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Nonlinear equilibrium adjustment dynamics and predictability of the term structure of interest rates☆,☆☆

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ABSTRACT

We analyze money market dynamics under a long-run equilibrium framework where commonly-monitored spreads serve as error correction terms, derived from a structural model incorporating autocorrelated risk premia, interest rate smoothing and monetary policy feedback. Using a dataset of monthly observations of the spot next and four-, thirteen-, twenty six- and fifty two-week Treasury Bills rates for the United States, Germany and United Kingdom from January 1999 to April 2016, we investigate the power of the expectations hypothesis theory of interest rates taking into account long-run deviations from equilibrium and inherent nonlinearities. We reveal short-run dynamic adjustments for the term structure of the USA, Germany and the UK, which are subject to regime switches. When forecastability is tested during May 2016–October 2017, the MSIH-VECM outperforms systematically the VECM. This is the first attempt to explore the possibility of parameter instability as a crucial factor in deriving the rejection of the restricted version of the cointegration space. Moreover, we investigate the dynamic out-of-sample forecasts of the term structure to assess the effectiveness of nonlinear MS-VECM modeling in capturing the after-effects of the global crisis. Overall, our results suggest that regime shifts in the mean and variance of the term structure may be intertwined with changes in fundamentals, that play a role in driving interest rate regimes, in particular business cycle and inflation fluctuations.

1. Introduction

In money markets, a wide array of participants trade highly liquid, short-term and low-risk debt. As banks and other financial institutions meet their marginal funding needs in money markets, strains in these markets may impair the flow of credit to the entire economy. Money markets also play a key role in monetary policy implementation. The term structure, linking short- and long-term interest rates, is of utmost importance for the transmission of monetary policy. The expectations hypothesis (EHT) represents the most influential theoretical explanation for term structure relations. A vast econometric research has been dedicated to examining the empirical evidence of the EHT. Interestingly, the sizeable predictive power of the spread as implied by the pure EHT version could regularly not be supported by the data.

Studies on term structure dynamics have always been at the center of macroeconomics and finance research. Campbell and Clarida (1986) investigate the predictability and comovement of risk premia in the term structure of Euro market interest rates, demonstrating that the term structure on European currencies revealed common factors with those of other non-European currencies. Shareef and Shijin (2016) tried to analyze the implication of the expectation hypothesis for the Indian and US term structure. Using VAR estimates, tried to test the dynamic interdependence of interest rates vis-à-vis FX fluctuations. They found evidence in line with the existence of the EHT, yet only in case of the emerging market. Consequently, the spread between the long and short rate of India is influenced by short-term rates and past values of the Indian spread. Campbell and Shiller (1987) highlight the cointegrating relationship between short and long term interest rates as implied by the expectations model of the term structure. Hall, Anderson, and Granger (1992), Campbell and Shiller (1987), Hall et al. (1992), Johansen and Juselius (1990), Juselius (2004) and Juselius and MacDonald (2000), studied the long run dynamics of the term structure of interest rates, focusing mostly on its cointegrating properties and therefore on building correction models.

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More recently, Clarida, Sarno, Taylor, and Valente (2006) proposed a nonlinear multivariate vector error correction (VECM) model to investigate the term structure of interest rates by incorporating asymmetries in the error correction mechanism. They studied the forecasting performance of the nonlinear dynamic interest rate model against some linear benchmark models. Despite the importance of these developments, few studies addressed the dynamics of the term structure under a genuine non-linear framework. Regime shifts and asymmetries may account for these nonlinearities which impact not only the short term interest rates but the whole term structure. Bandholz, Clostermann, and Seitz (2007) analyzed to what extent fundamental macroeconomic factors or more structural factors, temporary influence the low levels of US bond yields over the last few years. They established a stable long-run relationship hence the behavior of bond yields even during the last two years can be well explained. Alongside the more traditional macroeconomic determinants like core inflation, monetary policy and the business cycle, they also included foreign holdings of US Treasuries. The latter should capture the frequently mentioned *structural effects* on long-term interest rates. Their bond yield equation outperforms a random walk model in different forecasting exercises. Additionally, Dai, Singleton, and Yang (2007) developed and empirically implemented an arbitrage-free, dynamic term structure model with "*priced*" factor and regime-shift risks. Using monthly data of U.S. Treasury zero-coupon bond yields, they show a critical role of priced, state-dependent regime-shift risks in capturing the time variations in expected excess returns, and document notable differences in the behavior of the factor risk component of the expected returns, across high and low volatility regimes. Aristei and Gallo (2014) used a Markov-switching VAR model to analyze the interest rate pass-through between interbank and retail bank rates in the Euro area. Their empirical results, based on monthly data for the period 2003–2011, showed that during periods of financial distress bank lending rates to both households and non-financial corporations display a reduction of the degree of pass-through from the money market rate. Significant sectoral heterogeneities characterize the transmission mechanism of monetary policy impulses, with rates on loans to non-financial firms being more affected by changes in the interbank rate than loans to households, both in times of high volatility and in normal market conditions. Furthermore, Boroumand, Goutte, and Porcher (2014) proved that under a regime-switching quadratic term structure model, the conditional zero-coupon bond price assumes a quadratic term structure. The stochastic coefficients which appear in this decomposition satisfy an explicit system of coupled stochastic backward recursions. Araç and Yalta (2015) examined the empirical adequacy of the EHT by applying a nonlinear cointegrating approach, which was based on the linear smooth transition autoregressive (STAR) framework. Accounting for the effects of global financial and debt crisis, they found supportive evidence for the EHT for Greece during the period covering the sovereign debt crisis. Interestingly, more studies by e.g., Gray (1996), Anderson (1997), Enders and Granger (1998), Bansal and Zhou (2002) and Sarno and Thornton (2003) have argued that the dynamics of the term structure of interest rates may be characterized by a nonlinear correction model. Finally, Sarno, Thornton, and Valente (2007) tested the EHT using U.S. monthly data for bond yields spanning a 1952–2003 period and ranging in maturity from 1 month to 10 years. They applied the Lagrange multiplier test and extended it to increase the test power by introducing economic variables as conditioning information. While the conventional bivariate procedure provided mixed results, the more powerful testing procedures suggested rejection of the EHT throughout the maturity spectrum examined.

