ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS

DEPARTMENT OF ECONOMICS

WORKING PAPER SERIES 11-2013

Forecasting Economic Activity from Yield Curve Factors

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April 2, 2013

Abstract

This paper provides clear cut evidence that the slope and curvature factors of the yield curve contain more information about future changes in economic activity than the term spread alone, often used in practice as an indicator of future economic conditions. These two factors constitute independent sources of information about future economic activity, which are offset to each other in term spread regressions. The slope factor has predictive power on future economic activity over longer horizons ahead, compared to the curvature factor. The latter improves the forecasting ability of the term spread over shorter or medium horizons. These results hold for a number of world leading economies.

JEL classification: E23, E43, E44, F30, F44, G12

Keywords: Yield curve, dynamic Nelson Siegel term structure model, yield curve factors, term spread, economic activity, Kalman filter.

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1 Introduction

There is recently growing interest in examining empirically the information context of the term structure of interest rates about future economic activity (see, e.g., Harvey [14], [15], Estrella and Hardouvelis [12], Plosser and Rouwenhorst [21], Ang and Piazzesi [1], Rendu de Lint and Stolin [22], Rudebusch and Wu [23], Piazzesi [20], Diebold et al [11], Ang et al [2]). Most of these studies rely on a regression model which employes the term spread between long and short-term interest rates, referred to as the slope of yield curve, as a regressor and output (or industrial production index) growth rate as a regressand. According to the theory, the short-term interest rate directly depends on the central bank's decisions, while the long-term is determined by the expectations of the bond market participants. A zero or negative term spread (which means a flat, or inverted, yield curve) is often associated with a decline in future economic activity, or as a predictor of economic recessions. This can be explained as follows. Consider, for instance, a tight monetary policy, which increases the short-term interest rate. This policy will also decrease long-term rates and, thus, will flatten (or invert) the yield curve, since bond market's expectations about future recessionary conditions will increase the current demand for savings in the economy.

As is well known in the empirical term structure literature, the yield curve is spanned by three factors, referred to as level, slope and curvature factors (see, e.g., Litterman and Scheinkman [18] and Bliss [4]). Given that the level factor explains parallel shifts of interest rates independently of maturity intervals, often related to changes in long-term expectations about inflation in the economy, the term spread should be mainly determined by the two other factors, the slope and curvature. This paper empirically examines if these two factors constitute independent sources of information about future economic activity and contain more information about it than the term spread itself. The results of our analysis can also shed light on recent macroeconomic studies asserting that the slope factor of the yield curve reflects future business cycle (BC) conditions, while the curvature factor captures policy actions related to short or medium-term adjustments of the current stance of monetary policy (see, e.g., Bekaert [3], Dewachter et al. [7], Dewachter and Lyrio [6], Hordahl et al., [16] and Moench [19]). That is, the fact that, if for instance, economic growth is considered to be undesirably rapid, a restrictive monetary policy will be undertaken by the central bank, and conversely. To retrieve the unobserved factors driving the yield curve and, hence, the term spread, the paper fits into term structure data coming from five leading economies of world, the dynamic Nelson Siegel [17] model (DNSM) (see also Diebold et al. [11] and Diebold and Li [8], inter alia). This model is popular among market and central bank practitioners, as it has been found that fits adequately into yield curves (see, e.g., Diebold et al. [10]).

The results of the paper lead to a number of interesting conclusions. First, they show that the slope and curvature factors of the yield curve constitute independent sources of information about future economic activity. Together, these two factors have superior information about future economic activity than the term spread itself. Using the term spread to forecast future economic activity will thus undermine this information, as the slope and curvature factors are loaded into the term spread with opposite signs and can thus be offset to each other. For most of the countries examined, the paper finds that the slope factor contains significant information about future economic activity up to two-years ahead, while the curvature factor for shorter or medium, horizons. An increase in the slope factor is found to predict a slow down in future economic activity, as it affects negatively the term spread. That is, it implies a flat, or inverted, term spread. This is consistent with evidence provided in the literature by term spread regressions forecasting future economic activity (see above). On the other hand, an increase in the curvature factor is found to be positively associated with future economic activity, as this factor is positively associated with the term spread. These results are in accordance with the theory predicting that the slope factor of the yield curve reflects future business cycle conditions, while the curvature factor captures independent changes in the current monetary policy which last over shorter horizons.

The paper is organized as follows. In section 2, we describe the data and re-estimate term spread regressions forecasting future economic activity. In section 3, we fit the DNSM into our data set and retrieve the slope and curvature factors of the yield curve. Then, we examine if these two factors contain significant information about future economic activity, by conducting regression analysis. Section 4 concludes the paper.

2 Forecasting economic activity based on term spread regressions

Our data set consists of 265 monthly observations of zero-coupon yields from 1987:05 to 2009:05, with maturity intervals (denoted as τ) varying from 3 to 120 months.[1] This set covers the following five developed countries: the United States (US), Canada (CA), the United Kingdom (UK), Germany (DE) and Japan (JP). To approximate the economic activity of these countries, we rely on their Industrial Production Index (IPI) from 1989:01 to 2009:05, obtained from the OECD data base.[2] For every country i, we measure the cumulative annualized economic growth from the current $t-$period to $k-$periods ahead, denoted as $g_{it,t+k}$, in percentage terms, i.e., $g_{it,t+k} = 100(12/k)(\ln g_{it+k} - \ln g_{it})$.

Figure 1 presents graphs of the term spread between the 5-years and the 3-months zero-coupon interest rate of our data set, which plays the role of the short-term interest rate. This spread is denoted as $spr_{it}(5y) \equiv r_{it}(5y) - r_{it}(3m)$, for all countries i. The shaded areas of the graphs indicate recession periods, announced by the official authorities of the countries. Inspection of the graphs of Figure 1 indicates that a flat (or inverted) yield curve, where short-term

[1] Our data set is taken from Wright [24]. See http://www.aeaweb.org/articles.php?doi=10.1257/aer.101.4.1514
[2] http://stats.oecd.org

rate $r_t(3m)$ is almost the same with long-term rate $r_t(5y)$ (or it takes higher values than it, implying that $spr_{it}(5y)$ takes negative values) precedes economic slow downs, or recessions, as discussed in the introduction.

The graphs of the figure indicate that term spread $spr_{it}(5y)$ precedes economic slow downs for most of the countries examined, with the exceptions Germany for period 1990-1993, where the yield curve inverts during this recessionary period, and Japan for periods 1997- 1999 and 2000-2002. For the case of Germany, this can be attributed to the tight monetary policy of the Bundesbank followed Germany's unification in October of year 1990 in order to avoid inflationary pressures. For Japan, it can be attributed to the very tight regulation of Japanese financial markets by the government during the above recessionary periods, which limited the role of market expectations in determining long-term interest rates. Finally, another interesting conclusion which can be drawn from the graphs of Figure 1 is that almost all the countries examined (especially the US, UK and Canada) tend to simultaneously enter into the recessions occurring during our sample. This can be obviously attributed to common economic policies followed by the countries examined over our sample.

