What Does the Global Yield Curve Tell about World Economic Activity?

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Comments are welcome

Abstract

This paper bridges the connection beween the global yield curve and international economic activity. I find global yield curve factors are relevant for predicting the real growths and inflations across countries, especially at long horizon. Further, global factors play a significant role in predicting the conditional covariances of real growths and inflations across countries. I also find global factors have predictive power on international business cycle synchronization. The results seem to indicate that inflations are more internationally synchronized than the business cycles. The findings have important policy implication.

1 Introduction

Evidence has accumulated that a few financial variables such as interest rates and spreads have enduring power of predicting the aggregate economic activity. This predictive usefulness of interest rates and spreads thereafter has been well-estabilished across countries. The countercyclical monetary policy accounts for at least some of the predictive power. When there is evidence of probably economic recession, the market expects the future short-term interest rate will fall, it leads to a bigger fall in long-term interest rate. The expectation thus flattens the yield curve. In bad times, investors want to escape the risk, this behavior drives up the risk premia and make risk premia also a countercyclical indicator. This is the typically heuristic explanations of where coming out of the predictive power. Estrella (2004) provides a theoretial model based on the rational expectation in an attempt to interprete relationship between the yield curve and the economic activity.

So far, empirical studies investigate the ability of yield curve as a predicator in some specific countries independently. Nevertheless few studies examine the existence of a global yield curve that predicts the world or corss-country economic activity. The financial deregulations may increase the integration degree of financial market, in such case a global yield curve may explain most of variation of yield curves across countries. As early in 1994, Plosser and Rouwenhorst provide evidence that foreign yield curves can predict domestic economic activity at a low frequency. Diebold, Li and Yue (2007) find that there do exist the global yield curve factors. It deserves a further and full investigation of the relationship between the global yield curve and world economic activity.

From the perspective of globalization of world economy, this article tries to find some determinants of international business cycles. This is the second contribution of the paper. A large litature has provided strong evidence that there are cross-country links in macroeconomic fluctuations. Kose et al (2003) identifies a common world factor that plays an important role in explaining the variability of aggregate economic activity in most countries in a 60-country model. The common forces that induce world economic fluctuations have three major sources, respectively increasing international trade in goods and services, increasing financial asset market integration and increasing foreign direct investment (FDI). The global yield curve associated with the international financial asset trade is likely a determinant of common international business cycle factor, at least it has information about the common factor. Although a lot studies examine the driving forces from perspectives of internaional trade and FDI, few evidences provided from an financial market integration perspective. This is therefore a useful exercise, it contributes to the generation and propagation of international business cycle.

I use the dynamic Nelson-Siegel model from Diebold and Li (2006) to describe the dynamic evolution of yield curve. This model is neither a general equilibrium model nor a no-arbitrage model. However the forecasting performance of the model is good, in constrast, the affine term structure models, which is important for pricing interest rate derivative, forecast poorly (Duffee 2002). The dynamic Nelson-Siegel model has good performance in fitting maturity structure of yield curves, and it is extensively empolyed by financial institutions and central banks. Three factors of the model, respectively level, slope and curvature factors , have close interactions with macroeconomic dynamics across countries (Diebold, Rudebusch and Aruoba (2006), Tam and Yu (2008)).Simplicity is another advantage of the model. The continuous no-arbitrage model of term structure might be untractable in a big model with a lot common and idiosyncratic factors. Therefore, I use this parsimonious specification to fit the yield curves, although there is a no-arbitrage version of Nelson-Siegel model recently developed by Christen, Diebold and Rudebusch (2008).

To extract global yield curve factors, we have to depend on the country-specific factors since there is no existence of world interest rates. In this paper I follow Zhu (2008) method to filter out global factors from country-specific factors, the difference is there country factors are from arbitrage-free dynamic Nelson-Siegel model. Except global factors, there are also idiosyncratic factors driving the government bond market in each individual country. Specifically I use latent factors for Germany, Japan, U.K. and U.S. to extract global latent factors with the Kalman filter. These global factors are used to predict the world economic activity.

The similar studies usually apply yield spreads to forecast the economic activity and inflation. I provide the evidence of forecasting usefulness of yield curve factors among countries. A comparison is made about the out-of-sample forecasting accuracy of using yield spreads and yield curve factors. The predictive power of the yield curve factors and yield spread for forecasting the real growth are country-dependent, but the yield curve is better for forecasting the inflation. For the purpose of examining the relationship of global financial variables and international business cycles, only the yield curve method is feasible now that we can't observe world interest rates.

Some major finding of the article can be summarized as follows. First I show that global yield curve factors do indeed have predictive power on real growth rate and inflation in countries investigated. The second finding is that global factors play a role in forecasting cross-country covariances of economic activity, particularly the covariances of inflations. This may imply that inflations are more synchronized than real growth, of course, real growth is a more complicated issue. The third finding is that global factors are useful predicators of world recession synchronization in a Possion regression. The recession synchronization is a count indicator, that is the sum of recession indicator of all relevant countries.

The results have straightforward policy implication. Forecasts of future path of economy is important for policy-making and bussiness decision. Businesses and policymakers would benefit from better forecasting the economic activity by taking into account the foreign yield curves since it has extra infromation on the domestic economic activity. This extra predictive power may come from common shocks, international trades or international portofolio diversification. The inflations seem to be more synchronized than real economic activiteis. This matter of fact has also policy implication about the direction of international policy coordination. Chiang (1997) concludes that financial integration can increase world economic welfare if and only if there is international policy coordination.

The rest of this paper is organized as follows: Data issues are summarized in section 2. Section 3 presents the dynamic Nelson-Siegel model for describing yield curves and the global yield curve model. Empirical properties and cross-country interactions of yield curves are documented. Section 4 investigates the predictive power of global yield curve. I begin this section by reviewing the forecasting ability of yield curve in each individual country, then compare the forecasting performance of yield spread and yield curve factors since previous works usually use spread as a predicator. The last subsection examines the predictive ability of global yield curve factors on world real economic growth, inflation and business cycle synchronization, the policy messege is also discussed. Section 5 concludes.

