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Dynamics of the Term Structure of Interest Rates: A Critical Literature Review

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Abstract: *Research on the determinants of the term structure of interest rates continues to be an area of substantial interest from the public and private sectors largely due to the economic impact of the term structure on both local and global economies. The purpose of this study was to critically review the literature and empirical evidence available in an effort to establish the key variables that have the greatest effect on the term structure of interest rates. Traditional theories that laid the foundation of understanding the variables include the unbiased expectations hypothesis, which identified forward interest rates as the key variable; liquidity premium hypothesis that found investors will require a higher yield in order to hold longer term bonds due to their preference for liquidity; and the market segmentation hypothesis and preferred habitat theory, which identified differing interest rates for differing market segments or habitats that investors belong to. Empirical research identifies economic variables and market data on the term structures the key variables. Multi- factor models with changes in regime have also found strong empirical support. The findings from the literature review indicate that short-term interest rates, economic cycles and regime changes have a significant relationship with the term structure of interest rates.*
Keywords: *Term structure, interest rates, determinants.*

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I. Introduction

Term structure of interest rates refers to the relationship between interest rates and their maturity periods. Empirical research on models of the term structure of interest rates have generally resulted into two schools of thought: Equilibrium models, which specify a process for the short-term interest rate that is based on assumptions about economic variables. As a result, they do not automatically fit market data on the term structure of interest rates at any point in time. Examples include Vasicek (1977), who assumes a mean reverting process for the short term rate; Rendleman and Bartler (1980), who assume that the short term risk free rate follows geometric Brownian motion with a drift; and Cox, Ingersoll and Ross (1985), who also assume mean reversion but require positive rates; and Arbitrage free models, which are calibrated, to fit market data and thus use market data on the term structure as an input in an effort to ensure that expected future rates are consistent with the current observed term structure. Examples include Ho and Lee (1986), Hull and White (1990) and Heath, Jarrow and Morton (1992). In between these two schools of thought is a third school of thought that was first proposed in the regime switching model of Gray (1996). The coefficients in the regime-switching model are different in each regime to account for the possibility that the economic mechanism that generates the short rate may undergo a finite number of changes over the sample period.

Numerous other studies have attempted to document the relationships between short term interest rates and the term structure that have not been captured by the two main interest rate schools of thought. These studies have typically focused on multi factor models. Archontakis and Lemke (2007) observed that within the affine class, bond yields of all maturities are linear functions of the state or factor vector, where the intercept and slope coefficients depend on the parameters governing short rate dynamics and the parameters governing the market prices of factor –innovation risk. Earlier related literature usually employed a version of the expectations hypothesis

Term structure dynamics have their theoretical foundations rooted in the early work of Fisher (1896) who first postulated the unbiased expectations hypothesis, which was further developed by Lutz (1940). The term structure is said to be unbiased if the expected future interest rates are equivalent to the forward rates computed from the observed bond prices. Hicks (1946) thereafter argued that a liquidity premium exists in the term structure of interest rates and shortly after the market segmentation hypothesis was proposed by Culbertson (1957), Walker (1954) and Modigliani and Sutch (1966) who argued that there is relatively little substitution between assets of different maturity because investors have preferred habitats. The preferred habitat theory proposed by Modigliani and Sutch (1966) is a combination of the market segmentation theory and the expectations theory and proposes that there are investor clienteles with preferences for specific maturities, and the interest rate for a given maturity is influenced by demand and supply shocks local to that maturity.