Table 1.a presents least squares (LS) estimates of the following regression model used in the literature to forecast economic activity:

$$g_{it,t+k} = const + \beta_i^{(k)} spr_{it}(5y) + \varepsilon_{it+k}, \text{ for all countries } i. \tag{1}$$

This is done for forecasting horizons $k = \{3, 6, 12, 24\}$ months ahead. The results of Table 1.a are consistent with previous evidence reported in the literature (see references mentioned in the introduction). Term spread $spr_{it}(5y)$ has significant power in predicting future economic activity. This tends to increase with forecasting horizon k. The only exception is Japan, where $spr_{it}(5y)$ has forecasting power on $g_{it,t+k}$ only for short-term horizons, i.e., $k = 3$. As was expected by the theory, the estimates of the term spread slope coefficients $\beta_i^{(k)}$ are positive, implying that a positive (negative) value of $spr_{it}(5y)$ predicts an increase (decrease) in future economic activity.

To see if the term spread holds its predictive ability on marginal changes of growth rate $g_{it+k-j,t+k}$, between two different future periods $t+k-j$ and $t+k$ where $j < k$, in Table 1.b we present LS estimates of term spread regression models, for $j = \{12, 24\}$ and $k = \{24, 36\}$ months ahead (see also Estrella and Hardouvelis [12]), using the following spreads: $[r_{it}(2y) - r_{it}(1y)]$ and $[r_{it}(3y) - r_{it}(1y)]$ as regressors, respectively. The results of this table clearly indicate that the term spread contains also important information about marginal changes in future economic activity, for all k and j examined. The estimates of slope coefficients $\beta_i^{(j,k)}$, reported in the tables, have the correct sign and are significant, for all j and k considered. Note that, for some countries (i.e., Germany and Japan), the forecasting power of these term spread regression models is higher than that of model (1), predicting cumulative growth changes $g_{it,t+k}$.

3 Forecasting economic activity from the slope and curvature factors of the yield curve

The term spread $spr_{it}(5y)$, used as regressor in model (1), contains composite information about future economic activity. As it is argued in many recent macroeconomic studies (see introduction), movements in future economic activity may be independently related to current changes in the slope and curvature factors of the yield curve.

To address the above questions, we first need to retrieve estimates of the slope and curvature factors from the yield curve. To this end, in this section we fit the dynamic term structure model of Nelson and Siegel [17], denoted as (DNSM), into the yield curve, for all countries i. This model enables us to decompose term spread $spr_{it}(5y)$ into the slope and curvature factors of the yield curve, by writing interest rates $r_{it}(\tau)$ in state-space form as follows:[3]

$$r_{it}(\tau) = l_{it} + s_{it}\left(\frac{1-e^{-\lambda_i\tau}}{\lambda_i\tau}\right) + c_{it}\left(\frac{1-e^{-\lambda_i\tau}}{\lambda_i\tau} - e^{-\lambda_i\tau}\right), \text{ for all } i, \tag{2}$$

where $\tau = \{\tau_1, \tau_2, ..., \tau_n\}$ denote maturity intervals, and l_{it}, s_{it} and c_{it} are latent variables which denote the three factors spanning the term structure of interest rates $r_{it}(\tau)$, for all τ. In particular, l_{it} denotes the level factor of the yield curve (referred to as term structure of interest rates $r_{it}(\tau)$) causing parallel shifts to $r_{it}(\tau)$, for all τ, which are often attributed to changes in long-run expectations about inflation. s_{it} denotes the slope factor of the yield curve. This factor converges to unity, as $\tau \to 0$, and to zero, as $\tau \to \infty$, for all t. Thus, it can reflect the effects of changes in future business cycle conditions on $r_{it}(\tau)$. These die out in the long run. c_t denotes the curvature factor of the term structure. This component of $r_{it}(\tau)$ converges to zero as $\tau \to 0$ and $\tau \to \infty$, which means that it is concave in τ. Its effects on $r_{it}(\tau)$ are more profound for short and medium term interest rates (see also Christensen et al. [5], inter alia). Finally, parameter λ_i determines the exponentially decaying effects of factors s_{it} and c_{it} on $r_{it}(\tau)$.

Taking the spread between two different maturity interest rates, i.e., $r_{it}(\tau_l)$ and $r_{it}(\tau_s)$, where τ_l and τ_s stand for the long and short-end maturity intervals, respectively, equation (2) implies that term spread $spr_{it}(\tau_l)$ is determined by the slope and curvature factors s_{it} and c_{it}, respectively, i.e.,

$$spr_{it}(\tau_l) \equiv r_{it}(\tau_l) - r_{it}(\tau_s) = \gamma_{si}s_{it} + \gamma_{ci}c_{it}, \tag{3}$$

for all i, where $\gamma_{si} = \left[\left(\frac{1-e^{-\lambda_i\tau_l}}{\lambda_i\tau_l}\right) - \left(\frac{1-e^{-\lambda_i\tau_s}}{\lambda_i\tau_s}\right)\right]$ and $\gamma_{ci} = \left[\left(\frac{1-e^{-\lambda_i\tau_l}}{\lambda_i\tau_l} - e^{-\lambda_i\tau_l}\right) - \left(\frac{1-e^{-\lambda_i\tau_s}}{\lambda_i\tau_s} - e^{-\lambda_i\tau_s}\right)\right]$. The level factor l_t is cancelled out from term spread $spr_{it}(\tau_l)$. The slope coefficients γ_{si} and γ_{ci} of the last relationship depend on maturity intervals τ_s and τ_l, and parameter λ_i. The patterns of γ_{si} and γ_{ci} with respect to τ_s, τ_l and λ_i will be studied latter on, after estimating λ_i from the data. These can indicate how fast the effects of a change in factors s_{it} and c_{it} on term spread $spr_{it}(\tau_l)$ slow down.

[3] See also Diebold et al [11] and Diebold and Li [8].