2 Data issues

The proxy for real economy activity is real GDP growth rates. Data on seasonally-adjusted nominal GDP and deflator for Germany, Japan, the UK, the US, is retrieved from the international financial statistics (IFS) compiled by international monetary fund (IMF). I denote the real GDP as RGDP. The annualized real growth rate from t to t+k at a quaterly frequency is constructed as follows:

$$g_{t\rightarrow t+k} = 400/k(\log RGDP_{t+k} - \log RGDP_t)$$

Consumenr price index (CPI) for all countries are also from IFS. Inflation is defined by taking the yearly percentage change in the CPI index as

$$\pi_t = 100 * (\log CPI_t - \log CPI_{t-4})$$

The year-over-year real growth rate ($g_{t\rightarrow t+4}$) is most frequently used index, and the predictive power of yield spred on this rate is one of most significant. I plot those growth rates across countries in figure 1. We see the comovement and heterogeneity on the economic fluctuatuions. There are two trends, one is the UK and the US trend, the correlation bewteen them is 0.6370, another trend is between Germany and Japan, the correlation is0.4545, but the corss comovement is not significant. The correlation matrix for growth rates is

$$\begin{pmatrix} g_{t\rightarrow t+4} & Germany & Japan & U.K. & U.S. \\ Germany & 1 & 0.4545 & 0.1342 & 0.1033 \\ Japan & 0.4545 & 1 & 0.0110 & 0.0181 \\ U.K. & 0.1342 & 0.0110 & 1 & 0.6370 \\ U.S. & 0.1033 & 0.0181 & 0.6370 & 1 \end{pmatrix}$$

In constrat, inflation is more hemogeneous, correlations are more significant, and there seems one common trend among them, though Germany infaltion comovements with other series to a less extent. In late 1980s, UK experienced relatively high inflation. On the other hand, Japan had deflation period since early 1990s, accompanying the frequent economic recession (figure 2). The correlation matrix of inflations is given below:

$$\begin{pmatrix} \pi_t & Germany & Japan & U.K. & U.S. \\ Germany & 1 & 0.5403 & 0.1981 & 0.3682 \\ Japan & 0.5403 & 1 & 0.7116 & 0.5943 \\ U.K. & 0.1981 & 0.7116 & 1 & 0.7346 \\ U.S. & 0.3682 & 0.5493 & 0.7346 & 1 \end{pmatrix}$$

The U.S. yield data consist of end-of-quater observations of 1, 3, 6, 12, 24, 36, 60, 84, 120 months zero-coupon yields on treasury securities covering the period from January 1985 to March 2008. The data source is econstats^{TM}. The U.K. zero-coupon yields with maturities of 6, 9, 10, 11, 12, 24, 36, 48, 60, 72, 84, 96, 108, 120 months are retrieved from econstats^{TM}. It covers the same period as the U.S sample and all datas are end-of-quater observations. For

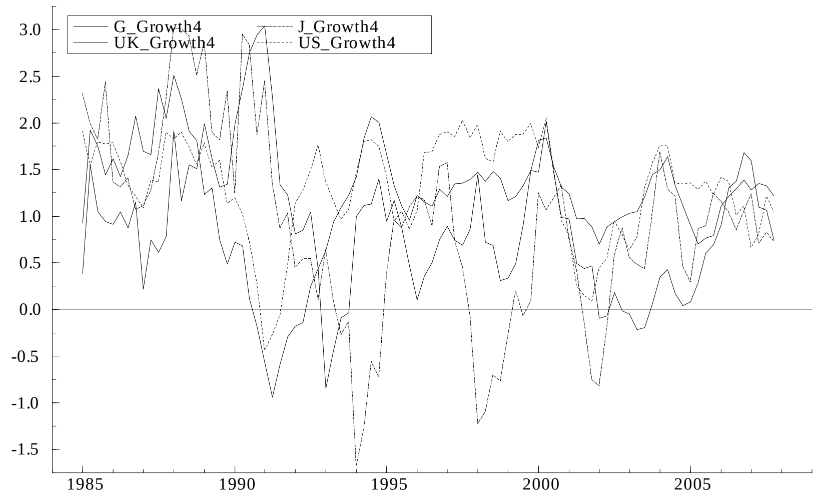

Figure 1: Year-Over-Year Real Growth Rates

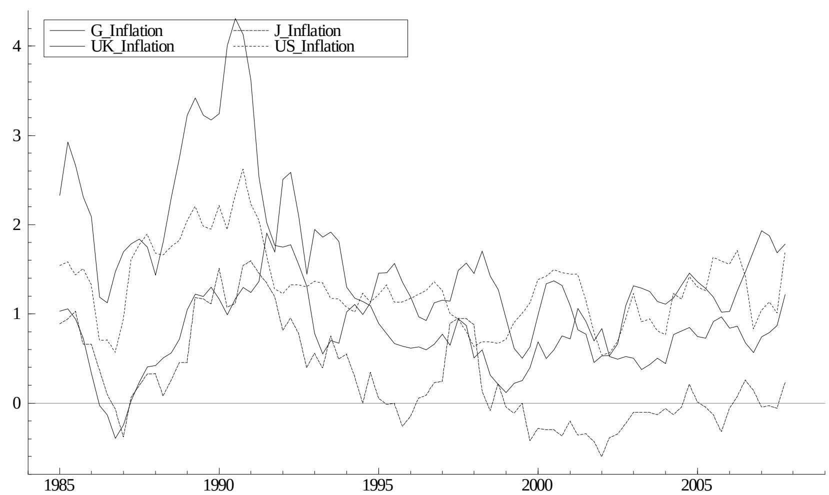

Figure 2: Year-Over-Year Inflation Rates

the Germany zero-coupon government bond yields, the quater-end observations with maturities 12, 24, 36, 48, 60, 72, 84, 96, 108, 120 months are retrieved from Deutsche Bundesbank, the central bank of Germany.

The Japanese dataset has two souces. The first sample covering the period from January 1985 to December 1991 is from the Key Economic Statistics Files of the PACAP Database-Japan^{TM} compiled by the Sandra Ann Morsilli Pacific-Basin Capital Markets Research Center at the University of Rhode Island. The end-of-month yields consist of government bond interest rates with maturities 12, 24,36, 60, 84, 120 months. The second sample covers the period from January 1992 to March 2008. The dataset is downloaded from Bloomberg. The maturities are 6, 12, 24, 36, 48, 60, 72, 84, 96, 108, 120 months.

The summary statistics including skewness and kurtosis of yields for each maturity and for each country is presented in Table 1[1]. One stylized fact of interest rates is they tend to exhibit considerable persistence and are believed to be nonstationary or better appromixated by the integrated process. This feature has profound implications for estimations and statistical inference.