Following Clarida et al. (2006) we analyze the term structure dynamics of the interest rates of USA, Germany and United Kingdom (UK) under five different maturities, by utilizing data of monthly frequency between 1999 and 2016. There are several important findings which stem from our estimation approach. Firstly, we robustly estimate the rank of the cointegration space for the system of the five rates. Secondly, we impose independent linear and homogeneous restrictions which are implied by the fulfilment of the EHTS. We impose various sets of restrictions implemented upon a sub-section of the estimated cointegration space. In this partially identified cointegration space we are able to show that part of the restrictions from the EHTS cannot be rejected. Thirdly, we explore the possibility of parameter instability as a crucial factor which might explain the rejection of the restricted version of the cointegration space; to that end we apply the recursive tests of Hansen and Johansen (1993, 1999), which show that the dimension of the cointegration space is sample independent and the estimated coefficients do not exhibit instabilities in recursive estimations, except for a small number of months during 2008. Fourthly, we show that while a long run equilibrium relationship between the five different maturities can be established, consistently with the expectations theory of the term structure, the linear vector error correction models are rejected when tested against regime-switching vector error correction models. Finally, we employ a Markov switching vector error correction approach to analyze the dynamic relationship between interest rates for the different maturities of each country, implementing the robust estimation techniques introduced by Krolzig (1997). Eventually, we are able to fully identify and characterize the dynamic relationships between the interest rates of various maturities for each country. Finally, we produced dynamic out-of-sample forecasts of the term structure within the period May 2016 to October 2017 using the optimally selected and estimated MSIAH(2)-VECM(p) model, in order to assess further the effectiveness of our proposed nonlinear VECM of the term structure.

Our study is different from the empirical studies already conducted, in three aspects. Firstly, to the best of our knowledge, none of these studies has explored the possibility of parameter instability as a crucial factor generating the rejection of the restricted version of the cointegration space. Secondly, we extend previous studies by examining the term structure over a more recent time span covering the period between January 1999 till April 2016, especially in terms of comparing the US economy versus two core European economies, i.e., Germany and UK. Thirdly, we investigate the dynamic out-of-sample forecasts of the term structure in order to assess the effectiveness of nonlinear MS-VECM modeling towards capturing the after-effects of the global crisis.

The paper is organized as follows: in the next section, we discuss the theories of term structure and the related statistical estimation issues. In Section 3, we thoroughly present the Markov switching theory and the econometric approaches applied in extending the current framework towards incorporating vector error correction modeling. In Section 4, we present the dataset, we conduct our comparative empirical investigation based on all estimated models and we explicitly report the results from the estimated Markov switching vector error correction approach in an attempt to detect and explain the inherent nonlinearities and observed parameter instabilities. Moreover, we produce dynamic out-of-sample forecasts of the term structure and perform a comparative analysis of the MSIAH-VECM (p) against those derived by the VECM models. The final section summarizes and concludes.

2. The term structure in the presence of nonstationarity: cointegration dynamics

It is known that the yield curve expresses the term structure of the interest rates on assets of different maturities. The short term rates, the slope of the yield curve and its curvature determine the shape of the yield curve; this shape can differ over time following, for instance, the variations on the expectations on the inflation rate and the phase of the business cycle. The Fisher equation takes into account this, because it analyzes the link between the nominal yield on the different maturities r_t, the real interest rate r_t^r and the expected inflation rate π_{te}:

$$r_t = r_t^r + \pi_{te} + [r_t\ \pi_{te}] \tag{1}$$

The Fisher condition has to be adjusted if uncertainty is introduced in the analysis. Given the hypothesis of risk-aversion of the investor, there is a risk premium to compensate for the value losses. This