The Macroeconomic Determinants of the US Term Structure during the Great Moderation[1]

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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.

JEL CODES: G12, E43, E44, E58

KEYWORDS: Term structure of interest rates, yield curve, VAR, Factor Model

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. (2010), Medeiros and Rodriguez (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 make 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

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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 Rodríguez, 2011; De Pace and Weber, 2013; Cenesizoglu, Larocque, and Normandin, 2013; and Contessi, De Pace, and Guidolin, 2014)

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 Rodriguez (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 IRFs 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 the term structure. We interpolate the term structure using the three latent factors, level, slope, and curvature. We repeat the IRFs 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,

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

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 IRFs 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 behaviour of all maturities in an IRFs 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 curve. 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 Rodriguez (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.

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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.

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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:

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

where $f_t\left(\tau\right)$ 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, $y\left(\tau\right)$, is:

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

The Nelson-Siegel yield curve also corresponding 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].

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

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 nonaffine model.

The loading on β_{3t} is $\left(\frac{1-e^{-\lambda_t \tau}}{\lambda_t \tau} - e^{-\lambda_t \tau}\right)$, which starts at 0 (and is thus not short-term), increases, and then decays to zero and thus is not long-term, so the third factor can be interpreted as a medium-term factor. The medium term factor is closely related to the yield curvature which we can define as $2y_t(24) - y_t(3) - y_t(120)$. Moreover, we can note that an increase in β_{3t} will have little effect on very short or very long yields, which load minimally on it, but will increase medium-term yields, which load more heavily on it, thereby increasing yield curve curvature.

As argued in Diebold et al. (2006) and in Gasha et al. (2010), we use the state-space

representation which provides a powerful framework for analysis and estimation of dynamic models due to the application of the Kalman filter in a maximum likelihood estimation to recover the underlying factors.

First, we re-write Eq. (2) as:

$$y_t(\tau) = L_t + S_t \left(\frac{1 - e^{-\lambda_t \tau}}{\lambda_t \tau} \right) + C_t \left(\frac{1 - e^{-\lambda_t \tau}}{\lambda_t \tau} - e^{-\lambda_t \tau} \right), \tag{3}$$

where L_t, S_t, and C_t are the time-varying *level, slope, curvature*. If the dynamic movements of L_t, S_t, and C_t follow a vector autoregressive process of first order, the model can be represented in a state-space format.

The transition equation, which governs the dynamics of the state vector, is:

$$\begin{pmatrix} L_t - \mu_L \\ S_t - \mu_S \\ C_t - \mu_C \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} L_{t-1} - \mu_L \\ S_{t-1} - \mu_S \\ C_{t-1} - \mu_C \end{pmatrix} + \begin{pmatrix} \eta_t(L) \\ \eta_t(S) \\ \eta_t(C) \end{pmatrix}, \tag{4}$$

$t = 1, ..., T.$

The measurement equation, which relates a set of N yields to the three unobservable factors, is:

$$\begin{pmatrix} y_t(\tau_1) \\ y_t(\tau_2) \\ ... \\ y_t(\tau_N) \end{pmatrix} = \begin{pmatrix} 1 & \frac{1-e^{-\lambda_t \tau_1}}{\lambda_t \tau_1} & \frac{1-e^{-\lambda_t \tau_1}}{\lambda_t \tau_1} - e^{-\lambda_t \tau_1} \\ 1 & \frac{1-e^{-\lambda_t \tau_2}}{\lambda_t \tau_2} & \frac{1-e^{-\lambda_t \tau_2}}{\lambda_t \tau_2} - e^{-\lambda_t \tau_2} \\ 1 & ... & ... \\ 1 & \frac{1-e^{-\lambda_t \tau_N}}{\lambda_t \tau_N} & \frac{1-e^{-\lambda_t \tau_N}}{\lambda_t \tau_N} - e^{-\lambda_t \tau_N} \end{pmatrix} \begin{pmatrix} L_t \\ S_t \\ C_t \end{pmatrix} + \begin{pmatrix} \varepsilon_t(\tau_1) \\ \varepsilon_t(\tau_2) \\ ... \\ \varepsilon_t(\tau_N) \end{pmatrix}, \tag{5}$$

$t = 1, ..., T.$

The state-space representation in a generic format is as follows:

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\begin{align}
(f_t - \mu) &= A(f_{t-1} - \mu) + \eta_t, \tag{6} \\
y_t &= \Lambda f_t + \varepsilon_t. \tag{7}
\end{align}
$$

where in the transition equation, Eq. (6), the unobservable vector $f_t = (L_t, S_t, C_t)$, the mean state vector μ is a 3×1 vector of coefficients, the transition matrix A is a 3×3 matrix of coefficients, η_t is a white noise transition disturbance with a 3×3 non-diagonal covariance matrix Q. Instead, in the measurement equation, Eq. (7), vector of yields y_t contains N maturities, the measurement matrix Λ is an $N \times 3$ matrix whose columns are the loadings associated with the respective factors, and ε_t is a white noise measurement disturbance with an $N \times N$ diagonal covariance matrix H.