Table 1 About Here

The autocorrelation coefficients and augumented Dickey-Fuller tests in Table 1 provide the evidence of persistence and non-stationarity. However, the yields are usualy cointegrated, as implied by the rational expectation hypothesis. The Johensen cointegration analysis presents the evidence of common trends in yields[2]. The cointegration may explain another important stylized fact of the yield curve: spreads are less persistent than yields. The skewness and kurtosis show some yields do deviate considerably from the normal distribution . The standard deviations in Table 1 tells that short-term yields usually are more volatile than long-term yields with exception of Japan. For Germany, Japan and U.S., the average yield curves are upward-sloping for the time period under analysis, in constrast, the U.K. average yield curve has S-shape. Over time yield cruves have many different shapes.

3 Yield curve models and empirical results

3.1 Dynamic Nelson Siegel Model

Most of term structure models use three factors to capture stylized facts of yields in cross-secition and time series. By properly restricting the factor loadings in the statistical factor model, Diebold and Li (2006) proposed the dynamic Nelson-Siegel model:

$$y_{t(\tau)} = l_t + s_t(\frac{1-e^{-\lambda_t \tau}}{\lambda_t \tau}) + c_t(\frac{1-e^{-\lambda_t \tau}}{\lambda_t \tau} - e^{-\lambda_t \tau}) + \varepsilon_t$$

[1]The statistics for Japan are based on the sample retrieved from Bloomberg. This applies to results for the Kalman filter estimates of global factors in table 3.

[2]The analysis results are available upon request.

where the l_t is level factor, the s_t denotes slope factor and the c_t represents curvature factor. Empirically, the level factor is corresponding to the long-term interest rates, the slope factor is associated with the difference between the short-term yield and long-term yield, the curvature factor corresponds to two times of medium-term yields minus the sum of long- and short-term yields. Therefore, the level factor is a long-term factor, the slope factor is a short-term factor and the curvature is a medium-term factor. Three factors contain information of the macroeconomic dynamics and vice versa (Diebold, Rudebusch and Aruoba(2006), Tam and Yu(2008)). The λ_t is the rate of changes of factors loadings along the maturity horizons, it also determines the maturity at which the curvature loading achieves its maximum.

For the entire yield curve with different maturities (τ) at time t, the model can be specificd as:

$$\begin{pmatrix} y_{t(\tau_1)} \\ y_{t(\tau 2)} \\ \vdots \\ y_{t(\tau_N)} \end{pmatrix} = \begin{pmatrix} 1 & \frac{1-e^{-\lambda_t \tau_1}}{\lambda_t \tau_1} & \frac{1-e^{-\lambda_t \tau_1}}{\lambda_t \tau_1} - e^{-\lambda_t \tau_1} \\ 1 & \frac{1-e^{-\lambda_t \tau_2}}{\lambda_t \tau_2} & \frac{1-e^{-\lambda_t \tau_2}}{\lambda_t \tau 2} - e^{-\lambda_t \tau_2} \\ \vdots & \vdots & \vdots \\ 1 & \frac{1-e^{-\lambda_t \tau_N}}{\lambda_t \tau_N} & \frac{1-e^{-\lambda_t \tau_N}}{\lambda_t \tau_N} - e^{-\lambda_t \tau_N} \end{pmatrix} \begin{pmatrix} l_t \\ s_t \\ c_t \end{pmatrix} + \begin{pmatrix} \varepsilon_{t(\tau_1)} \\ \varepsilon_{t(\tau_2)} \\ \vdots \\ \varepsilon_{t(\tau_N)} \end{pmatrix} \quad (1)$$

The dynamic Nelson-siegel has superior out-of-sample forecasting performance, especiall at long horizon. In constrast, some affine term structure models give poor forecasting performance (Duffee, 2002). Although the dynamic Nelson-Siegel is neither general equilibrium model nor no-arbitrage model, it provides empirical fit, simplicity and parsimony. Therefore this model is applied extensively.

If the dynamic movements of three latent factors follow a vector autoregressive process of first order as in Diebold et al (2006), the model becomes a state-space system. The state equation describing the dynamics of l_t, s_t, c_t is

$$\begin{pmatrix} l_t - \mu_l \\ s_t - \mu_s \\ c_t - \mu_c \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} l_t - \mu_l \\ s_t - \mu_s \\ c_t - \mu_c \end{pmatrix} + \begin{pmatrix} u_t(l) \\ u_t(s) \\ u_t(c) \end{pmatrix} \quad (2)$$

The measuremenat equation (1) and state equation (2) can be expressed in a compact form

$$y_t = \Lambda f_t + \varepsilon_t$$

$$(f_t - \mu) = A(f_{t-1} - \mu) + u_t$$

For linear least-square optimality of the Kalman filter, the disturbances are assumed to be vector white noise process and uncorrelated at all lags,

$$\begin{pmatrix} \varepsilon_t \\ u_t \end{pmatrix} = N \left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} R & 0 \\ 0 & Q \end{pmatrix} \right]$$

Furthermore, the disturbances are uncorrelated with the initial state,

$$E(f_0 \varepsilon_t') = 0$$

$$E(f_0' u_t') = 0$$

The state-space framework is a powerful system for analysis of dynamic models. The Kalman filter can provide maximum-likelihood estimates and optimal filtered and smoothed estimates of latent factors. The dynamic Nelson-Siegel model thus enjoys the state-space representation.

3.2 Global yield curve model

A number of studies have focused on the international linkages of bond markets. There seems concensus that the bond yields and returns are highly correlated across countries. Hafer et. al. (1997) finds long-term yields seem to be cointegrated across countries, hence there is comovement of international bond markets. Ilmanen (1995) finds that a small set of global instruments can forecast a significant fraction of monthly yields variation, the author concludes that the predictability of global bond returns come from a few global factors. The empirical study of Driessen et. al. (2003) find the world bond markets are correlated by using a linear factor model and principle component analysis, the driving force of the comovement is the level of yields in each country, this is consistent with the matter of fact that the level factor dominates the term structure of interest rates. Engsted and Tanggard (2007) finds the inflation news drive the comovement between the U.S. and Germany bond markets. Barr and Priestley (2004) applies international CAPM model allowing time-varying market segmentatiion to investigate the global market integration, they find almost 70% of the variation can be explained by world dynamic beta, and the degree of market integration is stable during the period covered by the sample.