3.1 Retrieving yield curve factors s_{it} and c_{it}

To retrieve estimates of factors s_{it} and c_{it}, next we fit the DNSM into our term structure of interest rates data. This is done through the application of the Kalman filter, by writing measurement equation (2) as follows:

$$r_{it} = \Gamma_i(\lambda_i)x_{it} + \varepsilon_{it}, \tag{4}$$

where $r_{it} = (r_{it}(\tau_1), ..., r_{it}(\tau_N))'$, $N = 17$ denote the different maturity intervals used in our estimation, for all i,[4] $\Gamma_i(\lambda_i)$ is an $(N \times 3)$-dimension matrix of loading coefficients, defined as

$$\Gamma_i(\lambda_i) = \begin{bmatrix} 1 & \left(\frac{1-e^{-\lambda_i\tau_1}}{\lambda_i\tau_1}\right) & \left(\frac{1-e^{-\lambda_i\tau_1}}{\lambda_i\tau_1} - e^{-\lambda_i\tau_1}\right) \\ 1 & \left(\frac{1-e^{-\lambda_i\tau_2}}{\lambda_i\tau_2}\right) & \left(\frac{1-e^{-\lambda_i\tau_2}}{\lambda_i\tau_2} - e^{-\lambda_i\tau_2}\right) \\ ... & ... & ... \\ 1 & \left(\frac{1-e^{-\lambda_i\tau_N}}{\lambda_i\tau_N}\right) & \left(\frac{1-e^{-\lambda_i\tau_N}}{\lambda_i\tau_N} - e^{-\lambda_i\tau_N}\right) \end{bmatrix},$$

where $\varepsilon_{it} \sim NIID(0, \Sigma_\varepsilon)$ and $x_{it} = (l_{it}, s_{it}, c_{it})'$ is the vector of state variables. Vector x_{it} is assumed that follows a vector autoregressive process of lag order one, i.e.,

$$\begin{bmatrix} l_{it} \\ s_{it} \\ c_{it} \end{bmatrix} = \begin{bmatrix} \mu_l \\ \mu_s \\ \mu_c \end{bmatrix} + \begin{bmatrix} \phi_{11} & \phi_{12} & \phi_{13} \\ \phi_{21} & \phi_{22} & \phi_{23} \\ \phi_{33} & \phi_{32} & \phi_{31} \end{bmatrix} \begin{bmatrix} l_{it-1} \\ s_{it-1} \\ c_{it-1} \end{bmatrix} + \begin{bmatrix} \eta^l_{it} \\ \eta^s_{it} \\ \eta^c_{it} \end{bmatrix}, \tag{5}$$

or

$$x_{it} = \mu + \Phi x_{it-1} + \eta_{it}, \tag{6}$$

where $\eta_{it} = (\eta^l_{it}, \eta^s_{it}, \eta^c_{it})'$, with $\eta_{it} \sim NIID(0, \Sigma_\eta)$. Equations (4) and (6) constitute a state space system, which can be written in a more compact form as follows:

$$r_{it} = \Gamma_i(\lambda_i)x_{it} + \varepsilon_{it}, \text{ with } x_{it} = \mu + \Phi x_{it-1} + \eta_{it},$$

where

$$\begin{bmatrix} \varepsilon_{it} \\ \eta_{it} \end{bmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \Sigma_\varepsilon & 0 \\ 0 & \Sigma_\eta \end{pmatrix} \right],$$

Σ_ε and Σ_η are the variance-covariance matrices of error terms ε_{it} and η_{it}, respectively. Note that error terms ε_{it} and η_{it} are assumed to be uncorrelated. This is a standard assumption made in the empirical literature (see, e.g., Diebold et al. [11]).

In Table 2, we report estimates of the parameters of the DNSM, for all countries i. Estimates of factors l_{it}, s_{it} and c_{it} are graphically presented in Figures 2.a-2.c. In Tables 3.a and 3.b, we present descriptive statistics and correlation

[4] In particular, we estimate the DNSM model based on the following maturities $\tau = \{3, 6, 9, 12, 15, 18, 21, 24, 30, 36, 48, 60, 72, 84, 96, 108, 120\}$ months, for all countries i.

coefficients among the estimates of l_{it}, s_{it} and c_{it}, respectively. The results of these tables can be used to investigate stochastic properties of the three yield curve factors which have economic interest.

The results of Tables 3.a-3.b and Figures 2.a-2.c indicate that, as was expected, the level factor l_{it} takes positive values which are very highly correlated among all countries i, thus implying common shifts in the levels of interest rates r_{it}, for all i. The slope factor s_{it} is also substantially correlated, for all countries i, with the exception of Germany and Japan with the US. These results indicate that possible future business cycles conditions reflected in the slope factor exhibit significant similarities across all countries examined. The exceptions for Germany and Japan can be attributed to the recessions of these two countries occurred in the nineties, due to Germany's unification and Japan's financial markets regulations mentioned before. The curvature factor c_{it} is less correlated among the countries, compared to s_{it}. Thus, it may be affected more from domestic factors influencing, separately, the yield curve of each country.

The estimates of coefficients λ, reported in Table 2, are very small in magnitude, for all countries i, varying between 0.04 and 0.06. These values of λ imply that the loading coefficients γ_{si} and γ_{ci} of factors s_{it} and c_{it} into term spread $spr_{it}(\tau_l) \equiv r_{it}(\tau_l) - r_{it}(\tau_s) = \gamma_{si}s_{it} + \gamma_{ci}c_{it}$ will be quite persistent with respect to maturity interval $\tau_l - \tau_s$. To see this more clearly, in Figure 3 we graphically present estimates of γ_{si} and γ_{ci} with respect to different maturity intervals τ_s of spread $r_{it}(\tau_l) - r_{it}(\tau_s)$, for $\tau_s = \{3m, 6m, 1y, 3y, 4y\}$, keeping fix the long-term maturity interval τ_l to $\tau_l = \{5y\}$. The results of this figure clearly show that changes in the slope factor s_{it} have more persistent effects on term spread, compared to those of the curvature factor. Changes in s_{it} determine the slope of the yield curve even at its long-end, i.e., $r_{it}(5y) - r_{it}(3y)$. In contrast, the effects of changes in c_{it} on the yield slope cease more shortly, i.e., after one (or two) years. These results mean that the forecasting ability of term spread $r_{it}(5y) - r_{it}(3y)$ on future marginal changes of economic activity at long term horizons, $g_{it+k-j,t+k}$, implied by the results of Table 1.b can be mainly attributed to slope factor s_{it}. This will be investigated more formally in the next section.

3.2 Forecasting economic activity based on yield factors s_{it} and c_{it}

Having obtained estimates of factors s_{it} and c_{it} from our term structure data, in this section we estimate the following regression model forecasting future economic growth rate g_{it+k}:

$$g_{it+k} = const + \beta_s s_{it} + \beta_c c_{it} + \varepsilon_{it+k}, \text{ for all } i, \tag{7}$$

using yield factors s_{it} and c_{it} as independent regressors. This is done for the same forecasting horizons k, considered in the estimation of the term spread regression (1), i.e., $k = \{3, 6, 12, 24\}$ months (see Tables 1.a-1.b). Table 4.a presents LS estimates of the above regression model. Newey-West standard errors, correcting for MA errors (due to the overlapping nature of the data) and heteroscedasticity are reported in parentheses.

The results of Table 4.a indicate that both factors s_{it} and c_{it} contain independent information about future economic activity. The values of the coefficient of determination R^2, reported in the table, indicate that s_{it} and c_{it} have higher forecasting power on future economic growth rate g_{it+k}, compared to term spread $spr_{it}(5y)$ (see Table 1.a) This is true for all countries i examined. The slope factor s_{it} contains significant information about future economic growth rate g_{it+k} for all forecasting horizons examined. Its slope coefficient, β_s, has negative sign, for all i and k, which is consistent with the macroeconomic interpretation given to factor s_{it} that reflects changes in future business cycle conditions. The negative sign of β_s implies that a flattened, or negative, term spread (or yield curve) will be followed by a slow down in economic activity, after a few periods ahead.