As shown in Diebold et al. (2006), for non linear least-squares optimality of the Kalman filter, we require the white noise transition and measurement disturbances be orthogonal to each other and to the initial state:

$$
\begin{align}
\begin{pmatrix} \eta_t \\ \varepsilon_t \end{pmatrix} &\sim WN \left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} Q & 0 \\ 0 & H \end{pmatrix} \right], \tag{8} \\
E(f_0 \eta_t^{'}) &= 0 \text{ and } E(f_0 \varepsilon_t^{'}) = 0 \tag{9}
\end{align}
$$

Diebold et al. (2006) assume that the H matrix is diagonal and the Q matrix is non-diagonal. The assumption of a diagonal H matrix, which implies that the deviations of yields of different maturities from the yield curve are uncorrelated, is quite standard[5].

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[5] For example, to estimate the no-arbitrage term structure models, "measurement error" is added to the observed yields. The same assumption is required for computational tractability given the large number of observed yields used.

The assumption of an unrestricted Q matrix allows the shocks to the three term structure factors to be correlated

2.2 Yield-Macro Nelson Siegel Model

In the Yield-Macro Nelson Siegel model, we emphasize on the relationships among $\widehat{L}_t$, $\widehat{S}_t$, and $\widehat{C}_t$ and the macroeconomic variables. As follows the approach proposed by Diebold et al. (2006) to use a state-space representation to incorporate macroeconomic factors in a latent factor model of the term structure to analyze the potential bidirectional feedback between the term structure and the macroeconomic variables. We include in the state vector the four key variables: industrial production index (IP_t), annual price inflation ($INFL_t$), personal consumption ($PCOM_t$), and the Federal Funds rate (FFR_t).

The extension of the yields-only model adds the three macroeconomic variables to the set of the state variables and replace Eqs. (6) - (8) with:

$$(f'_t - \mu) = A(f'_{t-1} - \mu) + \eta_t, \tag{10}$$

$$y_t = \Lambda f'_t + \varepsilon_t, \tag{11}$$

$$\begin{pmatrix} \eta_t \\ \varepsilon_t \end{pmatrix} \sim WN \left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} Q & 0 \\ 0 & H \end{pmatrix} \right]. \tag{12}$$

where $f'_t = (L_t, S_t, C_t, IP_t, INFL_t, PCOM_t, FFR_t)$ and the dimension of A, μ, η_t and Q are increased accordingly to 7×1, 7×7, and 7×1, respectively.

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3 Empirical Analysis

Before interpolating the term structure, we implement a VAR as a preliminary analysis to present the stylized facts about the relation between macroeconomic shocks and the yield curve. The same exercise is proposed with the interpolated term structure.

3.1 Data

We consider US Treasury monthly data from 1984:1 to 2007:12[6]. Figure 1a presents the plot of the seven observed maturity 3, 6, 12, 24, 36, 60, and 120 months[7]. Meanwhile, Figure 1b shows the complete term structure in a 3D format.
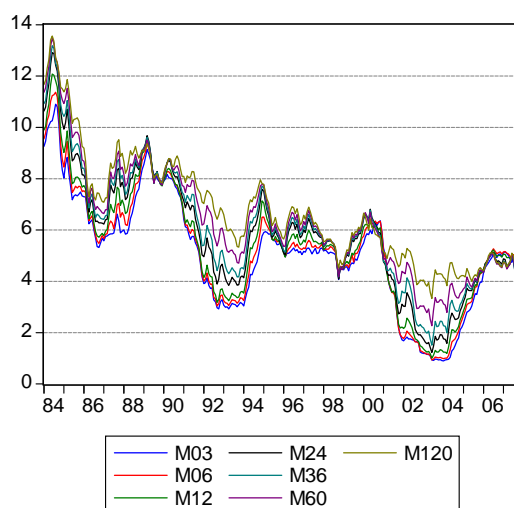
Figure 1a: US Treasury yields

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[6] The data are download from the database maintained by the Federal Reserve Bank of St. Louis (http://research.stlouisfed.org/fred2/).

[7] We select only these maturities, since they are longer and disposable for all years of the Great Moderation period.
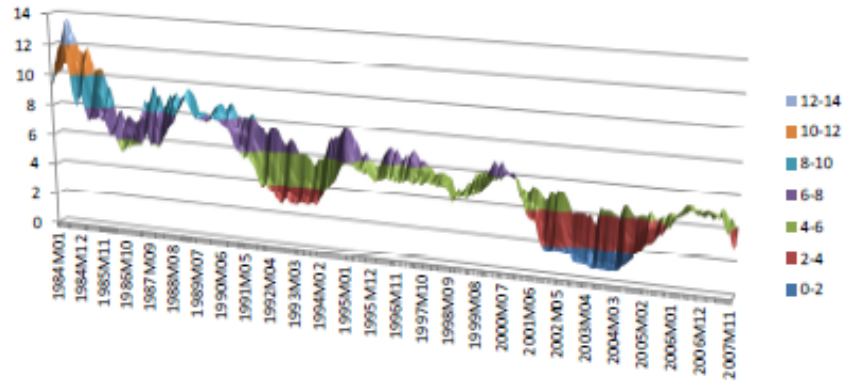
Figure 1b: US Treasury yields in 3D

Figure 1a and Figure 1b show that the U.S. yield curve exhibits sizable inter temporal variation in its level, and, although the variation in the slope and curvature is less marked, it is nonetheless evident. In particular, we can note that during the periods 1990-1995 and 2000-2005, the difference across the maturities (especially between the long term and the short term) is greater than the difference reported in other periods.