Key assumptions of the early term structure models have been subsequently challenged. Early scholars assumed that interest rates are nonstochastic. This has been disputed subsequently for example by Ball and Torous (1999) who found reliable evidence of stochastic volatility of interest rates across a number of countries and concluded that interest rate dynamics are impacted by transient economic shocks such as central bank announcements and other macro economic news. A second assumption made in early interest rate models is that interest rates are constant in a multi-period setting. Copeland, Weston and Shastri (2005) observed that this has been a convenient but misleading assumption as interest rates are not constant through time. Finally, early research on interest rates assumed mean reversion. In contrast most of the empirical work finds it hard to reject the hypothesis that the short-term interest rate determination is an integrated process (Archontakis and Lemke, 2007). In econometrics literature it is generally agreed that interest rates and especially short-term interest rates contain a unit root. This is shown by Rose (1988), Stock and Watson (1988), Enders and Siklos (2001), Hansen and Seo (2002) as well as Chan, Karolyi, Longstaff and Sanders (1992) who have estimated eight popular linear time series models used to specify interest rate dynamics, and have shown that there is only weak evidence for mean reversion. Lanne and Saikkonen (2002), Seo (2003) and Jones (2003) have argued that the resulting observations of random walk like behaviour of interest rates may be attributable to omitted non-linearity of the mean and volatility function. Piazzesi (2004) went further to suggest that models with regime switching are particularly prominent candidates for capturing these nonlinearities parametrically.

The objective of the current study is therefore to establish the variables that are key in determining the term structure of interest rates. The remainder of this study is divided into three sections. The next section provides the key theories identifying variables that affect the term structure. Thereafter an empirical literature review is provided. Finally, conclusions and recommendations for further research are provided in the last section.

II. Theoretical Literature Review

Interest rate theory is founded on the early work of scholars who first presented comprehensive theoretical models that provided insight into the determination of the term structure of interest rates.

Fisher (1896) first postulated the unbiased expectations hypothesis, which was further developed by Lutz (1940). The term structure is said to be unbiased if the expected future interest rates are equivalent to the forward rates computed from the observed bond prices. The unbiased expectations theory explains observed forward rates by arguing that expected future rates will, on average, be equal to the implied forward rates if investors' expectations of future one period rates are unbiased and if bonds of different maturity are perfect substitutes for each other. The latter condition requires, inter alia, that the risk and transaction costs for a strategy of rolling over a one-period bond multiple (n) times are the same as holding a multiple (n) period bond. If the two strategies are in fact perfect substitutes, investors will keep the rates in line with expectations by forming arbitrage positions whenever interest rates are "out of line". The expectations hypothesis implies that rational investors can predict future changes in interest rates by simply observing the yield spread i.e. the difference between long and short-term interest rates. The expectations theory, which has inspired numerous studies, has found little empirical support. Campbell and Shiller (1991) and Hardouvelis (1994) suggest that the empirical failure may be due to an over reaction of long rates to the expected change in short rates. In addition, Hardouvelis (1994) believes that large measurement errors can account for the forecast in the wrong direction of long-term rate prediction. Fama (1986), Cook and Hahn (1989), Tzavalis and Wickens (1997), among others, argue that a time-varying term premium correlated with the spread can account for the empirical failure of the expectations hypothesis. Froot (1989) however indicates that a violation of the rationality principle, rather than a time-varying risk premium, is one of the main reasons underlying the rejection of the expectations hypothesis. Mankiw and Miron (1986) admit that they cannot fully explain the failure of the expectations hypothesis, however, they believe that time varying risk premia, change in risk perception, adjustment in relative asset supplies, measurement errors and near rational (rather than rational) expectations can play a role in explaining the empirical rejection of the expectations hypothesis.

