The Slope of the U.S. Nominal Treasury Yield Curve and the Exchange Rate

Matiur Rahman* and Muhammad Mustafa**

Abstract

This paper examines the role of the exchange rate in the determination of the slope of the nominal Treasury yield curve in the context of the U.S.A. Monthly data from June 1976 through June 2005 are utilized. This paper concludes that changes in the U.S. dollar value index significantly influence the changes in the slope of the U.S. nominal Treasury yield curve. As a result, the exchange rate should be included as one of the explanatory variables in the yield curve empirics.

I. Introduction

The study of the Treasury yield curve in terms of its level, slope and curvature is of profound importance as it provides information on the current monetary policy stance, expected future economic activity, inflation and the real interest rate [Bernanke and Blinder (1992), Estrella and Hardouvelis (1991), Blanchard (1985), Mishkin (1990)].

The treasury yield curve, which is the plot of the term structure or varying yields of Treasury bonds at increasing maturity, has been the subject of many studies because it sets the basis for expected movements of interest rates in the future. Fixed-income investors use it as a reference point in forecasting interest rates, in pricing bonds and in setting strategies to boost their portfolio returns. The assumption behind a steep yield curve, for example, is that interest rates will rise in the future. As the economy expands, the associated risks of higher inflation and interest rates can hurt investors or bondholders due to dropping prices of bonds that move inversely to yields.

On the other hand, monetary policymakers use the yield curve in making decisions about long-run interest rates and inflation-targeting. A monetary policy tightening usually causes an upward shift in the entire yield curve with a stronger impact on the short-term end. With the threat of higher inflation as the economy expands, a monetary tightening, signals that the central bank expects upward pressure on

*Professor of Finance, McNeese State University, Lake Charles, LA 70609, Tel: (337) 475-5573, Fax: (337) 475-5010, E-mail: mrahman@mcneese.edu
**Professor of Economics, South Carolina State University, Orangeburg, SC 29117, Tel: (803) 536-7949, Fax: (803) 533-3639, E-mail: mmustafa@scsu.edu

inflation and higher interest rates. Investors respond by selling government securities in the secondary market resulting in lower prices and higher yields.

The yield curve has been characterized in several ways but the model of Nelson and Siegel (1987) is the one widely used by central banks around the world according to a survey by the Bank for International Settlements (1999). They identified three factors which they call the *level*, *slope* and *curvature*. These factors represent the long-, short- and medium-term interest rates and could account for 96 percent of the shape of the yield curve.

Studies relating macroeconomic variables to the components of the yield curve are fairly recent and the work of Ang and Piazzesi (2003) led investigations. In their paper, they find that inflation largely accounts for the movement in the level and slope of the yield curve. Evans and Marshall (2001) and Diebold, Rudebusch and Aruoba (2003) show that monetary policy shocks affect the slope. While Dewachter and Lyrio (2003) and Hordahl, Tristani and Vestin (2002) claim that shocks to inflation and the output gap account for curvature. .

Irving Fisher (1930) was the first paper to clearly distinguish between the real and the nominal interest rates. Several theories have been proposed to characterize the relationship between the interest rate and term to maturity, a relationship that is called the term structure of interest rates. Fisher's theory predicts that the yield curve, which is the plot of the term structure, will be upward sloping if expected inflation is positive.

Traditionally, there are three main theories on the term structure of interest rates. The first is the expectations theory which states that the observed long-term rate is the average of current short rates and expected future short rates. This means that an upward-sloping yield curve implies that investors anticipate increases in short-term interest rates in the future. On the other hand, the downward sloping yield curve suggests that investors anticipate the opposite.

The second is the liquidity preference theory, which assumes that long-term bonds are more risky and investors will demand a premium for holding them. Long-term rates are equal to the sum of average future short rates and a liquidity premium. An extension of this theory incorporates not just the liquidity premium but also the risk premium for inflation, default and maturity mismatch. This proposes that even if the expected future short-term rates stay constant (or even decline), the yield curve could be upward sloping, if the liquidity premium is high enough. But if the yield curve is downward sloping and the liquidity premium is positive, then the future short-term rates are expected to drop.