Recently, DLY focuses on the entire term structure of interest rates. They use latent factor dynamic Nelson-Siegel model to fit the yield curve. For a set of country yield curves, they fit them by allowing common global factors and idiosynchratic factors. There is interaction between global factors and country-specific factors, and the loading of country-specific factor on global factors is allowed to vary across countries. The finding is global factors explain a big fraction of country yield curve. In this paper I use country-specific factors from the AFDNS model to extract the global yield curve factors. The specification is different with DLY. DLY use two-factors model, while the dynamic Nelson-Siegel model estimation[3] shows that three-factors model significantly improve the goodness-of-fit according to the R-square. Secondly, the level, slope and curvature factors seem to be independent as presented in the macro-finance model of Tam and Yu (2008). CDR manifests the forecasting performance of the independent factors model is no worse than the correlated factors model. Taking

[3] The OLS estimation of Diebold and Li (2006) model is applied by fixing the λ equal to 0.0600. Results available upon request.

into account above points, we use three-factors model, but assume global level (slope, curvature) factor only depends on the domestic level (slope, curvature) factors.This simplifies the estimation and alleviate the local maximum problem associated with the numerical optimization.

For extracting the common factor, principle component analysis is a popular method. The shortcoming is no economic significance. In this paper, we use Kalman filter to extract global factors, and principle component is an interesting basis for comparision. First, we decompose the country-specific factors:

$$\begin{array}{rcccc} l_{it} & = & L_t & + & u_{it}^l \\ s_{it} & = & S_t & + & u_{it}^s \\ c_{it} & = & C_t & + & u_{it}^c \end{array} \tag{3}$$

where l_{it}, s_{it}, c_{it} are country-specific factors from the independent AFDNS estimation, L_t, S_t, C_t are global level, slope and curvature factors. The u_{it}^l, u_{it}^s, u_{it}^c are country idiosyncratic level, slope and curvature factors. The i denotes one of four countries: the US, the UK, Germany and Japan. As aforementioned, the assumption of independent level, slope and curvature dynamics are reasonable, therefore, we extract three global factors independently. we assume country idiosyncratic factors follow an AR(1) process:

$$\begin{pmatrix} l_{1t} - L_t \\ l_{2t} - L_t \\ \vdots \\ l_{kt} - L_t \end{pmatrix} = \begin{pmatrix} \beta_1 & 0 & 0 & 0 \\ 0 & \beta_2 & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \beta_k \end{pmatrix} \begin{pmatrix} l_{1t-1} - L_{t-1} \\ l_{2t-1} - L_{t-1} \\ \vdots \\ l_{kt-1} - L_{t-1} \end{pmatrix} + \begin{pmatrix} w_{1t} \\ w_{2t} \\ \vdots \\ w_{kt} \end{pmatrix} \tag{4}$$

k is no. of countries. The specification assumes the country idiosyncratic factors are independent, with the diagonal variance-covariance matrix. This make sense economically if there is no regional factors in the hierachical model. It is more an empirical problem than a theoretical one.

The alternative specification is

$$\begin{pmatrix} l_{1t} - \varphi_1 L_t \\ l_{2t} - \varphi_2 L_t \\ \vdots \\ l_{kt} - \varphi_k L_t \end{pmatrix} = \begin{pmatrix} \beta_1 & 0 & 0 & 0 \\ 0 & \beta_2 & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \beta_k \end{pmatrix} \begin{pmatrix} l_{1t-1} - \varphi_1 L_{t-1} \\ l_{2t-1} - \varphi_2 L_{t-1} \\ \vdots \\ l_{kt-1} - \varphi_k L_{t-1} \end{pmatrix} + \begin{pmatrix} w_{1t} \\ w_{2t} \\ \vdots \\ w_{kt} \end{pmatrix}$$

This specification allows different factor loadings of country-specific factors on global factors, while the fit is also an empirical problem, this specification nests the (4) specification. The global factor dynamic is also given by an AR(1) process:

$$L_t = \alpha + \rho L_{t-1} + \epsilon_t \tag{5}$$

if we replace the L_t and l_{it} with S_t, C_t, the model can be used to extract the global slope and curvature factors.

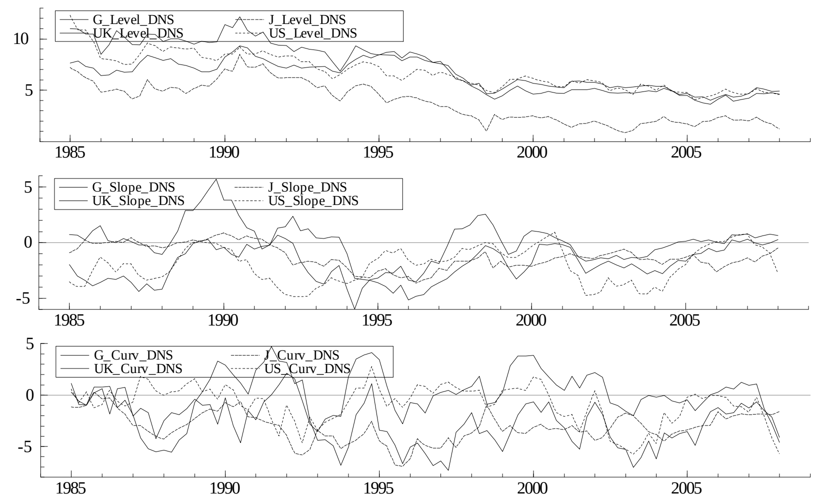

Figure 3: Empirical Level, Slope and Curvature Factors across Countries

3.3 Estimates of country-specific and global factors

Non-linear lease squares can be employed to estimate the dynamic Nelson-Siegel model. In Diebold and Li (2006), they fix the λ_t and set it equal to value that maximize the loading on the curvature factor at 30 months. In so doing, one can estimate the DNS model by ordinary least squares and make the numerical optimization more reliable. The Kalman fiter is an efficient method for estimating the state-space system (1) and (2). The state-space estimation fully exploits the signal extraction information that is not captured by independent OLS estimation. The free λ_t estimates may improve the estimations, but here I fix the λ_t at 0.600 because the estimates are otherwise incomparable when we are extracting out global factors. In practice, free or fixed λ_t is not an issue, I get almost same estimates of Iatent factors from either method.

The Kalman filter estimation is initialized by unconditional covariance matrix of the state vector and mean vector from the OLS estimates. The starting transition matrix parameters are also from regression of factors extracted by independent OLS estimation. Figure 3 plots the empirical level, slope and curvatures factors across countries.