Hicks (1946) argued that a liquidity premium exists in the term structure of interest rates. This is because future interest rates become more uncertain the further into the future one tries to predict and therefore a given change in interest rates will have a greater effect on the price of long-term bonds than on short-term bonds. Hence there is greater risk of loss with long-term bonds consequently making risk adverse investors require a higher yield in order to hold longer-term bonds. This extra yield is what is known as the liquidity premium. Kessel (1965) found that the liquidity premium could vary with the level of interest rates. However, McCulloch (1975) discussed some research refuting this relationship and found no empirical support for this assumption. Fama (1986) argued against the liquidity premium theory by postulating that, while the return on longer term bills exceeded of one-month bills, the premium did not increase monotonically with maturity; rather it tended to peak at around eight or nine months. The high variability of longer-term bond returns made it impossible to draw any conclusions about liquidity premia on their returns. McCulloch (1987) supported the liquidity premium theory and pointed out that there was a problem in the data sample with the selected time window due to the bid-ask spreads for the nine and ten months maturity in Fama's work. As a result McCulloch disputed Fama's conclusions and argued that the premium increased monotonically with maturity. Regarding monotonicity, Wolak (1989) also rejected the hypothesis of increasing term structure. Boudoukh et al (1999) reinvestigated Fama's (1986) work and argued that it was important to evaluate the joint inequality constraints and the type of conditioning information used in the estimate. Their findings are consistent with the liquidity premium hypothesis. Patton and Timmermann (2010) argued that the term structure does not increase monotonically and therefore that the liquidity premium cannot be substantiated.

The market segmentation hypothesis attributable to Culbertson (1957), Walker (1954) and Modigliani and Sutch (1966) argued that there is relatively little substitution between assets of different maturity because investors have preferred habitats. For example, recipients of capital to finance long term projects will prefer to issue long term debt to match its debt payments to the long term receipts expected from its projects. Similarly insurance companies with long-term liabilities prefer to lend long term. Thus the market segmentation hypothesis argues that suppliers and users of funds have preferred habitats and interest rates for a given maturity are explained by the supply and demand for funds of that specific maturity.

The preferred habitat theory also attributable to Culbertson (1957) and Modigliani and Sutch (1966) is a combination of the market segmentation theory and the expectations theory and proposes that there are investor clienteles with preferences for specific maturities, and the interest rate for a given maturity is influenced by demand and supply shocks local to that maturity. Vayanos and Vila (2009) point out that even though the preferred habitat view is relevant in practice and was proposed more than half a century ago, it has not entered into the academic mainstream; it has typically been confined to short discussions in text books partly because of the absence of a formal model and partly because of an impression that preferred habitat can conflict with the logic of no-arbitrage. Vayanos and Vila (2009) however attempt to build a qualitative model of preferred habitat in their 2009 paper. Recent papers have explored the empirical implications of preferred habitat, as well as the implications for bond issuance. Krishnamurthy and Vissing-Jorgensen (2008) finds a strong negative correlation between credit spreads and the debt-to-gdp ratio, and argue that this reflects a downward sloping demand for government bonds. Greenwood and Vayanos (2009) show that catering to maturity clienteles is an optimal issuance policy; a welfare maximizing government issues more long-term debt when the fraction of long (relative to short) horizon investors increases. Greenwood, Hanson and Stein (2009) find that corporations engage in gap filling behaviour, issuing long-term debt at times when the supply of long-term government debt is small.

While the market segmentation hypothesis can explain why implied forward and expected future rates may differ, the direction and magnitude are not systematic. However, in the liquidity premium postulated by Hicks (1946) forward and future rates differ systematically, depending on the maturity of the bonds.

III. Empirical Literature Review

The aforementioned comprehensive theoretical models laid the foundation for numerous empirical studies that followed, which critiqued the early works or built on them.

Models of term structure fall into three categories – equilibrium, arbitrage free and regime switching. Equilibrium models specify a process of short-term interest rate that is based on assumptions about economic variables. As a result, they do not automatically fit market data on the term structure of interest rates at any point in time. In contrast, arbitrage free models are calibrated to fit market data. The coefficients in the regime-switching model are different in each regime to account for the possibility that the economic mechanism that generates the short rate may undergo a finite number of changes over the sample period.