In contrast to s_{it}, the curvature factor c_{it} is found to contain important information about future economic activity g_{it+k} only for short horizons ahead, i.e., for $k = \{3, 6\}$ months. For forecasting horizons higher than 12 months months ahead, this factor does not seem to contain significant information about future levels of g_{it+k}, with the only exception of the US. The sign of the slope coefficient of this factor, β_c, is positive for all forecasting horizons up to $k = 12$ months ahead. This means that a positive (or negative) shock to this factor is associated with future economic growth (or slow down), which is opposite to what happens with a positive (or negative) shock in s_{it}. In term spread regressions like (1), note that these effects of c_{it} on g_{it+k} are offset by those of s_{it}. This happens because they have opposite sign, as the analysis of the previous section has shown.

The more temporary in nature and different in sign forecasting ability of c_{it} about future economic activity than s_{it} is consistent with the macroeconomic interpretation given to this factor by Dewachter and Lyrio [6], inter alia. It is considered that captures policy actions beyond the endogenous responses of monetary authorities to inflation and output gap deviations from their target rates, which the business cycle factor s_{it} summarizes. For example, changes in c_{it} can be associated with changes in the current stance of monetary policy with the aim of tightening monetary policy in the short and medium terms, if economic growth or inflation are undesirably high. These changes in the stance of monetary policy can anchor expectations about future inflation and output pressures, and will thus reduce the term premia effects embodied in the yield curve. This will result in an increase of interest rates of intermediate maturities relative to the short-term rate, as also noted by Moench [19]. Thus, a positive shock in curvature factor c_{it} will be associated with an increase in future economic activity in short and medium horizons.

The above interpretation of curvature factor c_{it} means that the ability of term spread $spr_{it}(5y) = r_{it}(5y) - r_{it}(3m)$ to forecast future marginal changes in output growth rate $g_{it+k-j,t+k}$, between future periods $t + k - j$ and $t + k$ (see

Table 1.b), can be solely attributed to slope factor s_{it}. To see if this is true, in Table 4.b. we present LS estimates of regression model (7), using $g_{it+k-j,t+k}$ as dependent variable. As in Table 1.b, this is done for horizons $k = \{24, 36\}$ and $j = \{12, 24\}$ ahead. The results of this table are consistent with the above macroeconomic interpretation of factor c_{it}. For all countries examined, c_{it} does not have any forecasting power on $g_{it+k-j,t+k}$. In contrast, slope factor s_{it} successfully forecasts future changes in economic activity between future periods $t+k-j$ and $t+k$. The results of Table 4.b are in accordance to those of Table 1.b and Figure 3, which imply that any predictive power of term spread $spr_{it}(5y)$ on future economic activity at longer horizons (i.e., higher than one year ahead) lies in its slope factor s_{it}.

3.3 Out-of-sample forecasting performance

In this section we investigate if the superior information contained in factors s_{it} and c_{it} about future economic activity than term spread $spr_{it}(5y)$, found by our in-sample estimates in the previous section, also holds for out-of-sample. To this end, we compare the out-of-sample forecasting performance of yield factor model (7) to that of term spread model (1).

Table 5 presents values of the mean square error (MSE) and mean absolute error (MAE) metrics for the above two models. It also reports values of Diebold-Mariano [9], denoted as (DM), and Giacomini and Rossi [13], denoted as GR, test statistics. A negative and significantly different than zero value of DM statistic means that model (7) provides smaller in magnitude errors than (1), and thus it rejects the null hypothesis that the two models have the same forecasting ability. The GR statistic can test if the two models can produce consistent forecasts with their in-sample ones, which means that they do not suffer from structural breaks problems.

To carry out our out-of-sample forecasting exercise and calculate the values of the above metrics and statistics, we have recursively estimated regression models (7) and (1) after period 1999:04, by adding one observation at a time and, then, re-estimating the two models until the end of sample. The total number of observations used in our out-of-sample forecasting exercise is $n \equiv T - k - m + 1$, where $T = 245$ denotes the total sum of our sample observations, $k = \{3, 6, 12, 24\}$ denotes the forecasting periods (months) ahead and m denotes our sample window. The latter is set to $m = 120$ observations. All reported values of the MSE and MAE are in percentage terms.

The results of Table 5 clearly indicate that regression model (7) provide better forecasts about future economic activity than term spread model (1), especially for short and medium horizons k ahead. For all cases of k and i (countries) examined, the values of MSE and MAE metrics, reported in the table, are smaller for model (7) than model (1), with the exception of Germany (DE) and United Kingdom (UK) for $k = 12$ and $k = 6$, respectively. The reported values of DM test statistic are consistent with the above results. These confirm the better forecasting performance of model (7) than model (1) confirmed at 1% and 5% significance levels. Finally, the values of the GR test indicate that the out-of-sample forecasts of model (7) are consistent with those in-sample. Thus, they are robust to possible structural breaks occurred during our sample.

4 Conclusions

Many recent studies use the term spread between the long and short-term interest rates to forecast future economic activity, or economic recessions. In this paper, we provide some new interesting results about the predicting ability of the yield curve and term spread. We indicate that the slope and curvature factors spanning the yield curve contain superior information about future economic activity than the term spread itself. This is shown for five word leading economies. To extract the slope and curvature factors of the yield curve, the paper fits the dynamic model of Nelson-Siegel into term structure data of the above countries.

The paper presents clear cut evidence that the slope factor of the yield curve contain significant information about future economic activity over much longer horizons than the curvature factor, for all countries examined. The latter seems to affect the short (or medium) end of the yield curve. The sign of the predictions of the slope and curvature factors on future economic activity is different. They imply that an increase in the slope factor is associated with a slow down in economic activity, while the opposite is predicted for an increase in the curvature factor. These results are consistent with the theoretical predictions of recent macroeconomic studies asserting that the slope factor of the yield curve should reflect future changes in business cycle conditions, which can last for a few years ahead, while the curvature factor may be associated with short or medium term changes in the current stance of monetary policy. The fact that the slope and curvature yield factors have opposite in sign effects on the term spread can explain why the latter becomes less successful in predicting future economic activity over shorter, or medium, horizons, compared to a regression model using these two factors as independent variables. The effects of these two factors on the term spread are offset to each other, and thus reduce the ability of the term spread to forecast the correct direction of future changes in economic activity. The above results are also confirmed by an out-of-sample.