The summary statistics of factors from Kalman filter estimation is presented in Table 2. We note that the level and slope factors is persistent, while the curvature factor is less persistent in all countries. The augumented Dickey-Fuller (ADF) test show all U.S. factors are stationary, but yield curve factors in other countries are nonstationary with expection of U.K. curvature factors. Although the Pearson and likelihood ratio tests reject the independence of level factor and slope factor, in empirical macro-finance model (Diebold, Rudebusch and Aruoba

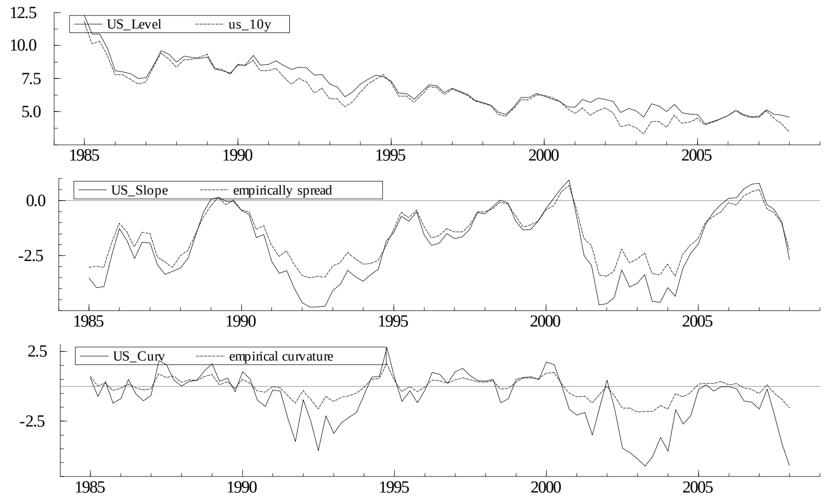

Figure 4: Level, Slope, Curvature Factors and Empirical Correspondents

(2006), Tam and Yu (2008)), one factor contains little extra information about other factors or macro-variables. Diebold and Li (2006) provides the empirical evidence of the interpreation of leve, slope and curvature factors as long-term, short-term and medium term factors. In figure 4 I plot the 10-year yield, 3-month yield minus 10-year yield, and two times 2-year yield minus 10-year and 3-month yields with the level, slope and curvature factors for the United States[4].

Table 2 About Here

The estimation results indicate that the dynamic Nelson-Siegel model fits the yield curve. The DNS model replicates the average upward sloping yield curves of Germany, Japan, the US and the S-shape of the UK. It is important to note that the model fits the middle region of yield curves better than the end regions. This might be a stylized fact of the DNS model, as pointed out in Diebold and Li (2006): "......because the maturities are not equally spaced, we implicitly weight the most "active" region of the yield curve most heavily when fitting the model".

The Kalman filter estimation of system equation (4) and (5) is applied to extract the global factors of yield curves. The unrestricted vector autoregression (VAR) estimation shows one factor has little extra information about the dynamic of other factor, plus empirical evidence from Diebold and Li (2006), Tam and Yu (2008), therefore we extract the global level, slope and curvature factors by independently iterating the Kalman filter. This simplifies the extraction of

[4]For other countries, the3-month yield is not available.

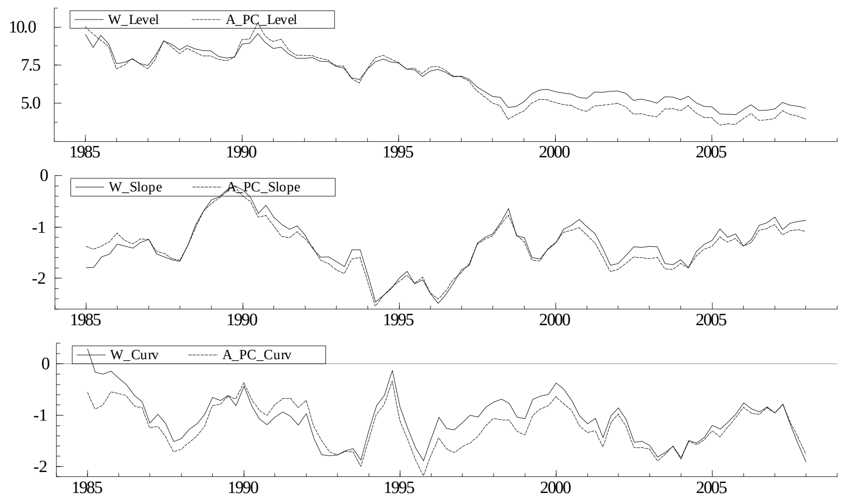

Figure 5: Global Level, Slope and Curvature Factors

global factors significantly. We initilize the Kalman filter with the unconditional covariance matrix and a mean vector from the average of country-specific factors. The estimated parameters are reported in Table 3.

Table 3 About Here

The golable factors in essence is a common component of country-specific factors. Two interesting questions before we scrutinize the global factors are: what is the interpretation power of one common component at most? what is the relationship of the component extracted by the Kalman fiter and component from principle component analysis? To answer questioins, the principle component analysis results are presented in the down panel of Table 5. As we metioned, the cross-correlation of level factors is higher than slope and curvature factors. The first principle component can explain 91% of variation of the country-specific level factors. For slope and curvature factors, only 50% and 39% of variation can be interpretated by the first principle component. There is strong interactions between global factors from the Kalman filter and the first principle component. The adjusted first principle component and global factors are plotted in the figure 5. The correlations of level, slope and curvature factors and the correspoding first principle components are respectively 0.95, 0.87 and 0.75. The table 6 gives the descriptive statistics of global factors. As in the country model, the level factor is more persistent than the slope and curvature factors.

4 Global yield curve and world economic activity

4.1 Country-specific yield factors and economic activity

It is well-established that yield factors contain information about the future path of economic activity. Examples have: Bonser-Neal and Morley (1997), Estrella and Hardouvelis (1991), Estrella and Mishkin (1997), Hamilton and Kim (2002), Plosser and Rouwenhors (1994), Rudebusch and Williams (2007), among others.

There are three major conclusions from the previous empirical studies. First, yield spreads and interest rates have enduring power of predicting the real economic growth and inflation, thus these financial variables as a leading indicator are robust. Second, for most OECD countries, the yield slope predicts real growth rate better than predicts nominal growth rate. The exception is UK, that might be induced by the high inflation in late 1980s. The third conclusion is that binary models are more stable than continuous models in most circumstances.

Most of previous studies used the following regression to investigate the predictibility of the yield spread for real activity

$$g_{t\to t+k} = \alpha_0 + \alpha_1 Spread_t + \eta_t$$
$$Spread_t = y_{t(\tau n)} - y_{t(\tau 1)}$$

Alternatively, we use extracted latent slope and curvature factors for predicting real economic growth:

$$g_{t\to t+k} = \alpha_0 + \alpha_1 s_t + \alpha_2 c_t + \eta_t$$

This specification is based on the economic intepretation of factors of dynamic Nelson-Siegel (Diebold and Li (2006), Diebold, Rudebusch and Aruoba (2006), Tam and Yu (2008)), figure 4 presents the evidence. The curvature factor may provide extra information in predicting the future real activity.