Economic models are firstly looked at as one-factor models where the stochastic process for the short-term rate (r) is a linear function of the form

$$dr = m(r)dt + w(r)dz,$$

Where the instantaneous drift (m) and standard deviation (w) are related to the short-term rate but are not a function of time and dz is normally distributed with mean 0 and variance of dt (i.e. z is a Wiener process) (Copeland, Weston & Shastri, 2005). Rendelman and Bartter (1980) assume that r follows a geometric Brownian motion by setting $m(r) = \mu r$ and $wr = \theta r$. The Rendelman-Bartter model has been criticized since it does not account for the empirical observation that interest rates tend to revert to a long-run average level over time. Vasicek (1977) assumes the following mean-reverting process for the short rate:

$$dr = v(\mu - r)dt + \theta dz$$

Where μ is the long term mean of the short-term rate, v is the speed of adjustment of the short-term rate to the long-term mean and θ is the instantaneous standard deviation. There is mean reversion in the process specified in the above equation since a higher (lower) current short-term rate, r, as compared to the long-run mean, μ, implied a negative (positive) drift, which, in turn implies that on average the short-term rate will decrease (increase) towards the long run mean.

One of the problems of the Vasicek model is that it allows the short-term rate to become negative. To rectify this problem, Cox, Ingersoll and Ross (1985) (CIR) propose a mean reverting process for the short rate where the standard deviation of the changes in interest rate are proportional to the square root of the level of the rate. A number of papers have directly tested the Cox, Ingersoll and Ross (1985) model. These include Brown and Dybvig (1986) who found that the CIR model overestimates the short-term rate and appears to fit treasury bills better than other treasury issues; Gibson and Ramaswamy (1993) who found that the CIR model performs reasonably well in explaining short term treasury bill returns; and Pearson and Sun (1994) who, in contrast, concluded that the CIR model fails to provide a good description of the treasury market. Other researchers who have assumed a mean reverting framework include Courtadon (1982), Chan et al. (1992) and Duffie and Kan (1993). Chan et al. (1992) test several one-factor models on one month treasury bills and conclude that the models that best describe the dynamics of interest rates over time are those that allow the conditional volatility of interest rate changes to be highly dependent on the level of interest rate. Aït-Sahalia (1996) also empirically tests several of these one-factor models on the seven-day Euro dollar deposit rate and finds the linearity of the drift term is the main source of misspecification. According to Copeland, Weston and Shastri (2005), other empirical research that have examined the applicability of general Affine Term Structure Models (ATSMs) that contain Vasicek and CIR specifications as special cases include Ahn, Ditmar and Gallant (2002) who argue that ATSMs have several drawbacks including the fact that they cannot simultaneously allow for negative correlations between the state variables and guarantee that interest rates would be positive and they fail to capture important nonlinearities in the data. ADG suggest that a class of term structure models where yields are specified as quadratic functions of the state variables may be superior to affine term structure models since the former overcome many of the drawbacks of the latter. They estimate the parameters of four versions of the quadratic term structure models and assess their goodness of fit using data on 3-month and 12-month treasury bills and 10-year bonds. They conclude from these tests that the quadratic term structure models outperform affine term structure models in explaining historical price behavior in treasury securities. Dai and Singleton (2000) find that the ATSMs pass several goodness of fit tests when applied to LIBOR based yields in the ordinary fixed-for-variable rate swap market but this is refuted by Duffie (2000) whofinds that these models provide poor forecasts of future yield changes.

Arbitrage free models use the market data on yield curves as an input to ensure that the model and the future values of the short-term rate are fully consistent with the current term structure. Arbitrage free models define the price of zero coupon bonds at some time in the future in terms of today's bond prices and the short-term rate at the future date. Ho and Lee (1986) develop an arbitrage free model and propose a binomial model for bond prices. However, a drawback of the Ho-Lee model is that it allows interest rates to become negative. Hull and White (1990) address this issue by analyzing an extended version of the Vasicek model that allows for a time-varying drift in the short rate. In contrast to Ho and Lee and Hull and White, who model the process for the short rate, Heath Jarrow and Morton (1990,1992) (HJM) model the evolution of forward rates. The implementation of this model is similar to the binomial approach of Ho and Lee with one major exception. In the Ho-Lee binomial process, the tree is recombining; that is an up perturbation followed by the down perturbation results in the same bond price as a down perturbation followed by an up perturbation. In contrast, the HJM tree is not recombining. As a result this model is computationally more complicated than the Ho-Lee approach. It is widely believed that arbitrage free models are more useful than equilibrium models for pricing derivatives. Since derivatives are priced against the underlying assets, a model that explicitly captures the market prices of those underlying assets is superior to models that more or less ignore market values.