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Tables

Table 1.a: Forecasting economic activity from term spread $spr_{it}(5y)$

Model:	$g_{it,t+k} = const + \beta_i^{(k)} spr_{it}(5y) + \varepsilon_{it+k}$, with $spr_{it}(5y) \equiv r_{it}(5y) - r_{it}(3m)$									
Horizon	US		CA		DE		UK		JP	
k (months)	$\beta_i^{(k)}$	R^2	$\beta_i^{(k)}$	R^2	$\beta_i^{(k)}$	R^2	$\beta_i^{(k)}$	R^2	$\beta_i^{(k)}$	R^2
3	0.53	0.007	2.01	0.12	1.40	0.01	0.82	0.05	2.13	0.01
	(0.55)		(0.48)		(0.86)		(0.35)		(1.18)	
6	0.67	0.02	1.92	0.16	1.72	0.04	0.84	0.10	1.91	0.02
	(0.62)		(0.45)		(0.89)		(0.37)		(1.47)	
12	1.18	0.07	1.71	0.24	2.07	0.12	0.74	0.15	1.61	0.02
	(0.54)		(0.32)		(1.09)		(0.27)		(1.40)	
24	1.37	0.22	1.21	0.23	1.40	0.15	0.44	0.12	0.78	0.02
	(0.48)		(0.24)		(0.56)		(0.11)		(0.89)	

Notes: The table presents estimates of the slope coefficients of term spread forecasting regressions (1), for the United states (US), Canada (CA), Germany (DE), the United Kingdom (UK) and Japan (JP). Term spread $spr_{it}(5y)$ is defined as $spr_{it}(5y) = r_{it}(5y) - r_{it}(3m)$ and $g_{it,t+k}$ as $g_{it,t+k}$= $100(12/k)(\ln g_{it+k} - \ln g_{it})$, where k denotes a forecasting horizon ahead. Newey-West standard errors corrected for heteroscedasticity and moving average errors up to k- periods ahead are reported in parentheses. R^2 is the coefficient of determination.

Table 1.b: Forecasting future marginal changes in economic activity from spreads

US		CA		DE		UK		JP	
$g_{it+k-j,t+k} = const + \beta_i^{(j,k)}[r_{it}(2y) - r_{it}(1y)] + \varepsilon_{t+j}$, for $k = 24, j = 12$									
$\beta_i^{(j)}$	R^2	$\beta_i^{(j)}$	R^2	$\beta_i^{(j)}$	R^2	$\beta_i^{(j)}$	R^2	$\beta_i^{(j)}$	R^2
0.48	0.17	0.24	0.07	0.42	0.06	0.13	0.06	0.07	0.004
(0.23)		(0.10)		(0.26)		(0.05)		(0.40)	
$g_{it+k-j,t+k} = const + \beta_i^{(j,k)}[r_{it}(3y) - r_{it}(1y)] + \varepsilon_{t+j}$, for $k = 36, j = 24$									
$\beta_i^{(j)}$	R^2	$\beta_i^{(j)}$	R^2	$\beta_i^{(j)}$	R^2	$\beta_i^{(j)}$	R^2	$\beta_i^{(j)}$	R^2
0.03	0.10	0.05	0.14	0.08	0.23	0.02	0.08	0.06	0.08
(0.02)		(0.02)		(0.02)		(0.01)		(0.03)	

Notes: The table presents estimates of the slope coefficients of term spread regressions forecasting marginal changes of economic activity $g_{it+k-j,t+k}$ between two future periods $t+k-j$ and $t+k$, for $j = \{12, 24\}$ and $k = \{24, 36\}$ months, based on the following term spreads: $r_{it}(2y) - r_{it}(1y)$ and $r_{it}(3y) - r_{it}(1y)$, respectively. Newey-West standard errors corrected for heteroscedasticity and moving average errors up to j- period ahead are reported in parentheses. R^2 is the coefficient of determination.

Table 2: Kalman filter estimates of (4) and (6)

United States (US)			Canada (CA)		
	Φ			Φ	
0.96	-0.003	0.03	0.98	0.01	0.02
(0.01)	(0.005)	(0.004)	(0.007)	(0.008)	(0.01)
0.002	0.97	0.03	0.01	0.96	0.04
(0.006)	(0.008)	(0.006)	(0.01)	(0.01)	(0.01)
0.06	0.02	0.88	0.003	-0.0004	0.79
(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.03)
	Σ_η			Σ_η	
0.12	-0.10	-0.13	0.11	-0.05	-0.10
(0.007)	(0.006)	(0.01)	(0.01)	(0.009)	(0.02)
	0.16	0.13		0.25	-0.03
	(0.008)	(0.01)		(0.02)	(0.03)
		0.94			1.25
		(0.06)			(0.10)
	μ			μ	
6.87	-2.99	-1.12	6.56	-1.66	-1.08
(0.61)	(0.70)	(0.46)	(0.81)	(0.84)	(0.30)
	λ			λ	
	0.04			0.06	
	(0.0003)			(0.0006)	

Notes: The table presents estimates of (4) and (6) for the United States (US), Canada (CA), Germany (DE), United Kingdom (UK) and Japan (JP). Our sample consists of 265 monthly observations from 1987:05 to 2009:05. Standard errors are reported in parentheses.

Table 2 (continued): Kalman filter estimates of (4) and (6)

Germany (DE)			United Kingdom (UK)			Japan (JP)		
	Φ			Φ			Φ	
0.98	-0.004	0.01	0.99	0.02	0.02	0.99	0.02	0.02
(0.01)	(0.01)	(0.01)	(0.007)	(0.01)	(0.008)	(0.005)	(0.01)	(0.01)
0.01	0.94	0.04	0.02	0.98	0.03	0.004	0.93	0.03
(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.006)	(0.01)	(0.01)
0.02	0.05	0.87	-0.03	-0.05	0.88	-0.04	0.11	0.80
(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)
	Σ_η			Σ_η			Σ_η	
0.08	-0.07	-0.12	0.11	-0.08	-0.08	0.07	-0.07	-0.04
(0.006)	(0.007)	(0.01)	(0.009)	(0.01)	(0.01)	(0.005)	(0.006)	(0.009)
	0.13	0.09		0.26	0.05		0.10	0.03
	(0.01)	(0.02)		(0.02)	(0.02)		(0.008)	(0.01)
		0.76			0.70			0.43
		(0.06)			(0.06)			(0.03)
	μ			μ			μ	
6.20	-2.57	-2.24	6.39	-0.96	0.28	3.55	-1.78	-1.99
(0.81)	(0.97)	(0.79)	(1.77)	(1.20)	(0.76)	(0.91)	(0.26)	(0.17)
	λ			λ			λ	
	0.05			0.05			0.04	
	(0.0003)			(0.0006)			(0.0003)	