To select the key macroeconomic variables, we follow Evans and Marshall (2007). Industrial production index is detrended with both a deterministic and a stochastic trend, Inflation is measured as monthly changes in the consumer price index, the consumption is given by the personal consumption expenditures and the policy instrument is the Federal funds rate. In Figure 2, we report the macroeconomic variables already transformed and used for the empirical analysis.
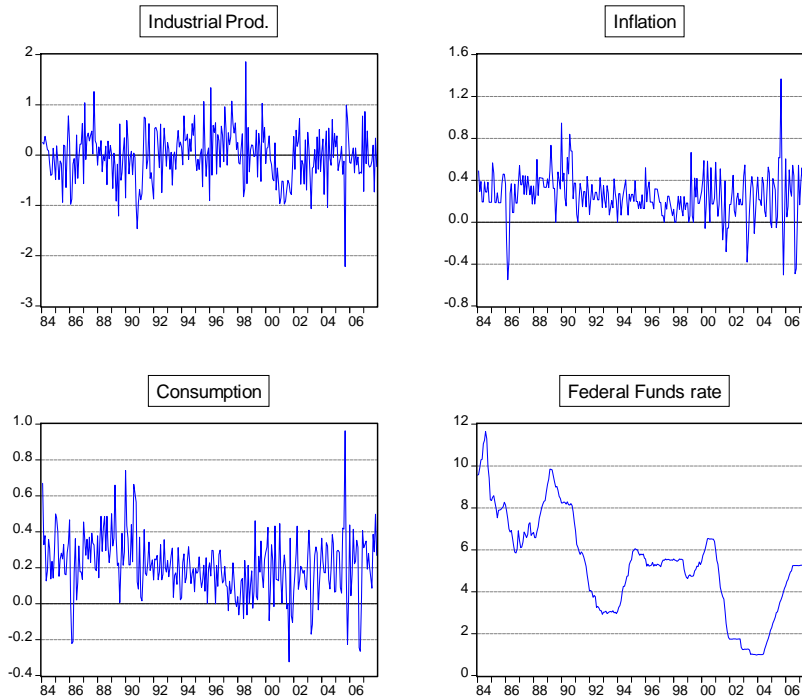
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Figure 2: US Macroeconomic variables

At first glance, in Figure 2, we note that the macroeconomic variables do not present high volatility and especially for the short term interest rate there are no different regimes. Considering years before (the Great Inflation era) and year after (the Financial crisis) the Great Moderation, it implies a more in-depth discussion of the relation between the yield curve and the macroeconomic variables, studying the changes in regimes, the nonlinearities, and the time variation (see Mumtaz and Surico (2009) and Bianchi et al. (2009) for more details).

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3.2 IRFs: a preliminary analysis

To investigate about the macroeconomic determinants of the term structure, we implement a preliminary impulse-response exercise (IRFs). We estimate a VAR model with 12 lags considering the macroeconomic variables $(IP_t, INFL_t, PCOM_t, FFR_t)$ and the seven maturities, using the Cholesky identification strategy.

