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The macroeconomic determinants of the US term structure during the Great Moderation☆

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ABSTRACT

We study the relation between the macroeconomic variables and the term structure of interest rates during the Great Moderation. We interpolate a term structure using three latent factors of the yield curve to analyze the responses of all maturities to macroeconomic shocks. A Nelson–Siegel model is implemented to estimate the latent factors which correspond to the level, the slope, and the curvature of the curve. As policy implication, the interpolated term structure informs the policymaker how all the macroeconomic shocks impact the whole term structure, even if the impact has a different magnitude across maturities.

1. Introduction

There is a close relation between the term structure of interest rates and macroeconomic variables: the real activity and expectations of future inflation can be important determinants of the yield curve. A strand of the financial literature discusses the role of the latent factors extracting from the term structure, such as the level, the slope, and the curvature, to summarize the main features of the yield curve (see e.g., Ang and Piazzesi (2003), Diebold and Li (2006), Diebold et al. (2006), Mumtaz and Surico (2009), Bianchi et al. (2009), Gasha et al. (2010), Aguiar-Conraria et al. (2012), Medeiros and Rodrguez (2011), and Afonso and Martins (2012)).

In this paper, we show an empirical contribution using the latent factors to interpolate a term structure to study the impact of the macroeconomic shocks on the US yield curve during a calm down era, the Great Moderation, before the Great Financial Crisis of 2007–2009.[1] The years between 1984 and 2007, the Great Moderation period as named by Stock and Watson (2002), were characterized by a reduction in the volatility of business cycle fluctuations, especially for US macroeconomic variables; even if in the same period there were several international financial crises (such as, the financial crisis in the South-East Asia in 1997 and in Russia in 1998, and the Argentine economic crisis in the late 90s, see Reinhart and Rogoff, 2009 for more details). During the Great Moderation, the absence of high volatility in macroeconomic variables and of monetary policy regime makes the study of the relationship between the yield curve and macroeconomic variables easier and bereft of financial turmoil. Moreover, considering this historical period we can avoid the changes in regime and time-variation which need to be studied using specific econometric tools as shown in Mumtaz and Surico (2009) and Bianchi et al. (2009). Even if there are well documented discussions of analysis of the term structure and macroeconomic variables such as Diebold and Li (2006), Diebold et al. (2006), Gasha et al. (2010), and Medeiros and Rodrguez (2011), no paper focuses on the Great Moderation years. Furthermore, the empirical analysis focuses only on US economy, ignoring spillovers and global interactions with other economies.[2]

As a preliminary analysis, we implement an Impulse-Response Functions (IRFs) exercise to understand the reaction of the term structure to macroeconomic shocks, using a yield curve of seven maturities. According to the IRF analysis, a common behavior of the overall term structure corresponded to a specific macroeconomic shock would be impossible to define.

Since the term structure depicts a set of yields on US Treasury securities of different maturities, focusing on the relationship among short-, medium-, and long-term yields, a term structure with several maturities is necessary to implement a complete analysis. The cross-section of the observed yields is not sufficient to explain the term structure, for example the yield series for 1-month Treasury bond starts only from 2001. To recover a complete US Treasury yield curve, we use a latent factor no-arbitrage model which, in addition, exploits the relationship between these factors and the macroeconomic variables that underlie

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[1] Several papers discuss the impact of the Financial Crisis of 2007–2009 on the term structure and on the spreads (see, Medeiros and Rodrguez, 2011; De Pace and Weber, 2013; Cenesizoglu et al., 2013; and Contessi et al., 2014).

[2] For discussion about Euro area and UK, see respectively Lemke (2008) and Bianchi et al. (2009).

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the term structure. We interpolate the term structure using the three latent factors, level, slope, and curvature. We repeat the IRF exercise with the new interpolated term structure.

In the finance literature, there are essentially two models to study the yield curve, the Nelson–Siegel models, or NSMs, and Affine-Term Structure models, or ATSMs as discussed in Diebold et al., 2005; Van Deventer et al., 2005; Baz and Chacko, 2004; and Bolder, 2001. The main feature of these two models is to mimic an observed yield curve. On one side, in the NSMs, we rely on latent factors (such as level, slope, and curvature) which are the parameters related to a mathematical approximating function. Diebold and Li (2006), Diebold et al. (2006), and Gasha et al. (2010) introduce a dynamic version of NSMs and the possibility to include observable macroeconomic variables; instead, in Ang and Piazzesi, 2003, the discussion about the joint behavior of the term structure and macroeconomic variables is proposed in a no-arbitrage framework. On the other side, the ATSMs refer to traditional yield curve models in the finance literature, such as the general single-factor model, the Cox–Ingersoll–Ross (CIR) model, and the multi-factor model. In Christensen et al. (2009, 2011), they show how to reconcile the NSM with the absence of arbitrage by deriving an affine model that maintains the dynamic component of the term structure. This hybrid model combines the best of both yield-curve modeling traditions.

We concentrate the empirical analysis on the NSMs. Diebold and Li (2006) discuss the power of these models which can account for the existence of unobservable, or latent factors, and their corresponded factor loadings and key economic variables. The three factors are compared to their empirical counterparts, i.e. level, slope, and curvature. The level factor reports the same pattern as two measures of the inflation expectations, Survey of Professional Forecasters and FED Greenbook. The slope and the curvature factors are related respectively to the short-term rate and to two macroeconomic variables such as the industrial productivity and the consumption.