Table 3.a: Descriptive statistics of the estimates of yield curve factors

	US							CA						
	mean	st. dev	min	max	$\rho(1)$	$\rho(12)$	$\rho(24)$	mean	st. dev	min	max	$\rho(1)$	$\rho(12)$	$\rho(24)$
l_{it}	6.80	1.48	3.91	9.78	0.97	0.84	0.76	6.90	2.12	3.12	11.37	0.98	0.91	0.84
s_{it}	-2.32	2.08	-6.54	1.00	0.97	0.50	-0.13	-1.50	1.99	-5.56	3.64	0.96	0.46	0.03
c_{it}	-1.20	2.13	-11.10	2.69	0.88	0.34	0.20	-1.23	1.84	-7.22	2.96	0.79	0.22	-0.008
	UK							DE						
	mean	st. dev	min	max	$\rho(1)$	$\rho(12)$	$\rho(24)$	mean	st. dev	min	max	$\rho(1)$	$\rho(12)$	$\rho(24)$
l_{it}	6.88	2.36	3.85	12.37	0.98	0.91	0.83	6.34	1.57	3.49	9.47	0.98	0.80	0.67
s_{it}	-0.46	2.15	-6.13	5.74	0.97	0.50	0.05	-1.88	1.87	-5.73	2.76	0.97	0.50	-0.003
c_{it}	-0.25	1.98	-7.22	2.96	0.90	0.11	0.16	-1.81	2.11	-6.32	4.10	0.91	0.19	-0.007
	JP													
	mean	st. dev	min	max	$\rho(1)$	$\rho(12)$	$\rho(24)$							
l_{it}	3.81	1.92	0.72	7.35	0.99	0.91	0.83							
s_{it}	-2.04	1.36	-5.47	1.47	0.97	0.68	0.32							
c_{it}	-2.27	1.50	-7.40	2.59	0.89	0.40	0.11							

Notes: The table presents descriptive statistics of the estimates of yield curve factors l_{it}, s_{it} and c_{it}, namely their mean, standard deviation, minimum and maximum values, and autocorrelation coefficients of one month, one and two years.

Table 3.b: Correlation among yield curve factors and term spread $spr_{it}(5y)$

	s_{it}					c_{it}					Correlations	
	US	CA	UK	DE	JP	US	CA	UK	DE	JP	$(spr_{it}(5y); s_{it})$	$(spr_{it}(5y); c_{it})$
US	1.00	0.58	0.52	-0.03	-0.04	1.00	0.53	0.43	0.23	-0.08	-0.86	-0.02
CA		1.00	0.75	0.54	0.60		1.00	0.46	0.26	0.12	-0.96	0.10
UK			1.00	0.48	0.63			1.00	0.21	-0.10	-0.90	0.48
DE				1.00	0.57				1.00	0.48	-0.89	-0.31
JP					1.00					1.00	-0.90	-0.35

Notes: The table presents values of correlation coefficients between slope s_{it} and curvature c_{it} factors, as well as between these factors and term spread $spr_t(5y) = r_{it}(5y) - r_{it}(3m)$, for all countries examined.

Table 4.a: Forecasts of economic activity from slope and curvature factors

Model: $g_{it,t+k} = const + \beta_s^{(k)} s_{it} + \beta_c^{(k)} c_{it} + \varepsilon_{it+k}$

Horizon	US			CA			DE		
k	$\beta_s^{(k)}$	$\beta_c^{(k)}$	R^2	$\beta_s^{(k)}$	$\beta_c^{(k)}$	R^2	$\beta_s^{(k)}$	$\beta_c^{(k)}$	R^2
3	-0.38	1.68	0.32	-1.19	1.00	0.16	-1.36	1.15	0.04
	(0.19)	(0.36)		(0.31)	(0.45)		(0.62)	(0.61)	
6	-0.41	1.43	0.28	-1.21	0.51	0.18	-1.41	0.66	0.06
	(0.22)	(0.42)		(0.30)	(0.40)		(0.76)	(0.57)	
12	-0.55	1.12	0.24	-1.08	0.05	0.25	-1.07	0.18	0.10
	(0.27)	(0.53)		(0.24)	(0.30)		(0.76)	(0.64)	
24	-0.64	0.53	0.22	-0.80	-0.05	0.25	-0.61	-0.28	0.22
	(0.28)	(0.26)		(0.22)	(0.21)		(0.27)	(0.19)	

Table 4.a: Forecasts of economic activity from slope and curvature factors (cont'd)

Model: $g_{t,t+k} = const + \beta_s^{(k)} s_t + \beta_c^{(k)} c_t + \varepsilon_{it+k}$

Horizon	UK			JP		
k	$\beta_s^{(k)}$	$\beta_c^{(k)}$	R^2	$\beta_s^{(k)}$	$\beta_c^{(k)}$	R^2
3	-0.19	0.49	0.03	-1.62	1.33	0.02
	(0.26)	(0.28)		(0.60)	(0.52)	
6	-0.38	0.26	0.07	-1.32	0.97	0.02
	(0.24)	(0.29)		(0.71)	(0.52)	
12	-0.52	0.12	0.17	-1.09	0.88	0.03
	(0.20)	(0.30)		(0.76)	(0.65)	
24	-0.51	-0.18	0.30	-0.30	0.03	0.01
	(0.13)	(0.11)		(0.60)	(0.42)	

Notes: The table presents LS estimates of the slope coefficients $\beta_s^{(k)}$ and $\beta_s^{(k)}$ of regression model (7), forecasting $g_{it,t+k}$ from yield curve factors s_{it} and c_{it}, for US, Canada, Germany, UK and Japan. The sample is from 1989:1 to 2009:5. Newey-West standard errors corrected for heteroscedasticity and moving average errors up to $k-$periods ahead are reported in parentheses. R^2 is the coefficient of determination.

Table 4.b: Marginal forecasts of economic activity from slope and curvature factors

Model: $g_{it+k-j,t+k} = const + \beta_s^{(k)} s_{it} + \beta_c^{(k)} c_{it} + \varepsilon_{it+j}$, for $k = 24, j = 12$

	US			CA			DE			UK			JP	
$\beta_s^{(k)}$	$\beta_c^{(k)}$	R^2	$\beta_s^{(k)}$	$\beta_c^{(k)}$	R^2	$\beta_s^{(k)}$	$\beta_c^{(k)}$	R^2	$\beta_s^{(k)}$	$\beta_c^{(k)}$	R^2	$\beta_s^{(k)}$	$\beta_c^{(k)}$	R^2
-0.07	0.04	0.17	-0.05	-0.01	0.08	-0.06	-0.02	0.11	-0.04	-0.02	0.14	0.07	-0.06	0.02
(0.03)	(0.03)		(0.03)	(0.02)		(0.03)	(0.02)		(0.01)	(0.01)		(0.06)	(0.06)	

Model: $g_{it+k-j,t+k} = const + \beta_s^{(k)} s_{it} + \beta_c^{(k)} c_{it} + \varepsilon_{it+j}$, for for $k = 36, j = 24$