Figure 4 shows the responses of each maturity to the macro variables shocks, ordered by maturity. At first glance, there is not a clear evidence across maturities. In the shorter term (m03) and for impulses of inflation and Federal Funds rate, we note an initial decreasing pattern which switches to an increasing one. Contrary, responses to the consumption and the industrial production index show an opposite behavior. We notice that for m24, m36, and m120 all the macroeconomic variables have an initial positive response.
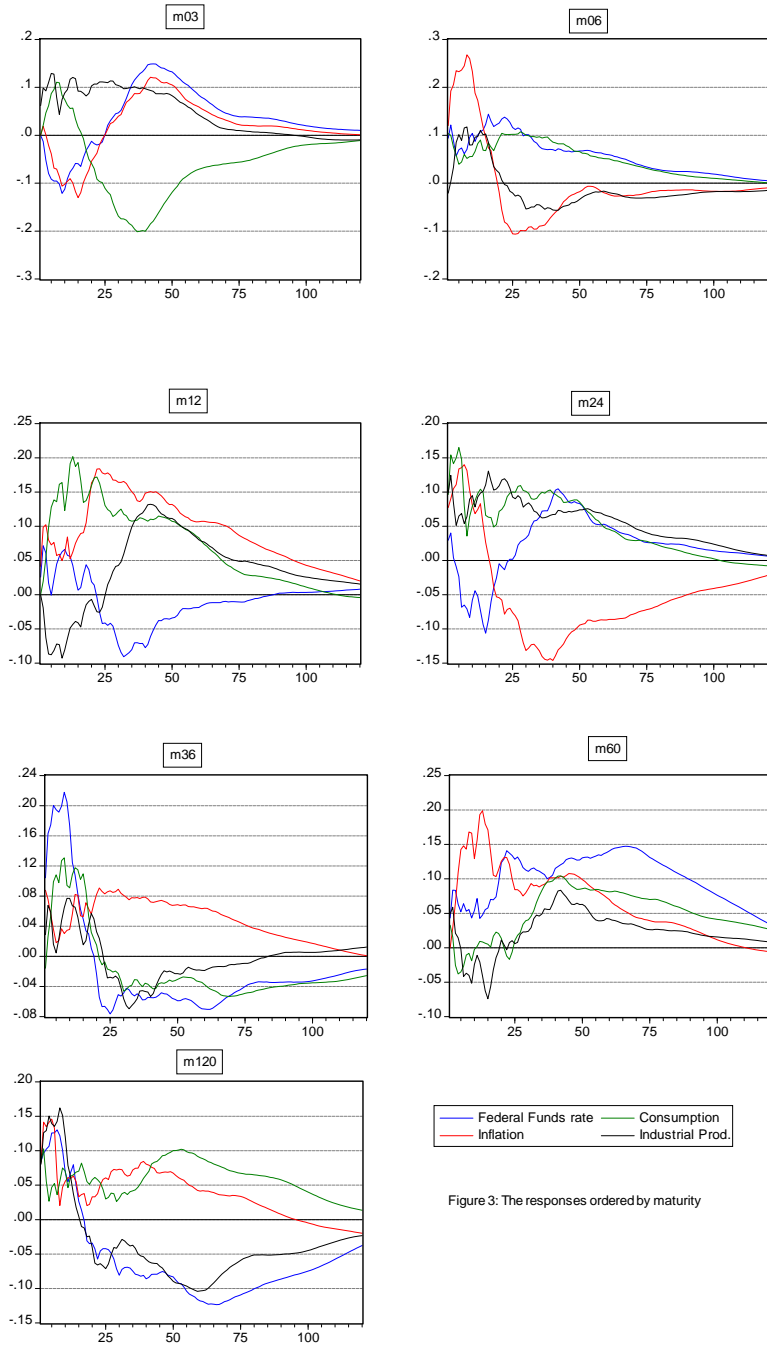
Figure 3: The responses ordered by maturity

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Figure 4 shows the responses of each maturity to the macroeconomic variables shocks, ordered by macroeconomic variable. For the same variable, the response changes across different maturities and we cannot find a precise behavior. Moreover, the response to a monetary policy shock shows the most puzzling picture.
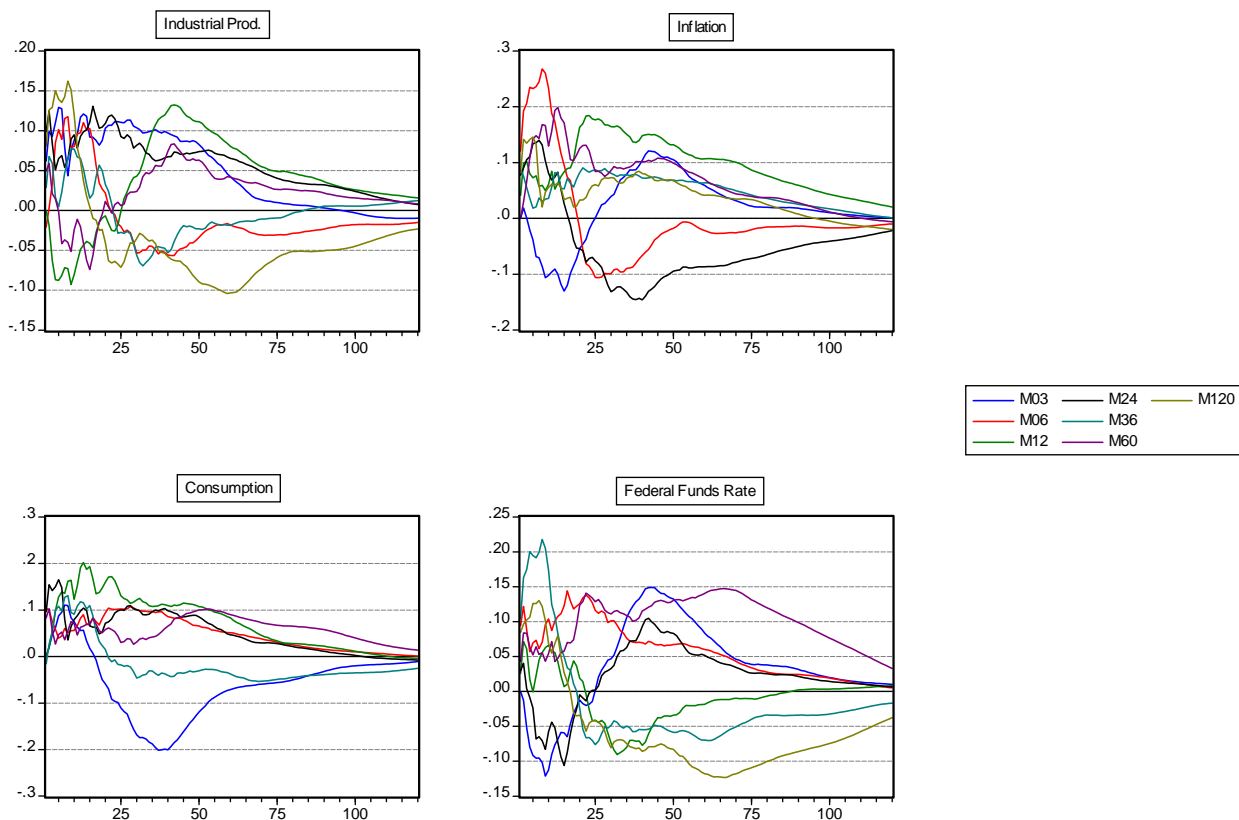