For predicting the future inflation, the most frequently used specification is

$$\pi_t = \alpha_0 + \alpha_1 Spread_t + \eta_t$$

In our yield curve factors model, the corresponding specification is

$$\pi_t = \alpha_0 + \alpha_1 l_t + \alpha_2 s_t + \eta_t$$

Empirically, the long-term bond should have information about expected inflation according to the rational expectation hypothesis and Fisher equation. Therefore, the level factor that have explainment of long-term factors is employed, in addition, the short-term slope factore is also employed because it stand for the stance of monetary policy.

First of all, I review the forecasting usefulness of yield curves for Germany, U.K., U.S and Japan. Table 5 and Table 6 present the results of regressions for predicting real growth rates and inflations. There are some points to note about the results. First, the most useful predictor depend on the specific country. For Germany, the medium-term curvature factors has significant predective power on forecasting. For the United States, it is also the curvature factor predicting the real economic activity. However, for Japan, it is the short-term slope factor has the predictive power. Second, for Germany, Japan and the US, the predictive ability is particularly strong at long horizon. Third, for the UK, yield factors seem have lower power of predictbility, only at long horizon it is significant. This finding is consistent with Plosser and Rouwenhorst (1994) who provide furthere evidence that the yield spread can predict the nominal growth rate significantly. The t-valus are calculated using Newey-West (1987) heteroskedasticity and autocorrelation consistent standard errors. That eliminates the effect of moving average due to the overlapping forecasting horizions. This applies to all the following results except the Possion regression results.

Table 5 About Here

The level factor is consistently significant on prediciting the inflation rate. The slope factor, as conjectured, contains extra information on the future inflaiton. The forecasting power is strong for Germnay, Japan and the UK, but to a less extent for the US.

Table 6 About Here

Regarding the predictive ability on future inflation, the explainment is usually Fisher decomposition which states that nominal interest rate can be divided into the ex ante real interest rate and the expectated inflation. The predictive power of future real activity is thought from the monetary policy and investor expectations. The tighting monetary policy implies a rise in short-term interest rates, typically the long-term interest rates will also rise but usually be less. As a consequence, the yield spred narrows, the polar case is it turn to negative, this is so-called inverted yield curve. if inverstors expect future economic growth, it means more profitable investment opportunities. In order to take the advantage of opportunties, more bond are issued, and these bonds are usually long-term for avoiding risk, this increase the bond return. This behavior thus connects the spread with the expected future economic activity.

4.2 Out-of-sample forecasting accurcy of yield spread and factors

Recently, the macro-finance model in the framework of (latent) affine term structure provides strong evidence of interactions with macro-variables, such as Ang, Piazzesi and Wei (2006) and Dewachter and Lyrio (2003). Theoretically, the entire term strucutre should have more information about future economic activities since the slope is a member of the yield curve information set. However, empirically, it is more complicated since the relationship may be nonlinear, latent factors are possible correlated therefore lead to multicollinearity. Empirically, we need compare the forecasting ability of two models.

Because the world interest rates are not observable, we can't examine the predictive ability of world spread on forecasting the world economic activity. The yield curve model in section 3 provide us a tool for extracting out global factors. It is suitable for the purpose in this paper. However to proof the predictive usefulness of factors from dynamic Nelson-Siegel model, we need compare it with the spread's forecasting performance, since previouly most of studies on this strand of literature focus on the spread.

In order to test the predictive power, we should choose actively traded debt securities that incoporate the market's expectations. The government bond is obviously a good choice. But which yield spread? the spread between 10-year and 3-month or 1-year? We choose yield spread according to two empirical criterions. First, availablity of yields. Second, in forecast of real activity, the most significant results from two treasury yields whose maturities are far apart. Hence, the spread for the US is the difference between 10-year yield and 3-month yield, for Germany and Japan, 10-year yield and 1-year yield, for the UK, the difference between 10-year yield and 6-month yield.

The out-of-sample forecasting accurcy of the yield spread and yield factors is presented in Table 7. We note that the relative forecasting performance of two models is country-dependent. For Germany, yield factors forecast better. It is consistent with results in Table 5, the empirical correspondent of the yield spread, the slope factor has low interpretation power. For Japan, Both RMSE and MAE criterions support that the yield spread is preferrable. For the US, interesting, at short horizon, factors are preferred, at medium horizion, the spread is a better choice. Due to lack of predictive power of both factors and spread on real economic activity, the UK results are skipped. However, the predictive differnces with spreads or yield factors are not big. This supports employment of factors for the purpose of examining the relationship between global yield curve and world economic activity.

Table 7 About Here

4.3 Global yield factors and economic activity across countries

The predictive usefulness of yield curve is not only well-established in the US but also internationally. Jorion and Mishkin (1991) found strong evidence the term structure have predicitve power on future inflation in West Germany, Bratain and Switzerland. Plosser and Rouwenhorst (1994) evaluated the information in the term structure about future real economic growth in three industrialized countries. In addition, they found evidence of linkages between real economic growth and yield spreads acorss countries. Bonser-Neal and Morley (1997) investigated the predictive power of the term strucutre on real economic activity in 11 industrial countries.

Although there are a lot of international studies on the predictive power of the yield curve, but usually investigate each country independently. Few studies examine the existence of a global yield curve that predicts the world or corss-country economic activity. However this is an interesting exercise. There is increasing international trade, FDI and international asset trade, Kose eat al (2003) identified a common world business cycle factor. On the other hand, The financial deregulations may increase the integration degree of financial market, in such case a global yield curve may explain most of variation of yield curves across countries. Diebold, Li and Yue (2007) find that there do exist the global yield curve factors. The main purpose of the paper is to investigate relationship between the global yield curve and world economic activity. Our empirical question is: Does global yield factors predict the economic activity in each country?

Which countries should be investigated? The data availability is the first criterion. The available data should cover a long period, particularly this study is about a low frequency phenomenon, quaterly real growth rate. Second, only countries with well-developed financial markets can be included. Otherwise, the yield spread can't reflect the market expectation. Third, the country should play a significant role in world business cycles. Thus, in this study, I investigate Germany, Japan, the UK and the US cases. The Japanese finacial market are restrictive before 1980, but since 1985, the deregulation is completed and markets are liquid and transparent (Zhu 2007).