	US			CA			DE			UK			JP	
$\beta_s^{(k)}$	$\beta_c^{(k)}$	R^2	$\beta_s^{(k)}$	$\beta_c^{(k)}$	R^2	$\beta_s^{(k)}$	$\beta_c^{(k)}$	R^2	$\beta_s^{(k)}$	$\beta_c^{(k)}$	R^2	$\beta_s^{(k)}$	$\beta_c^{(k)}$	R^2
-0.06	0.03	0.22	-0.03	0.002	0.08	-0.04	-0.02	0.21	-0.02	-0.02	0.12	0.01	-0.06	0.05
(0.02)	(0.02)		(0.02)	(0.02)		(0.02)	(0.02)		(0.007)	(0.01)		(0.05)	(0.05)	

Notes: The table presents LS estimates of the slope coefficients $\beta_s^{(k)}$ and $\beta_s^{(k)}$ of regression model (7), forecasting marginal changes of economic growth rate $g_{it+k-j,t+k}$, between two future periods $t+k-j$ and $t+k$, for $j = \{12, 24\}$ and $k = \{24, 36\}$ months. The sample is from 1989:1 to 2009:5. Newey-West standard errors corrected for heteroscedasticity and moving average errors up to $k-$periods ahead are reported in parentheses. R^2 is the coefficient of determination.

Table 5: Out-of-sample forecasting performance for (7) and (1)

Horizon k		$g_{it,t+k} = const + \beta_s^{(k)} s_{it} + \beta_c^{(k)} c_{it} + \varepsilon_{it+k}$					$g_{it,t+k} = const + \beta spr_{it} + \varepsilon_{it+k}$				
		US	CA	DE	UK	JP	US	CA	DE	UK	JP
3	MSE	0.31	0.63	1.52	0.36	3.32	0.50	0.68	1.61	0.37	3.33
	MAE	3.98	5.67	7.11	3.96	9.70	4.45	5.84	7.36	3.97	9.80
	DM	-2.56**	-2.31*	-2.96**	-0.61	-2.53**	-	-	-	-	-
	GR	0.16	0.27	0.47	0.18	0.74	0.30	0.31	0.49	0.20	0.74
6	MSE	0.27	0.45	1.00	0.20	2.08	0.40	0.47	1.10	0.19	2.07
	MAE	3.56	4.67	5.73	2.66	8.12	3.82	4.71	5.77	2.62	8.20
	DM	-2.55**	-1.96*	-2.35**	1.26	-3.27**	-	-	-	-	-
	GR	0.09	0.10	0.05	0.01	0.12	0.11	0.10	0.05	0.01	0.12
12	MSE	0.17	0.15	0.41	0.08	0.86	0.22	0.20	0.39	0.10	0.87
	MAE	2.80	3.16	4.13	1.84	5.92	2.81	3.17	3.94	1.87	5.96
	DM	-2.25*	-1.00	3.00**	-1.42	-1.95*	-	-	-	-	-
	GR	-0.03	-0.14	-0.34	-0.10	-0.53	-0.06	-0.18	-0.43	-0.10	-0.52
24	MSE	0.07	0.08	0.12	0.02	0.25	0.07	0.09	0.13	0.04	0.26
	MAE	1.88	2.41	2.50	1.10	3.85	1.86	2.35	2.61	1.35	3.86
	DM	-2.05*	-1.40	-1.35	-4.98**	-3.18**	-	-	-	-	-
	GR	-0.26	-0.35	-1.36	-0.40	-1.80	-0.49	-0.38	-1.39	-0.32	-1.79

Notes: The table presents values of the MSE and MAE metrics, and of the DM and GR test statistics assessing the forecasting performance of regression models (7) and (1). DM and GR denote the Diebold-Mariano and Giacomini-Rossi test statistics, respectively. These statistics follow the standard normal distribution. Note that the GR test statistic is an out-of-sample test statistic, which can test the stability of the out-of-sample forecasts of the above models compared to their in-sample one. To calculate the out-of-sample values of the above metrics and statistics, we rely on recursive estimates of models (7) and (1) of economic activity after period 1999:04, by adding one observation at a time and, then, re-estimating the models until the end of sample. The total number of observations used in our out-of-sample forecasting exercise is $n \equiv T - k - m + 1$, where $T = 245$, the forecasting horizon is $k = \{3, 6, 12, 24\}$ months and our in-sample window is $m = 120$ observations. All values concerning MSE and MAE are expressed in basis points. (*) and (**) mean significance at 5% and 1% level, respectively.