Figure 4: The responses ordered by macroeconomic variable

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, the Nelson-Siegel model, which, in addition, exploits the relationship between these factors and the macroeconomic variables that underlie the term structure.

3.3   Extracted Latent Factors

Using the NSMs, we extract three latent factors using the state-space representation augmented by the macro variables as described in Eq. (10) and Eq. (11). For more technical details, see Diebold et al. (2006) and Gasha et al. (2010). The three factors, level, slope, and curvature, are extracted considering the US Treasury yield curve with maturities of 3, 6, 12, 24, 36, 60, and 120 months. Figure 5 shows the comparison between the factors extracted using the NSM and their "empirical counterparts". The empirical counterparts of the factors can be thought of as crude proxies for the level, slope and curvature of the yield curve and following Diebold and Li (2006) are calculated as:

$$\text{Level: } [y_t(3) + y_t(24) + y_t(120)]/3$$
$$\text{Slope: } y_t(3) - y_t(120)$$
$$\text{Curvature: } 2y_t(24) - y_t(3) - y_t(120).$$

In the top left panel of Figure 5, we show the level factor (blue line) and the counterpart (red line). The correlation between the level factor and its counterpart is around 0.90, which is similar to the numbers reported by Diebold et al. (2006) and Mumtaz and Surico (2009) [8]. The bottom left panel reports two measure of inflation expectations: the Survey of Professional Forecasters (SPF) and the FED Greenbook 1 year head as shown in Mumtaz and Surico (2009)[9]. Comparing the level factors and the two measures of expectations, we

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[8] Mumtaz and Surico (2009) report a correlation around 0.90 with time-varying coefficients and around 0.80 without time-varying coefficients for the sample period from 1970 to 2000. Diebold et al. (2006) consider a range from 1985 to 2000 with a correlation around 0.97.

[9] These forecasts for the two measures of expectations are available at quarterly frequency on the web site of the Federal Reserve Bank of Philadelphia, respectively at http://www.phil.frb.org/econ/spf/spfmed.html

can recognize a strong link between the level of the yield curve and inflation expectations (see Kozicki and Tinsley (2001); Hordahl et al. (2006)).

In the middle of the panel, we report the slope factor which is correlated with the empirical counterpart with a number around 0.99. In the Nelson–Siegel model, the slope is identified as the factor that is loaded more heavily by yields of short maturities, hence we can find a similar pattern between slope and Federal Funds rate. Lastly, the correlation between the curvature factor and the empirical counterpart is around 0.98 and we can recognize a similar behaviour between the curvature and the industrial productivity index.
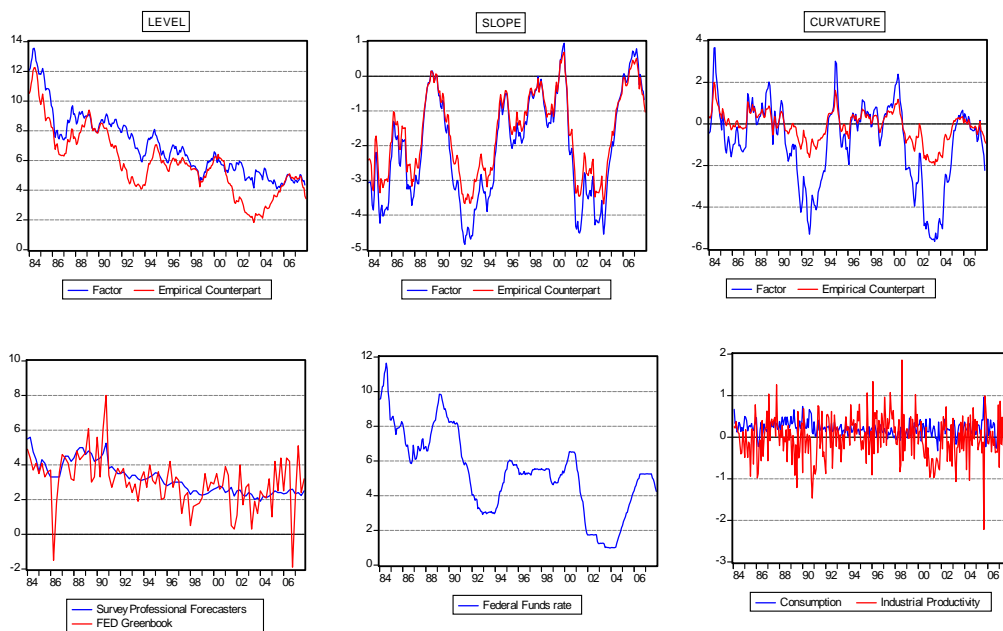

Figure 5. Factors and empirical counterpart

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3.4 Interpolating the term structure

The three extracted factors are used to interpolate a complete term structure using the Eq (2):

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

where β_{1t}, β_{2t}, and β_{3t} are substituted by the three factors estimated and τ is substituted by the maturity for each corresponding yield[10].