The global factors are extracted in section 3. These factors are employed to examine the predictive power on real growth rates and inflation across countries. The results are reported in Table 8 and Table 9. There is strong evidence that global yield factors do indeed have information on the economic activity in each countries. R-square is usually lower for the real growth forecasting because although there are common world business cycle factor and global yield curve factors, there are also important idiosyncratic factors, therefore, the forecasting accurcy is not as high as in the model using country-specific factors. For inflations, the results using domestic and global factors are similar, this may indicate that inflations are more synchronized thatn real economic activity. This is no surprise since the real activity is a much more complicated variable and It subjects to the specific structure of country' macroeconomy.

Table 8 About Here

Table 9 About Here

4.4 Global yield factors and covariance of economic activities

The predictive power of global yield factors is not fully investigated in the model in above subsection. To get more insight on this issue, we need examine the links between bilateral business cycle correlations and global yield factors. This make the analysis more robust. The global yield factors should have information beyond those on country-specific factors.

The bilateral correlations are from the conditional dynamic correlation (DCC) analysis based on DCC-GARCH model (Engle 2002). This model is appropriate for the purpose here. It is extensively applied because it preserves the simplicity of univirate model in a multivariate setting. The DCC-GARCH model for factors is as follows:

$$\mathbf{f}_t|\Omega_t \; \tilde{} \; N(0, H_t)$$

$$H_t = D_t R_t D_t$$

$\mathbf{f}_t$ is the vector of factore, in this study, real growth rates for aformetioned four countries. The maximum likelihood method can be used to estimate the DCC-GARCH model.

The predictive ability of global factors on selected covariances is presented on Table 10 and Table 11. Like in above subsection, the global level and slope factors are consistently significant in accounting for the six bilateral covariances of inflations across countries. However, the evidenc on real growth is weaker. The global level and slope factors are most significant for predicing the covariance of real growths bewteen Germany and Japan. For the covariance between the UK and the US, the level factors is significant. Global factors also predicts the covariance between Germany and the UK.

Table 10 About Here

Table 11 About Here

From the variance-covariance matrix of real growths in section 2, we know that there are two trends in international business cycles. One is between Germany and Japan, the other is between the UK and the US. Although the evidence is not as strong as the inflation case, but global factors do have information about both trends in world business cycles. However it is important to note that there is asymmetric predictive power, global factors forecast covariances between Germany and Japan better. One natural question is: Does this means that the US is less subject global factors?

4.5 Global yield factors and business cycle synchronization

One conclusion from previous studies is that discrete model are more stable than continuous models in prediciting the future economic activity. One opinion is that the economy may envolve differently within distinct discrete states. Another argument in favor of discrete model is that the discrete model circumvents the spurious accurcy of countinuous variables due to the measurement errors.

In this part, I investigate the relationship between global factors and world business synchroniztion in a discrete model. The economic recession is indexed by 1. This provide a binary index for each country. The synchroniztion is indexed by the sum of binary indexes from four countries. Any single quater of negative year-over-year real GDP growth is defined as a recession. This is the R1 rule in Rudebusch and Williams. They show that this simple and straightforward rule works well, as it matches the NBER recession quaters well.

Table 12 presents the results on synchronization regression. The global slope and curvature factors show predictive power up to 5-quater ahead. This provides further evidence of predictive ability of global yield curve on world business cycles. The result offers extra information on determinants of international business cycles. Most studies on this strand of literature concentrate on relationship between international business cycles and international trade or FDI.

Table 12 About Here

4.6 Policy implications

This research has important policy implications. The global financial markets appear to have become an important channel for the international transimission of disturbances. This aspect of global interactions have predictive power on demestic economic activity, both real and nominal. Forecasts are an important component of many economic decisions. Such evidence on the predictive ability of global yield factors would be useful to national policy markers and international institutions. The domestic export industries would benefit from better forecasts of foreign economic activity. Policy makers can know better what is the impact of a foreign supply shock on domestic economic activity through channel of global yield factors.

The results above document that global inflations comovement more closely than real activities. This tendency implies that international trade and common supply shocks, such as oil shock, display significance in explaining global inflations. The different structures of macroeconomy probably play a role in accounting for a less synchornized real activities. Finding out the mechanism of different macroeconomic structures on world business cycles therefore constitutes an interesting and challenging research agenda.

5 Concluding remarks

This paper investigates the predictive power of global yield factors on demestic economic activities and international economic activities. I find the evidence of the predictive ability. Specificaly, global yield factors help forecast the real economic growth in countries investigated. In addition, the Possion regression shows that global factors contain information about international business cycle synchronization. Previous studies document the advantages and importance of discrete models in the robustness of predictive power of yield curve. This finding provide a further evidence but from a perspective of international environment. A significant fraction of covariances of real growths and inflations across countries can be explained by global yield factors. However the results indicate that inflations are more internationally synchronized than the business cycles.

This empirical study extends the existing literature and provides further evidence on global interactions of financial markets and business cycles. The findings has important policy implications. There are also a lot need to be further studied and constitute a future research agenda, such as, why global inflations comovement more closely than real activities. Why there are seemingly two economic growth trends in industrialized countries, one is between the US and the UK, the other is between Germany and Japan.

References

[1] Ahmed, S., Ickes, B.W., Wang, P., Yoo, B.S., 1993, International business cycles. American Economic Review 83, 335-359.

[2] Ang, A., Piazzesi, M., Wei, M., 2006. What does the yield curve tell us about GDP growth? Journal of Econometrics 131, 359-403.

[3] Bonser-Neal, C., Morley, T.R., 1997. Does the yield spread predict real economic activity? a multicountry analysis. Federal Reserve Bank of Kansas City, Economic Review, Third Quater, 37-53.

[4] Chang, R., 1997, Financial integration with and without international policy coordination. International Economic Review 38, 547-564.

[5] Dewachter, H., Lyrio, M., 2003. Macro factors and the term structure of interest rates. Journal of Money, Credit and Banking 38, 119-140.

[6] Diebold, F.X., Li, C., 2006. Forecasting the term structure of government bond yields. Journal of Econometrics130, 337-364.

[7] Diebold, F.X., Li, C., Yue, V.Z., 2006, Global yield curve dynamics and interactions: a generalized Nelson-Siegel approach. Journal of Econometrics, forthcoming.

[8] Diebold, F.X., Rudebusch, G.D., Aruoba, S.B., 2006, The macroeconomy and the yield curve: a dynamic latent factor approach. Journal of Econometrics 131, 209-338.

[9] Duffee, G., 2002, Term premia and interest rate forecasts in affine models. Jounal of Finance 57, 405-443.