Regime switching models first appeared with the Markov switching model of Hammilton (1989), also known as the regime-switching model, which involves multiple structures (equations) that can characterize the time series behaviour in many regimes. By permitting switching between these structures, this model is able to capture more complex dynamic patterns. A novel feature of the Markov switching model is that the switching mechanism is controlled by an unobservable state variable that follows a first order Markov chain. In particular the Markovian property that regulates the current value of the state variable depends on its immediate past value. As such a structure may prevail for a random period of time and it will be replaced by another structure when a switching takes place. The Markov switching model is a sharp contrast to the random switching model of Quandt (1972) in which the events of switching are independent over time. The Markov switching model also differs from the models of structural changes. While the former allows for frequent changes at random time points, the latter admits only occasional and exogenous changes. The Markov switching model is therefore suitable for describing correlated data that exhibit distinct dynamic patterns during different time periods. Gray (1996) observed that one potential source of misspecification of the short-term interest rate in models that do not factor regime changes is that the structural form of conditional means and variances is relatively inflexible and is held fixed throughout the entire sample period. These models are single regime models in the sense that they effectively assume a single structure for the conditional mean and variance. In regime switching models, the assumption of a single regime is relaxed. The coefficients in the regime-switching model are different in each regime to account for the possibility that the economic mechanism that generates the short rate may undergo a finite number of changes over the sample period. A number of papers have also successfully used Markov regime switching models to fit the dynamics of the short-term interest rate. Examples include Kugler (1996) who employed a Markov switching framework for linking longer term yields to short rate processes; Pfann, Schotman and Tschernig (1996) who used a Self Exciting Threshold Autoregressive (SETAR) model to link short and long term yields; Bhansal and Zou (2002) who applied an arbitrage free approach within their Markov switching models; Lanne and Saikkonen (2002) who proposed a family SETAR processes to determine the dynamics of short-term interest rates;Dai, Singleton and Yang (2003) who also applied an arbitrage free approach that allowed for state dependent transition probabilities in making the link between long and short-term rates; Gaspodinov (2005) who used a TAR-GARCH model; Audrino and Giorgi (2005) who used discrete beta-distributed regime shifts constructed on multiple thresholds; andAng, Bekaert and Wei (2006) who used a no-arbitrage regime-switching model that simultaneously captures the nominal as well as the real yield curve.Wu and Zeng (2005) observed strong empirical evidence suggesting that the aggregate economy is characterized by periodic shifts between distinct regimes of the business cycle. An extreme case of a regime shift would be the 2007 global financial crisis. The regime dependence introduced by the regime switching models implies richer dynamic behaviour of the market prices of risk and therefore offers greater econometric flexibility for the term structure models to simultaneously account for the time series and cross-sectional properties of interest rates. However as pointed out by Dai and Singleton (2003) the risk of regime shifts is not priced in these models and hence does not contribute independently to bond risk premiums.

IV. Conclusion

Research on the implications of short-term interest rates on the term structure is not exhaustive and there is not one model that has been developed that comprehensively and exhaustively explains the determination of the term structure of interest rates. While the early works contributing to the theoretical framework of interest rate theory are critical in developing any credible interest rate model, the subsequent empirical work around equilibrium models, arbitrage free models and regime switching models has added significantly in the understanding of the term structure. Based on the empirical work that has been carried out, which has built on the four main interest rate theories, there is significant evidence to suggest that the variables that are key in determining the term structure of interest rates are tenor, economic variables, short term interest rates and regime changes.

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