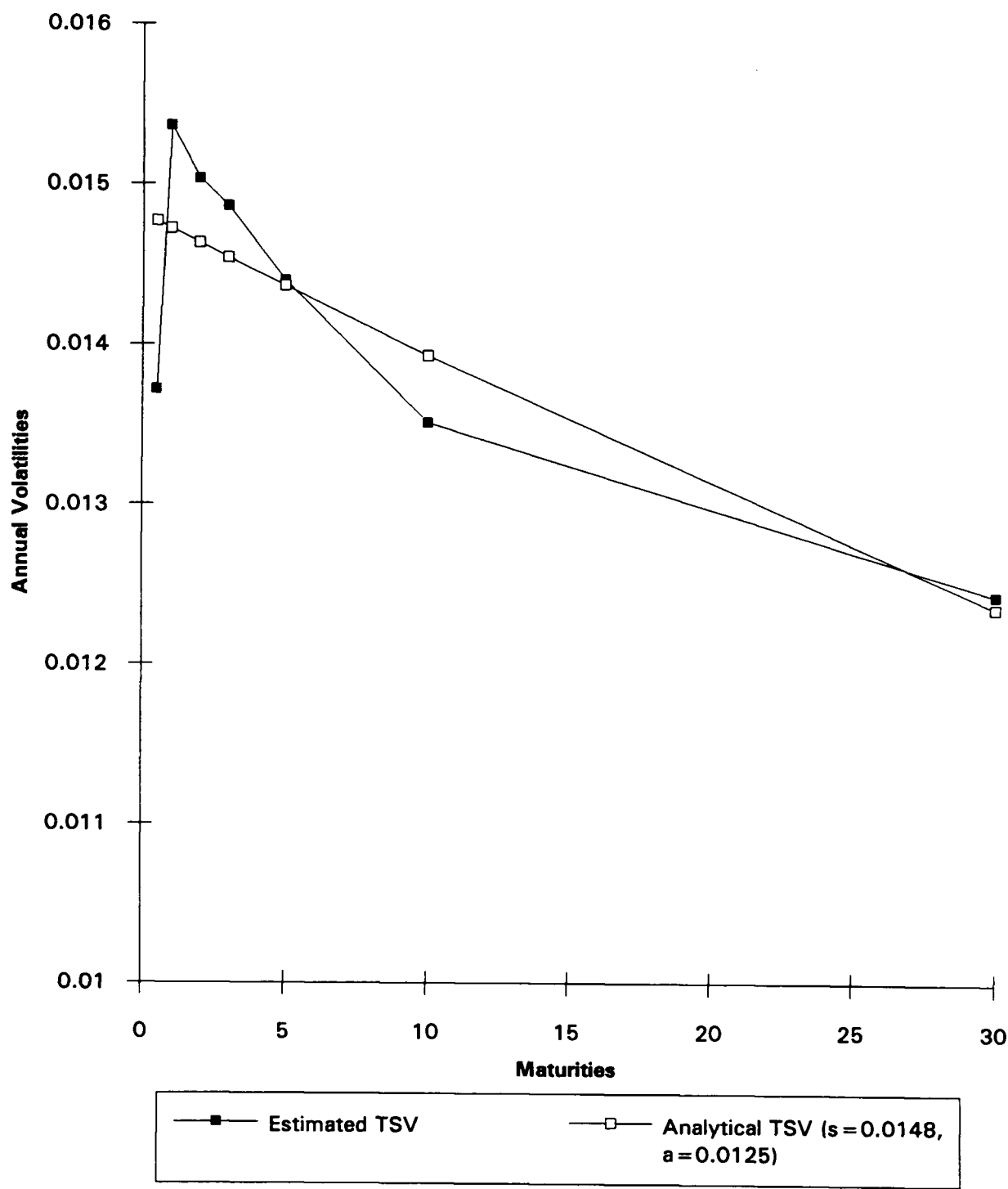
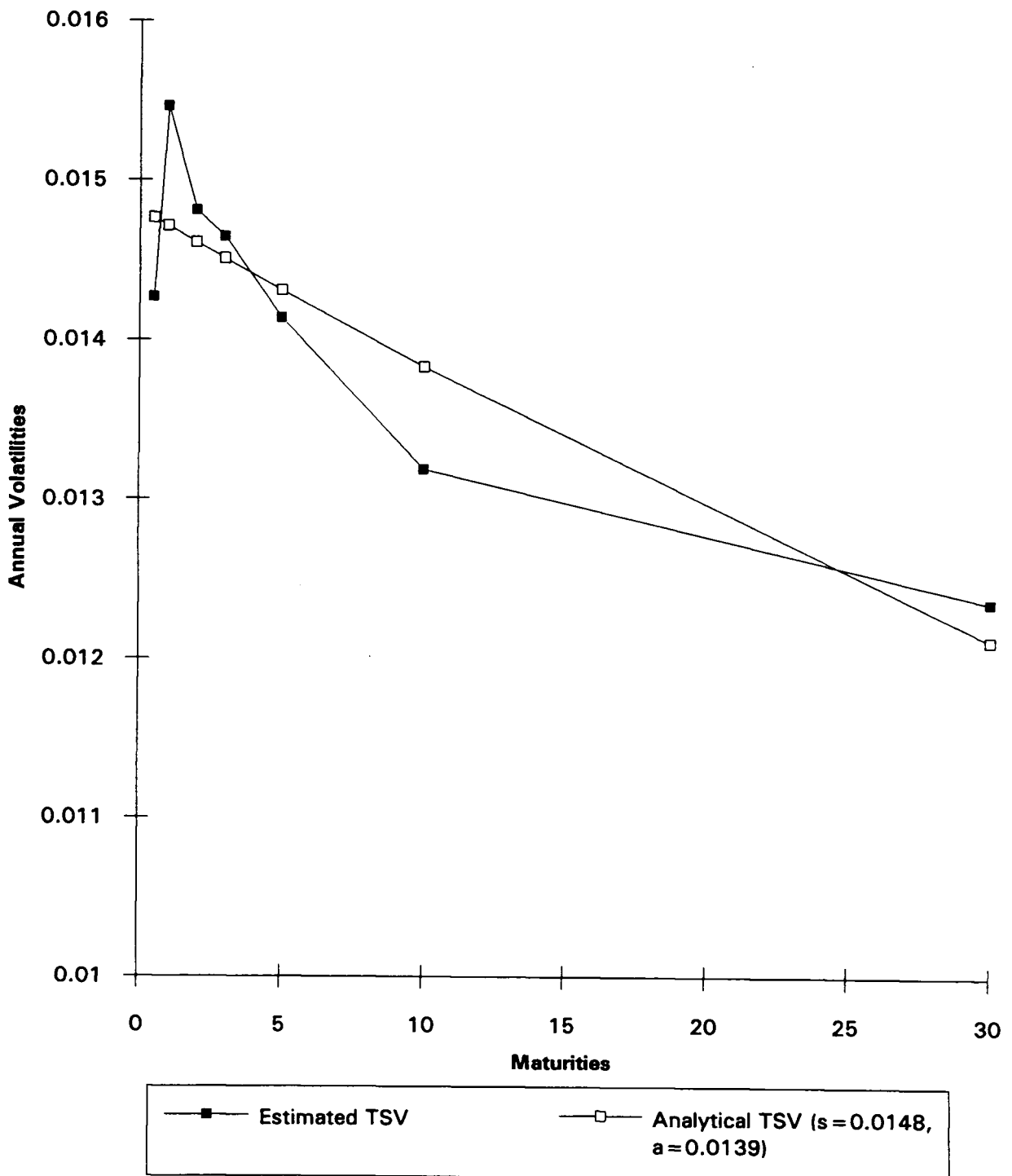


Figure 3

Term Structure of Volatilities U.S. T Rates (First Diff.)



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