Figure 6 compares the observed maturities with the maturities interpolated with the latent factors. We note that the interpolated yields is very close to the observed yields and the correlation is over 0.95 for each maturity.

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[10] We repeat the interpolation for 21 maturities (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 24, 36, 48, 60, 72, 96, 108, 120 months).
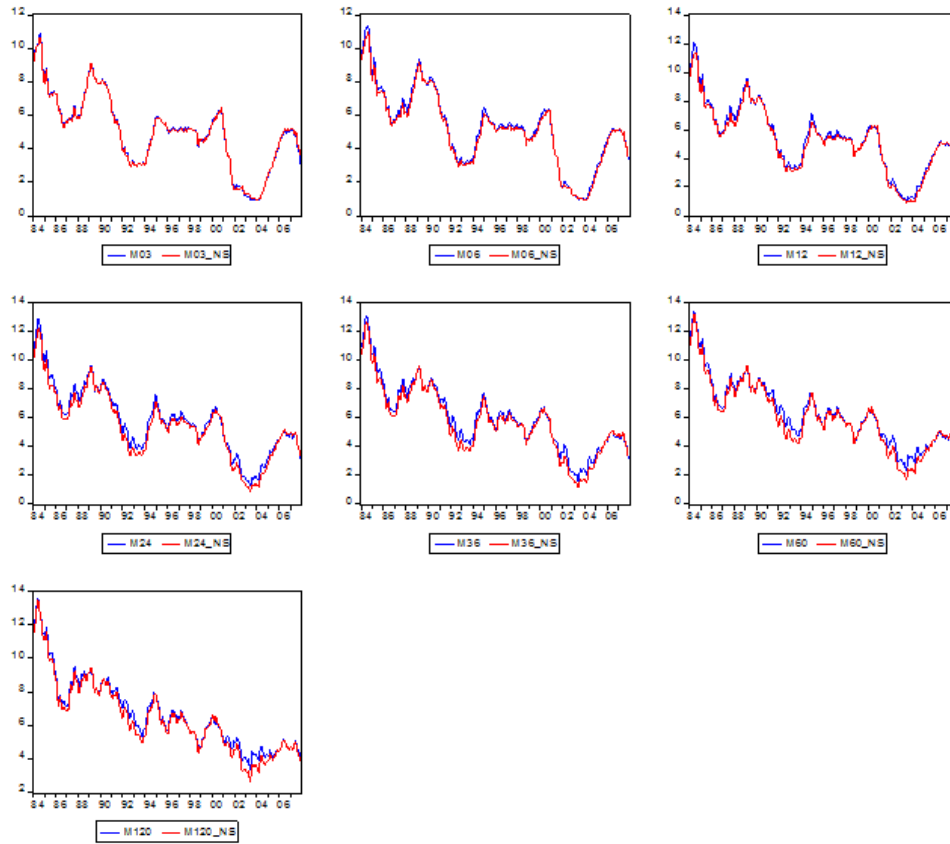
Figure 6: Comparison observed and interpolated yields

Figure 7a and Figure 7b show the interpolated term structure with 21 maturities. Both plots show a compact behaviour across the yields.
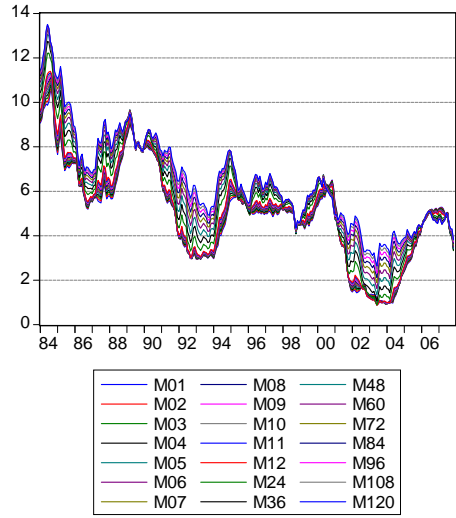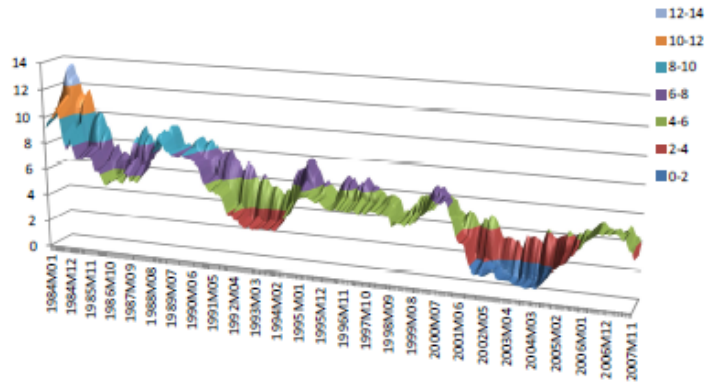
Figure 7a: The interpolated term structure

Figure 7b: The interpolated term structure in 3D

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3.5 IRFs with the interpolated term structure

We repeat the preliminary analysis of the responses of each maturity to the macroeconomic shocks, using the term structure with 21 yields.