Last is the market segmentation theory where it is assumed that there are two distinct markets for short- and long-term bonds. Demand and supply in the long-term bond market determine long-term yields, and the demand and supply in the short-term bond market determine the short-term rates. This implies that the expected future rates have little to do with the shape of the yield curve. Along this line, the preferred habitat theory further modifies market segmentation by stating that investors will switch out of their preferred bond markets if premiums are inadequate.

The question of how to respond to changes in the slope of the yield curve received some attention in the United States at the end of 1995. In the United States, the yield curve became very flat in 1995. Based on the historical relationship between economic activity and the slope of the yield curve, the probability of a recession would have been very high (Estrella and Mishkin, 1997). The policy question was whether in that situation short-term interest rates should be reduced to avoid a downturn. However, the low-term spread in 1995 was mainly the result of falling long-term rates due to a smaller term premium as a result of reduced inflationary expectations in the U.S. bond market. Interestingly enough, this fall in the term premium coincides with the pre-emptive tightening by the Federal Reserve in the same period. By implication, the particularly flat yield curve should not have been interpreted as signaling an economic downturn because inflation scare shocks have only nominal effects.

In all of these prior studies, the impact of exchange rate movements on the slope of the yield curve has been ignored. In this age of globalization, the rising international mobility of capital and the foreign investment component of global portfolios are affected by exchange rate changes. This paper seeks to explore the effects of the changes in the U.S. overall exchange rate (external value index of the dollar) on the slope of the U.S. nominal Treasury yield curve using monthly data.

The remainder of the paper is organized as follows. Section II provides a survey of the literature. Section III outlines the empirical methodology. Section IV reports results, and section V offers conclusions.

II. Survey of Literature

Models of the term-structure of interest rates have been mostly formulated in continuous time and in an arbitrage-free framework. Typically, bond yields are affine functions of a number of state variables that capture the uncertainty present in the economy. In many specifications, the state variables are unobserved. Econometrically, the latent factors are extracted from bond prices or yields by either assuming that a few bonds are priced perfectly by the model or by filtering techniques if all bonds are assumed to be priced with error. When three factors are specified, they are often interpreted as the level, slope, and curvature of the yield curve, following Litterman and Scheinkman (1991). Dai and Singleton (2003) and Piazzesi (2003) provide thorough surveys of this class of models.

Recently, several researchers have added observable macroeconomic variables to the latent factors in an attempt to understand the channels through which the economy influences the term structure, and not simply describe or forecast the movements of the term structure. Ang and Piazzesi (2003) and Ang, Dong, and Piazzesi (2007) estimate Taylor (1993) rules and identify monetary policy shocks using no-arbitrage pricing techniques. They find that inflation and the output gap account for over half of the variation of time-varying excess bond returns and most of the movements in the term spread. Models with more macroeconomic structure have also been proposed recently by Hordahl, Tristani, and Vestin (2006), Rudebusch and Wu (2004), and Bekaert, Cho, and Moreno (2003). These models combine the affine arbitrage-free dynamics for yields with a New Keynesian macroeconomic model, which typically consists of a monetary policy reaction function, an output equation, and an inflation equation.

In each of the aforementioned models, risk premiums for the various sources of uncertainty are obtained by specifying time-varying prices of risk that transform the risk-factor volatilities into premiums. The prices of risk, however, are estimated directly from the data without accounting for the fact that investors' preferences and technology may impose some constraints between these prices. Indeed, according to Diebold, Piazzesi, and Rudebusch (2005), the goal of an estimated no-arbitrage macro-finance model specified in terms of underlying preference and technology parameters (such that the asset pricing kernel is consistent with the macro dynamics) remains a major challenge.

In Piazzesi (2003), affine general-equilibrium models are specified with preference shocks that are related to state variables, as in Campbell (1986) and Bekaert and Grenadier (2003). Wachter (2006) also proposes a consumption-based model of the term structure of interest rates, where nominal bond yields depend on past consumption growth and inflation. This model is essentially the same as the habit model of Campbell and Cochrane (1999), but the sensitivity function of the surplus consumption to innovations in consumption is chosen so as to make the risk-free rate a linear function of the deviations of the surplus consumption from its mean. Moreover, Wachter calibrates her model so as to make the nominal risk-free rate in the model equal to the yield on a three-month bond at the mean value of surplus consumption.