Figures

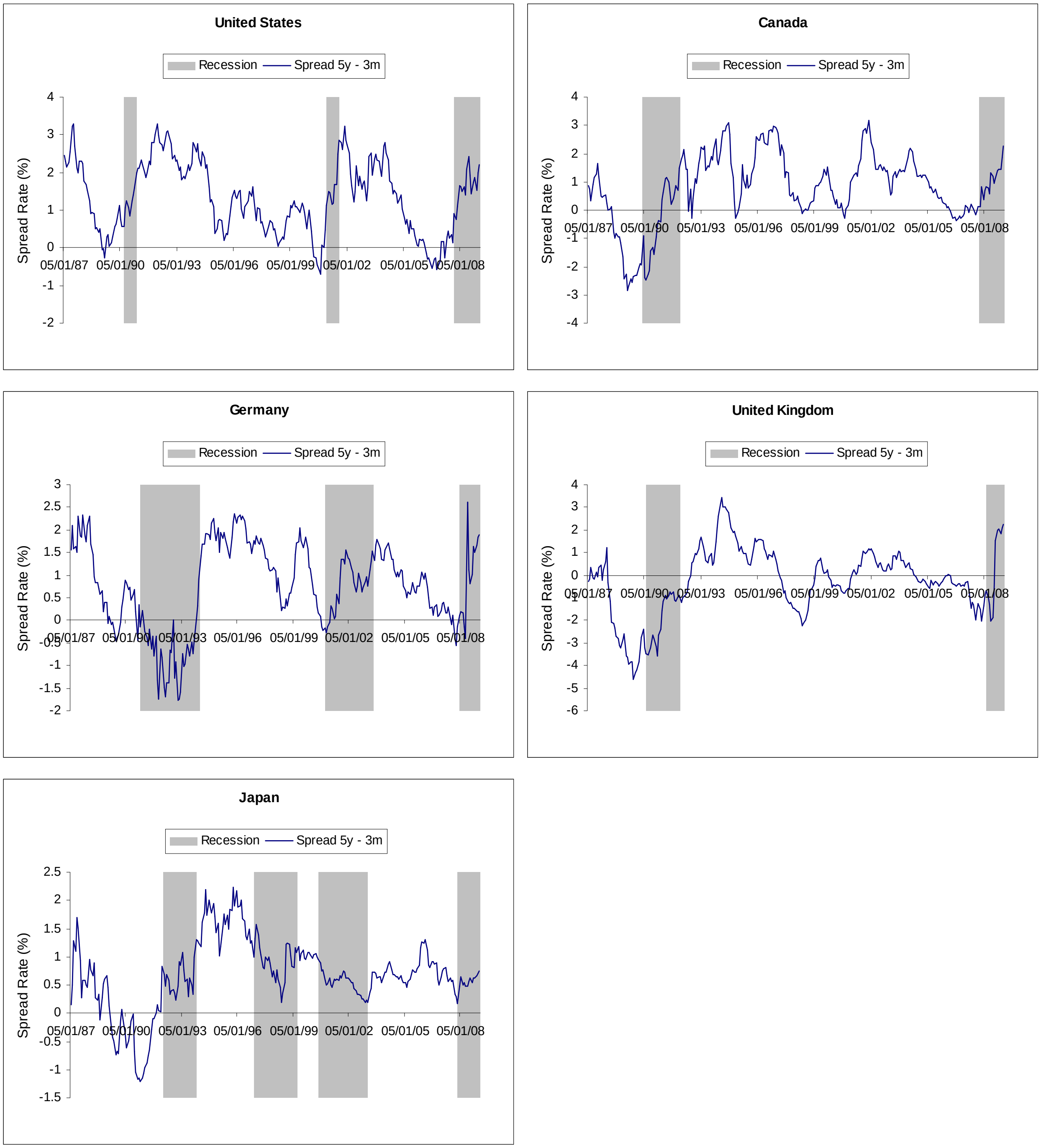

Figure 1. Term spreads and recesionary periods (shaded areas).

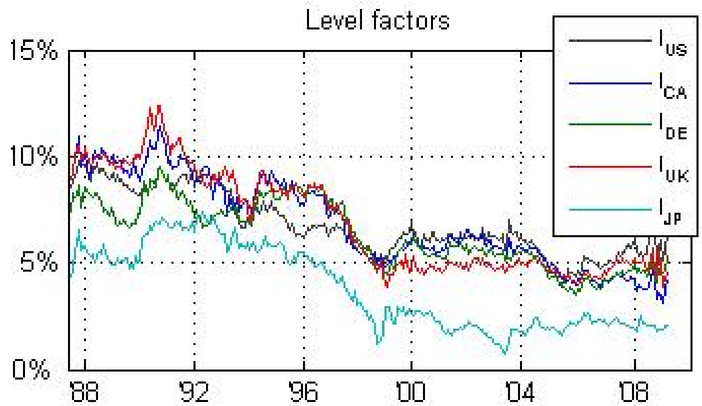

Figure 2a: Estimates of level factors l_{it}.

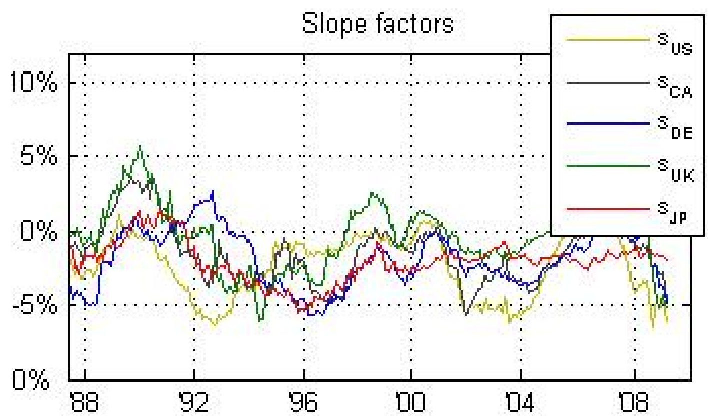

Figure 2b: Estimates of slope factors s_{it}.

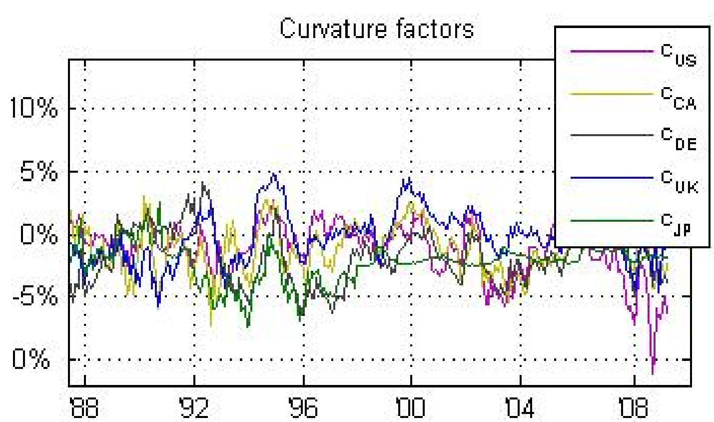

Figure 2c: Estimates of curvature factors c_{it}.

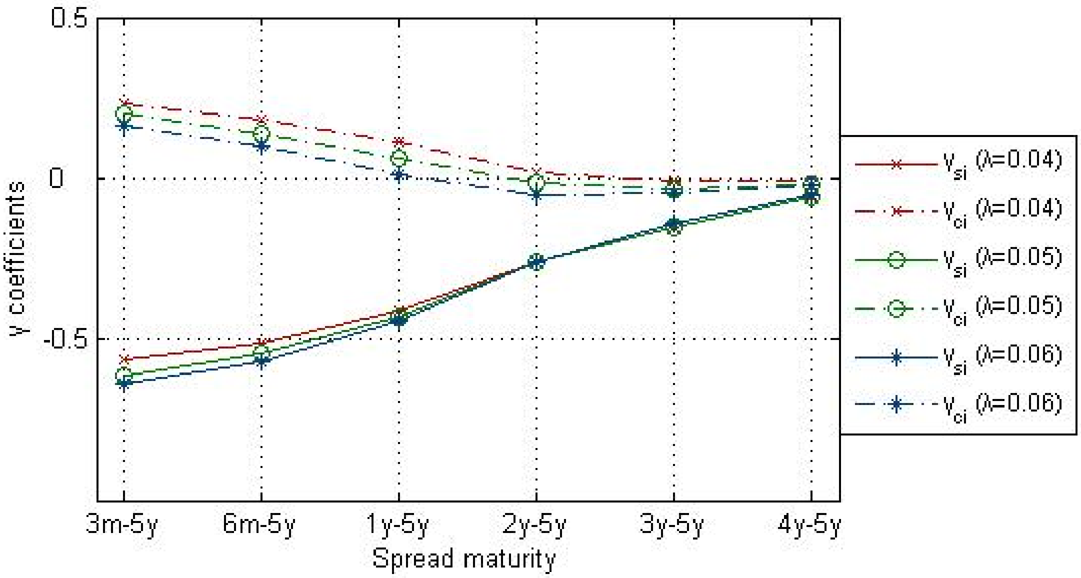

Figure 3. Loading coefficients γ_{si} and γ_{ci} with respect maturity interval $\tau_l - \tau_s$, for $\tau_l = 5y$ and $\tau_s = \{3m, 6m, 1y, 2y, 3y, 4y\}$