Figure 8, plotting the IRFs ordered by macroeconomic variable, shows how in the short period the responses are compact over maturities. However, between 20 and 60 months, the thickness of the responses decreased, reporting a wide difference from a short yield to a medium yield. The only exception is given by a monetary policy shock which reports a wide difference in responses in the short and in the medium period up 60 months. Another interesting aspect is that for all shocks, except for the consumption shock, around 25-30 months, there is a point in which all the responses are equal. In the medium period, we note that consumption shows the smaller distance between the short and the long yields. Instead, inflation is the variable which has a sizable impact across different maturities showing two episodes of wider responses of the maturities. The industrial productivity index as the Federal Funds rate evidence only one big episode of a large response between the short and the long yields, reporting a similar behavior. In the long period, after 60 months, we note a compact pattern for all responses. Consequently, we conclude how the macroeconomic shocks have implications for the whole term structure, this also means that the entire yield curve, not just the short rate, contains potentially valuable information about not only the monetary policy shifts, but also about an industrial productivity shock, inflation and consumption shocks.
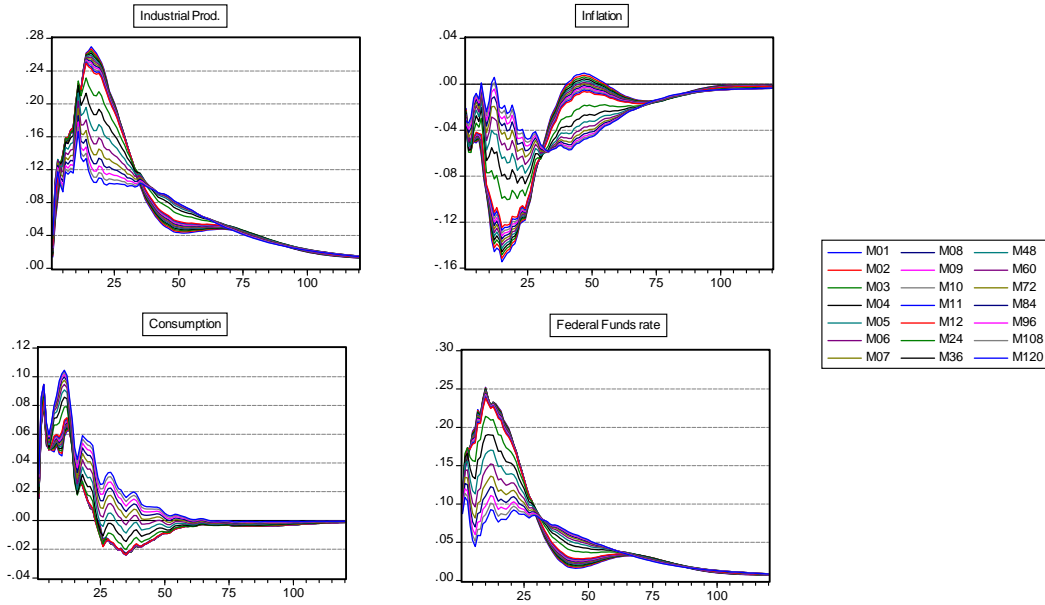
Figure 8: IRF from the interpolated term structure

4   Concluding Remarks

We study the impact of the macroeconomic determinants on the US term structure during the Great Moderation period. To interpolate the yield curve, we extract, using a Nelson-Siegel Model, three latent factors, level, slope, and curvature. The three factors, even if they come from the yield curve, can be associated to relevant macroeconomic variables, such as, inflation, industrial productivity index, Federal Funds rate, and consumption. Our contribution is to interpolate the term structure with the latent factors to investigate the impact of each macroeconomic variable on each maturity of the yield curve.

As policy implication, the interpolated term structure informs the policymaker how

all the macro shocks, not only the monetary policy shifts, impact the overall yield curve. Moreover, the responses are of less thickness, reporting a wide difference in response from a short period to a medium period, between 20 and 60 months.

References

[1] Afonso A, Martins MMF. 2012. Level, slope, curvature of the sovereign yield curve, and fiscal behaviour. Journal of Banking and Finance, 36, 1789–1807.

[2] Aguiar-Conraria L, Martins MMF, Soares MJ. 2012. The yield curve and the macro-economy across time and frequencies, Journal of Economic Dynamics and Control, Elsevier, vol. 36(12), pages 1950-1970.

[3] Andersen TG, Lund J. 1997. Stochastic volatility and mean drift in the short term interest rate diffusion: source of steepness, level and curvature in the yield curve. Working Paper 214, Department of Finance, Kellogg School, Northwestern University.