The dynamic interaction between the macro economy and the term structure is explored by Diebold, Rudebusch, and Aruoba (2006) in a Nelson-Siegel empirical model of the term structure, complemented by a VAR model for real activity, inflation, and a monetary policy instrument. They find that the causality from the macro economy to yields is much stronger than in the reverse direction.

III. Empirical Methodology

First, it is necessary to examine the stationary/nonstationarity property of time series data to determine the most appropriate econometric technique in order to avoid incorrect conclusions. Provided the time series data are found to be stationary, the most appropriate procedure is the simple Granger causality test. In the case of nonstationarity in the time series data, the most appropriate procedures are cointegration and error-correction models.

To begin with this examination, the cointegration regressions are specified as follows:

$$x_t = \alpha_0 + \alpha_1 y_t + e_t \tag{1}$$

$$y_t = \alpha_0' + \alpha_1' x_t + u_t \tag{2}$$

where, x_t is the slope of Treasury yield curve (as common practice, this is the difference between 10-year T-bond yield and 2-year T-bond yield), y_t is the U.S. dollar value index, and e_t is the stochastic error term.

The variables x_t and y_t are integrated of order d (i.e., I(d)) if the time series data on x_t and y_t have to be differenced d times to restore stationarity. For d equal to 0, x_t and y_t are stationary in levels and no differencing is needed. For d equal to 1, first differencing is needed to restore stationarity.

Modified Dickey–Fuller and modified Phillips-Perron procedures are applied to test for nonstationarity in each variable. The KPSS test for level stationarity, developed in Kwiatkowsxi, Phillips, Schmidt and Shin (1992), is widely used as a counterpart of the ADF test. The test is outlined by considering the model:

$$y_t = \mu + \alpha y_{t-1} + u_t, \text{ t = 1,…., T.} \tag{3}$$

For convenience, it is assumed that T is an even number. The interest is in the null hypothesis of level stationarity,

$$H_0: |\alpha| < 1,$$

Against the alternative hypothesis of a unit root,

$$H_1: \alpha = 1.$$

The KPSS test for the null of level stationarity is

$$KPSS = \sum_{t=1}^{n} s_t^2 / \hat{\sigma}_u^2$$

where, $s_t = \sum_{j=1}^{t} \hat{u}_j$ and $\hat{\sigma}_u^2$ is the long − run variance estimator using $\{\hat{u}_t\}$.

The co-integration procedure developed in Johansen (1988) and Johansen and Juselius (1990, 1992), avoids the above drawback by allowing interactions in the determination of the relevant economic variables and being independent of the choice of endogenous variable. Most importantly, it allows explicit hypotheses tests of parameter estimates and rank restrictions using likelihood ratio tests. The empirical exposition of the Johansen and Juselius methodology is as follows:

$$\Delta V_t = \tau + \Omega V_{t-1} + \sum_{j=1}^{k-1} \Omega_j \Delta V_{t-j} + m_t \tag{4}$$

where, V_t denotes a vector of log of relevant variables, and Ω equals $\alpha\beta$. Here, α is the speed of adjustment matrix and β is the cointegration matrix. Equation (4) is subject to the condition that Ω is a less-than-full rank matrix, i.e., $r < n$. This procedure applies the maximum eigenvalue test (λ_{max}) and the trace test (λ_{trace}) for the null hypotheses on r. Of these two tests, the λ_{max} test is expected to offer a more reliable inference as compared to the λ_{trace} test (Johansen and Juselius (1990)). Again, the Johansen and Juselius test procedure suffers from its super-sensitivity to the selection of the lag structures. As a result, this study employs both the ADF and the Johansen-Juselius procedures for cointegration. It is likely that these two procedures will provide contradictory evidence in some instances.