This paper contributes to the literature presenting an empirical exercise in the spirit of Diebold and Li (2006) and Diebold et al. (2006). We use the three latent factors to propose an interpolated term structure which helps the policymaker to observe the response of the entire term structure to macroeconomic shocks. The interpolated term structure, the focus on the Great Moderation period, and an IRF analysis on the whole yield curve are the main novelties introduced by this paper in the literature of macro-finance term structure models. Using the interpolating curve, the policymaker can observe the behavior of all maturities in an IRF analysis. An interesting result is reported. More thickness of the responses means a smaller difference across maturities to respond to a macroeconomic impact; meanwhile, less thickness means a larger difference across maturities. Hence, as main policy implication, we note how any macroeconomic shock, not only a monetary shock, can affect the maturities of the yield curve differently.

The remainder of this paper is organized as follows. Section 2 introduces the Nelson–Siegel models as the methodology implemented to interpolate the term structure. Section 3 discusses the empirical analysis using the observed and the interpolated yield curves. Section 4 closes the article.

2. Methodology

The term structure depicts a set of yields on US Treasury securities of different maturities. The main feature of the term structure is to evidence the relationship among short-, medium-, and long-term yields. Several studies suggest no stable relationship over time with different shapes when considering different historical samples (Diebold and Li (2006), Mumtaz and Surico (2009), Gasha et al. (2010), and Medeiros and Rodrguez (2011)). The instability can be recovered using the Nelson–Siegel models (NSMs) which reproduce the historical average sample of the term structure. As explained in Diebold and Li (2006),[3] the NSMs can account for the existence of unobservable, or latent factors, and their associated factor loadings and key macroeconomic variables that underlie US Treasury security yields.

We use the NSM to recover the three factors, level, slope, and curvature, to interpolate the term structure.

2.1. Yield-only Nelson–Siegel model

At any given time, we have a large set of yields. As suggested by Diebold and Li (2006), we use the Nelson and Siegel (1987) functional form, which is a convenient and parsimonious three-component exponential approximation. The Nelson and Siegel (1987), as extended by Siegel and Nelson (1988), work with the forward rate curve:

$$f_t(\tau) = \beta_{1t} + \beta_{2t} e^{-\lambda_t \tau} + \beta_{3t} \lambda_t e^{-\lambda_t \tau}, \tag{1}$$

where $f_t(\tau)$ is the instantaneous forward rate, and where τ denotes maturity. The Nelson–Siegel forward rate curve can be viewed as a constant plus a Laguerre function, which is a polynomial times an exponential decay term and is a popular mathematical approximating function as described in Diebold and Li (2006). The corresponding yield curve, $y(\tau)$, is:

$$y_t(\tau) = \beta_{1t} + \beta_{2t} \left(\frac{1 - e^{-\lambda_t \tau}}{\lambda_t \tau} \right) + \beta_{3t} \left(\frac{1 - e^{-\lambda_t \tau}}{\lambda_t \tau} - e^{-\lambda_t \tau} \right). \tag{2}$$

The Nelson–Siegel yield curve also corresponds to a discount curve that begins at one at zero maturity and approaches zero at infinite maturity.

The parameter λ_t governs the exponential decay rate; small values of λ_t mean slow decay and can better fit the curve at long maturities; instead large values of λ_t mean fast decay and can better fit the curve at short. Moreover, λ_t governs where the loading on β_{3t} achieves its maximum.[4]

β_{1t}, β_{2t}, and β_{3t} are the three latent dynamic factors called in Diebold et al. (2006) as time-varying *level*, *slope*, and *curvature* factors. The loading on β_{1t} is 1, a constant that does not decay to zero in the limit, so the first factor can be interpreted as a long-term factor. The long-term factor β_{1t}, for example, governs the yield curve level. As shown in Diebold and Li (2006), the level can be represented by the following combination, $[y_t(3) + y_t(24) + y_t(120)]/3$. Moreover, we can note that an increase in β_{1t} increases all yields equally, as the loading is identical at all maturities, thereby changing the level of the yield curve. The loading on β_{2t} is $\left(\frac{1-e^{-\lambda_t \tau}}{\lambda_t \tau}\right)$, which is a function that starts at 1 but decays monotonically and quickly to 0, so the second factor can be interpreted as a short-term factor. The short-term factor β_{2t} is closely related to the yield curve slope, which we define as the three-month yield minus the ten-year yield. Moreover, we can note that an increase in β_{2t} increases short yields more than long yields, because the short rates load on β_{2t} more heavily, thereby changing the slope of the yield curve. As concerns this property, Dai and Singleton (2000) show that the three-factor models of Balduzzi et al. (1996) and Chen (1996) impose the restriction that the instantaneous yield is an affine function of only two of the three state variables, a property shared by the Andersen and Lund (1997) three-factor non-affine model.

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[3] On one hand, Knez et al. (1994), Duffie and Kan (1996), and Dai and Singleton (2000) consider models in which a handful of unobserved factors explain the entire set of yields. These factors are often given labels such as "level," "slope," and "curvature," but they are not linked explicitly to macroeconomic variables. On the other hand, as explained in Ang and Piazzesi (2003) and repropose by Diebold et al. (2006), we can incorporate macroeconomic determinants into multi-factor yield curve models.

[4] In our empirical exercise, we assume a fixed $\lambda = 0.0609$ for all t as used in Diebold and Li (2006).

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