[4] Ang A, Piazzesi M. 2003. A no-arbitrage vector autoregression of term structure dynamics with macroeconomic and latent variables. Journal of Monetary Economics, Elsevier, vol. 50(4), pages 745-787.

[5] Balduzzi P, Das SR, Foresi S, Sundaram R. 1996. A simple approach to three-factor affine term structure models. Journal of Fixed Income 6, 43–53.

[6] Baz J, Chacko G. 2004. Financial Derivatives: Pricing, Applications and Mathematics (Cambridge, United Kingdom: Cambridge University Press).

[7] Bianchi F, Mumtaz H, Surico P. 2009. The great moderation of the term structure of UK interest rates. Journal of Monetary Economics 56: 856–871.

[8] Bolder DJ. 2001. Affine term structure Models: Theory and Implementation. Working Paper 2001-15 (Ottawa: Bank of Canada).

[9] Cenesizoglu T, Larocque D, Normandin M. 2013. Conventional Monetary Policy and the Term Structure of Interest Rates during the Financial Crisis. mimeo.

[10] Chen L. 1996. Stochastic Mean and Stochastic Volatility—A Three Factor Model of the Term Structure of Interest Rates and its Application to the Pricing of Interest Rate Derivatives. Blackwell Publishers, London.

[11] Christensen JHE, Diebold FX, Rudebusch GD. 2009. An Arbitrage-Free Generalized Nelson-Siegel Term Structure Model, Econometrics Journal, 1, 1-31.

[12] Christensen JHE, Diebold FX, Rudebusch GD. 2011. The Affine Arbitrage-Free Class of Nelson-Siegel Term Structure Models. Journal of Econometrics, 164, 4-20.

[13] Contessi S, De Pace P, Guidolin M. 2014. How Did the Financial Crisis Alter the Correlations of U.S. Yield Spreads?, Journal of Empirical Finance forthcoming.

[14] Dai, Q, Singleton, K. 2000. Specification analysis of affine term structure models. Journal of Finance 55, 1943–1978.

[15] De Pace P, Weber K. 2013. High yield spreads, real economic activity, and the financial accelerator. Economics Letters, Volume 121, Issue 3, December 2013, Pages 346–355.

[16] Diebold FX, Li C. 2006. Forecasting the term structure of government bond yields. Journal of Econometrics 130: 337–364.

[17] Diebold, FX, Piazzesi M, Rudebusch, GD. 2005. Modeling Bond Yields in Finance and Macroeconomics. American Economic Review Papers and Proceedings, 95, 415–420.

[18] Diebold FX, Rudebusch GD, Aruoba SB. 2006. The macroeconomy and the yield curve: a dynamic latent factor approach. Journal of Econometrics 131: 309–338.

[19] Duffie D, Kan R. 1996. A yield-factor model of interest rates. Mathematical Finance 6, 379–406.

[20] Evans CL, Marshall D. 2007. Economic determinants of the nominal treasury yield curve. Journal of Monetary Economics 54: 1986–2003.

[21] Fama EF, Bliss RR. 1987. The information in long-maturity forward rates. American Economic Review 77(4): 680–692.

[22] Gasha G, He Y, Medeiros C, Rodriguez M, Salvati J, Yi J. 2010. On the Estimation of Term Structure Models and An Application to the United States. IMF Working Paper. WP/10/258.

[23] Hordahl P, Tristani O, Vestin D. 2006. A joint econometric model of macroeconomic and term structure dynamics. Journal of Econometrics 127(1–2): 405–444.

[24] Knez P, Litterman R, Scheinkman J. 1994. Exploration into factors explaining money market returns. Journal of Finance 49, 1861–1882.

[25] Kozicki TPA. 2001. Shifting endpoints in the term structure of interest rates. Journal of Monetary Economics 47(3): 613–652.

[26] Lemke W. 2008. An affine macro-finance term structure model for the euro area, The North American Journal of Economics and Finance, Elsevier, vol. 19(1), pages 41-69, March.

[27] Mumtaz H, Surico P. 2009. Time-varying yield curve dynamics and monetary policy. Journal of Applied Econometrics 24: 895–913.

[28] Medeiros C, Rodríguez M. 2011. The Dynamics of the Term Structure of Interest Rates in the United States in Light of the Financial Crisis of 2007–10. IMF Working

Paper. WP/11/84.

[29] Nelson CR, Siegel AF. 1987. Parsimonious modeling of yield curves. Journal of Business 60(4): 473–489.

[30] Reinhart C, Rogoff K. 2009. The Aftermath of Financial Crises. The American Economic Review Vol. 99, No. 2, Papers and Proceedings of the One Hundred Twenty-First Meeting of the American Economic Association (May, 2009) , pp. 466-472.

[31] Siegel AF, Nelson CR. 1988. Long-term behavior of yield curves. Journal of Financial and Quantitative Analysis 23, 105–110.

[32] Stock JH, Watson M. 2002. Has the Business Cycle Changed and Why? NBER Macroeconomics Annual.

[33] Van Deventer DR, Imai K, Mesler M. 2005. Advanced Financial Risk Management (Singapore: John Wiley & Sons (Asia) Pte Ltd).