If x_t and y_t are found to be cointegrated by either the ADF procedure or the Johansen-Juselius procedure or both, there will exist an error-correction representation (Engle and Granger (1987)). The error-correction model may take the following form:

$$\Delta x_t = \beta_1 e_{t-1} + \sum_{i=1}^{k} \phi_i \Delta x_{t-i} + \sum_{j=1}^{k} \delta_j \Delta y_{t-j} + u_{1t} \tag{5}$$

$$\Delta y_t = \beta_2 u_{t-1} + \sum_{i=1}^{k} \pi_i \Delta x_{t-i} + \sum_{j=1}^{k} \gamma_j \Delta y_{t-j} + u_{2t} \tag{6}$$

The reverse specification is considered due to plausible bidirectional causality. In these two equations, the series x_t and y_t are cointegrated when at least one of the coefficients β_1 or β_2 is not zero. If $\beta_1 \neq 0$ and $\beta_2 = 0$, then y_t will lead x_t in the long run. Again, if $\beta_2 \neq 0$ and $\beta_1 = 0$, then x_t will lead y_t in the long run. If δ_j's are not all zero, movements in y_t will lead those in x_t in the short run. If π_i's are not all zero, movements in x_t will lead movements in y_t in the short run.

The error-correction model (ECM) was first introduced by Sargan (1964) and subsequently popularized by numerous papers, (e.g., Davidson et al. (1978), Hendry et al. (1984)). It has enjoyed a revival in popularity due to the recent work of Granger (1986, 1988), and Engle and Granger (1987) on cointegration. Its importance lies in its ability to combine short-run dynamics and long-run relationships in a unified system. If two variables are cointegrated, the long-run Granger causality will stem from at least one direction. Sometimes, it is desirable to exclude insignificant lags to improve the efficiency of OLS estimates of parameters (Baghestani and Mott (1997)). A lack of cointegration does not, however, preclude the short-run dynamics and Granger causality. In the absence of a long-run relationship, equations (8) and (9) should not include the error-correction term for the detection of Granger causality between two variables (Bahmani and Payesteh (1993)). The optimum lag-lengths are determined by the FPE (Final Prediction Error) Criterion (Akaike, 1969).

Monthly data from June, 1976 through June, 2008 are employed. The data source includes various issues of the Federal Reserve Bulletin. The sample period begins from June, 1976 as the U.S. dollar value index data are available since then.

IV. Results

The unit root test results are shown in Table 1.

As observed in Table 1, both the modified Dickey-Fuller and the KPSS tests reveal nonstationarity in the slope of the U.S. Treasury yield curve and the U.S. dollar value index at the 1 percent level of significance with I(l) behavior.

Table 1: Unit Root Tests

SERIES	LEVEL		DIFFERENCES	
	DF-GLS	KPSS	DF-GLS	KPSS
x	-2.6017	0.389	-13.890	0.0536
y	-1.623	0.603	-13.542	0.0831

* The modified Dickey-Fuller (DF-GLS) critical values [in Elliot et al., (1996)] are-2.653 and -1.954 at 1 percent and 5 percent levels of significance, respectively. The KPSS critical values are 0.739 and 0.463 at 1 percent and 5 percent levels of significance, respectively.

Next, the Johansen-Juselius tests (λ_{trace} and λ_{max}) for cointegration are implemented. The results are shown in table 2.

Table 2: Johansen-Juselius Cointegration Tests

	Between x and y	
Hypothesized No. of CE(s)	λ_{trace}	λ_{max}
None	17.04048	11.88798
	(15.49471)	(14.26460)
At most 1	5.152505*	5.152505*
	(3.841466)	(3.841466)

* Trace test indicates two cointegrating relationships and Max-eigenvalue test indicates one cointegrating relationship at 5 percent level of significance. The associated critical values of λ_{trace} and λ_{max} tests are reported in parentheses.

Table 2 depicts cointegrating relationship between the variables as the null hypothesis of no cointegration is rejected at the 5 percent level of significance. This inference is based on the comparisons of the computed and the respective critical values of λ_{trace} and λ_{max} statistics.

Finally, the relevant error-correction models (5) and (6) are estimated. The results are:

Table 3: Error-Correction Models

Dependent Variable	Causal Variable	Lag Order	F-statistics	Error-Correction Terms
Δx	Δy	2	12.07921*	-0.029129 (-2.19956)**
Δy	Δx	2	9.8411*	0.000191 (2.2498)**

* Significant at the 1 percent level. ** Significant at the 5 percent level. The optimum lag orders are determined by the FPE criterion (Akaike, 1969). The associated t-values are reported in parentheses.

Table 3 discloses a long-run causal relationship flowing from the changes in the U.S. exchange rate to the changes in the slope of the U.S. Treasury yield curve. This long-run relationship between variables seems fairly strong. The negative sign of the coefficient of the error-correction term and its statistical significance in terms of the associated t-value suggests that U.S. dollar fluctuations affect the U.S.

Treasury yield curve. This long-run relationship between the variables seems to be fairly strong. The F-statistic at 12.08 suggests short-run feedback relationships between the variables. The estimates of the reverse specification of the error-correction model suggest otherwise, though.

V. Conclusions

The slope of the U.S. nominal Treasury yield curve and the U.S. dollar value index are non-stationary in levels depicting I(l) behavior. The variables are cointegrated. There is an evidence of a long-run causal flow from the changes in the external dollar-value index to the changes in the slope of the U.S. nominal Treasury yield curve with short-run interactive feedback effects. This finding suggests that the U.S. overall external dollar-value index should be included as one of the determinants in the empirical estimates of the slope of the U.S. nominal Treasury yield curve.

REFERENCES

Akaike, H. (1969). "Fitting Autoregression for Prediction," *Annals of the Institute of Statistical Mathematics*, 21, 243-247.

Ang, A., S. Dong, and M. Piazzesi (2007). "No-Arbitrage Taylor Rules," NBER Working Paper No. W13448.

Ang, A., and M. Piazzesi (2003). "A no-arbitrage vector autoregression of term structure dynamics with macroeconomic and latent variables," *Journal of Monetary Economics* 50, 745-87.

Baghestani, H., and T. Mott (1997). "A Cointegration Analysis of the U.S. Monetary Supply Process," *Journal of Macroeconomics*, 19, 269-83.

Bahmani, O., and S. Payesteh (1993). "Budget Deficits and the Value of the Dollar: An Application of Cointegration and Error-Correction Modeling," *Journal of Macroeconomics*, 15, 661-77.

Bank for International Settlements (1999). "Zero-Coupon Yield Curves: Technical Documentation," Bank for International Settlements, Switzerland.

Bekaert, G., S. Cho, and A. Moreno (2003). "New-Keynesian macroeconomics and the term structure," Columbia University Working Paper.

Bekaert, G., and S. Grenadier (2003). "Stock and bond pricing in an affine economy," Columbia Business School Working Paper.

Bernanke, B., and Blinder, A. (1992). The Federal Funds Rate and the Channels of Monetary Transmission, *American Economic Review*, 82: 901-921.

Blanchard, O.J. (1985). "Debt, Deficits, and Finite Horizons," *Journal of Political Economy*, 93: 223-247.

Campbell, J. (1986). "A defense of the traditional hypotheses about the term structure of interest rates," *Journal of Finance*, 41, 183-93.

Campbell, J., and J. Cochrane (1999). "By force of habit: a consumption-based explanation of aggregate stock market behavior," *Journal of Political Economy*, 107, 205-51.

Dai, Q. and K. Singleton (2003). "Term structure modeling in theory and reality," *Review of Financial Studies*, 16, 631-781.

Davidson, J.E.H., D. Hendry, F. Srba, and S. Yeo (1978). "Econometric Modelling of the Aggregate Time Series Relationship between Consumers Expenditure and Income in the United Kingdom," *Economic Journal*, 88, 661-92.

Dewachter, H. and Lyrio, M. (2003). "Macroeconomic Factors in the Term Structure of Interest Rates," Manuscript, Catholic University of Leuven and Erasmus University Rotterdam.

Diebold, F.X., M. Piazzesi, and G. Rudebusch (2005). "Modelling bond yields in finance and macroeconomics," *American Economic Review (Papers and Proceedings)* 95, 415-20.

Diebold, F.X., G. Rudebusch, and S.B. Aruoba (2006). "The macroeconomy and the yield curve: a dynamic latent factor approach," *Journal of Econometrics*, 131, 309-38.

Diebold, F.X., Rudebusch, G.D. and Aruoba, S.B. (2003). "The Macroeconomy and the Yield Curve: A Non-Structural Analysis," Working Paper, University of Pennsylvania.

Elliot, G., Rothenberg, T.J., and Stock, J.H. (1996). "Efficient Test for an Autoregressive Unit Root," *Econometrica*, 64, 813-836.

Engle, R.F., and C.W.J. Granger (1987). "Cointegration and Error Correction: Representation, Estimation and Testing," *Econometrica*, 55, 251-76.

Estrella, A. and Hardouvelis, G. (1991). "The Term Structure as a Predictor of Real Economic Activity," *Journal of Finance*, 46: 555-576.

Estrella, A. and F. Mishkin (1997). "The predictive power of the term structure of interest rates in Europe and the United States: Implications for the European Central Bank". *European Economic Review*, vol.41(7), 1375-402.

Evans, C.L. and Marshall, D. (2001). "Economic Determinants of the Nominal Treasury Yield Curve," Manuscript, Federal Reserve Bank of Chicago.

Fisher, I. (1930), *The Theory of Interest*, New York: The MacMillan Company.

Granger, C.W.J. (1988). “Some Recent Developments in a Concept of Casualty.” *Journal of Econometrics*, 39, 199-211.

Granger, C.W.J. (1986). “Developments in the Study of Cointegrated Economic Variables,” *Oxford Bulletin of Economics and Statistics*, 48, 213-227.

Hendry, D.F., A.R. Pagan, and J.D. Sargan (1984). "Dynamic Specification," in *Handbook of econometrics II*, edited by Z. Griliches and M. Intriligator, Amsterdam: North-Holland.

Hordahl, P., O. Tristani, and D. Vestin (2006). "A Joint Econometric Model of Macroeconomic and Term Structure Dynamics," *Journal of Econometrics*, 131, 405-44.

Hordahl, P., Tristani, O. and Vestin, D. (2002). "A Joint Econometric Model of Macroeconomic and Term Structure Dynamics," Manuscript, European Central Bank.

Johansen, S. (1988). "Statistical Analysis of Cointegration Vectors," *Journal of Economic Dynamics and Control*, 231-54.

Johansen, S. and K. Juselius (1990). "Maximum Likelihood Estimation and Inference on Cointegration with Applications to the Demand for Money," *Oxford Bulletin of Statistics*, 169-210.

Johansen, S. (1992). "Testing Structural Hypotheses in Multivariate Cointegration Analysis of the PPP and the VIP for U.K.," *Journal of Econometrics*, 211-44.

Kwiatkowski, D., Phillips, P.C.B., Schmidt, P. and Shin, Y. (1992). "Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root," *Journal of Econometrics*, 54, 159-178.

Litterman, R., and J. Scheinkman (1991). "Common factors affecting bond returns," *Journal of Fixed Income*, 1, 54-61.

Mishkin, F. (1990). "The Information in the Longer Maturity Term Structure about Future Inflation," *Quarterly Journal of Economics*, 105, 815-828.

Nelson, C.R. and Siegel, A.F. (1987). "Parsimonious Modeling of Yield Curves," *Journal of Business*, 60, 473-489.

Piazzesi, M. (2003). "Affine term structure models," *Handbook of Financial Econometrics*, forthcoming.

Rudebusch G., and T. Wu (2004). "The recent shift in term structure behavior from a no-arbitrage macro-finance perspective," Federal Reserve Bank of San Francisco, Working Paper No. 2004-25.

Sargan, J.D. (1964). "Wages and Prices in the U.K.: A Study in Econometric Methodology," in *Econometric analysis for national economic planning*, edited by P. Hart et al., London: Butterworths.

Wachter, J. (2006). "A consumption-based model of the term structure of interest rates," *Journal of Financial Economics*, 79, 365-99.