[10] Engle, R., 2002, Dynamci conditional correlation: a simple class of multivariate generalized autoregressive conditional heteroskedasticity models. Journal of Business and Economic statistics 20, 339-350.

[11] Estrella, A., 2004. Why does the yield curve predict output and inflation? Economic Journal 115, 722-744.

[12] Estrella, A., Trubin, M.R., The yield curve as a leading indicator: some practical issues. Federal Reverve Bank of New York, Current Issues in Economics and Finance 12, 1-7.

[13] Estrella, A., Hardouvelis, G.A., 1991. The term structure as a predictor of real economy activity. Jouranl of Finance 46, 555-576.

[14] Estrella, A., Mishkin, F.S., 1998. Predicting U.S. recessions: financial variables as leading indicators. Review of Economics and Statistics 80, 45-61.

[15] Estrella, A., Rodrigues, A.P., Schich, S., 2003. How stable is the predictive power of the yield curve? evidence from Germany and the United States. Review of Economics and Statistics 85, 629-644.

[16] Hamilton, J., 1994. Time series analysis. Princeton University Press.

[17] Hamilton, J., Kim, D.H., 2002. A reexamination of the predictability of economic activity using the yield spread. Journal of Money, Credit and Banking 34, 340-460.

[18] Harvey, A., Rossi, G.D., 2006, Signal extraction. Palgrave Handbook of Econometrics vol 1, Palgrave Macmillan.

[19] Jansen, W.J., Stokman, A.C.J., 2004. Foreign direct investment and international business cycle comovement. European Central Bank, Working Paper Series No. 401.

[20] Jorion, P., Mishkin, F., 1991. A multicountry comparison of term-structure forecasts at long horizons 29, 59-80.

[21] Kose, M.A., Otrok, C., Whiteman, C.H., 2003. International business cycles: world, region, and country-specific factors. American Economic Review 93, 1216-1239.

[22] Nelson, C.R., Siegel, A.F., 1987. Parsimonious modeling of yield curves. Journal of Business 60, 473-489.

[23] Newey, W.K., West, K.D., 1987. A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. Econometrica 55, 703-708.

[24] Plosser, C.I., Rouwenhorst, K.G., 1994. International term structures and real economic growth. Journal of Monetary Economics 33, 133-155.

[25] Rudebusch, G.D., Williams, J.C., 2007. Forecasting recessions: the puzzle of enduring power of the yield curves. Federal Reserve Bank of San Francisco, Working Paper Series 16.

[26] Tam, C., Yu, I., 2008. Modelling sovereign bond yield curves of the US, Japan and Germany. International Journal of Finance and Economics 13, 82-91.

[27] Zhu, X., 2007. Testing present value model under regime shift with bootstrap-based Wald test: the Japanese term structure. Working Paper.

[28] Zhu, X., 2008. Global Yield Curves and Sovereign Bond Market Integration. Working Paper.

Table 1: Summary Statistics for Bond Yields

maturity (months)	Mean	Std. Dev.	skew-ness	kurto-sis	$\hat{\rho}_{(1)}$	$\hat{\rho}_{(4)}$	$\hat{\rho}_{(10)}$	ADF
Germany								
12	4.6839	1.9838	0.8804	2.8347	0.9726	0.8302	0.4741	-1.2844
24	4.8784	1.890	0.8263	2.8125	0.9644	0.8106	0.4992	-1.4170
60	5.4304	1.6828	0.5046	2.4525	0.9668	0.8256	0.6261	-1.3686
120	5.9123	1.4887	0.1356	2.0378	0.9721	0.8487	0.7493	-1.3637
Japan								
maturity (months)	mean	Std. Dev.	skew-ness	kurto-sis	$\hat{\rho}_{(1)}$	$\hat{\rho}_{(4)}$	$\hat{\rho}_{(10)}$	ADF
6	0.6377	0.9320	1.8128	5.1715	0.8747	0.5733	0.1031	-3.7950
12	0.7125	0.9531	1.7267	4.8016	0.9705	0.8606	0.6642	-1.366
60	1.4568	1.0944	1.3802	3.6660	0.9562	0.8501	0.6794	-1.757
120	2.2116	1.1401	1.0795	2.9977	0.9428	0.8689	0.7915	-1.405
U.K.								
maturity (months)	mean	Std. Dev.	skew-ness	kurto-sis	$\hat{\rho}_{(1)}$	$\hat{\rho}_{(4)}$	$\hat{\rho}_{(10)}$	ADF
6	7.1611	2.9614	0.8244	2.4724	0.9625	0.8175	0.5736	-1.6636
12	7.0951	2.7796	0.7371	2.3721	0.9637	0.8192	0.6133	-1.6068
60	7.1926	2.4158	0.3167	1.7399	0.9594	0.8606	0.7781	-1.4806
120	7.1836	2.3632	0.1929	1.5188	0.9674	0.8966	0.8242	-1.450
U.S.								
maturity (months)	mean	Std. Dev.	skew-ness	kurto-sis	$\hat{\rho}_{(1)}$	$\hat{\rho}_{(4)}$	$\hat{\rho}_{(10)}$	ADF
6	4.9666	2.0503	-0.1494	2.5227	0.9486	0.6980	0.2441	-1.3684
12	5.1406	2.0632	-0.0909	2.4999	0.9439	0.7075	0.3075	-1.3497
60	6.0008	1.9061	0.2592	2.6064	0.9165	0.7173	0.6228	-2.4572
120	6.3751	1.8007	0.4949	2.6518	0.9153	0.7222	0.7342	-2.692

Notes:
(1)The summary statistics for Japan is based on Bloomberg sample.
(2) $\hat{\rho}_{(\tau)}$is the autocorrelation coefficient with lag length τ periods.
(3) The lag length of ADF test is selected by BIC.

Table 2: Summary Statistics for Factors Across Countries (AFDNS Estimates)

Germany

factor	mean	Std.Dev.	skewness	kurtsis	$\hat{\rho}_{(1)}$	$\hat{\rho}_{(4)}$	$\hat{\rho}_{(10)}$	ADF
level	6.4618	1.4306	-0.1304	1.8934	0.9689	0.8076	0.7536	-1.5858
slope	-1.6631	1.6848	-0.0327	2.1199	0.9236	0.5359	-0.0926	-2.3954
curv	-2.3964	1.8087	0.4038	2.4149	0.8502	0.3255	-0.0314	-2.8127

Japan

factor	mean	Std.Dev.	skewness	kurtosis	$\hat{\rho}_{(1)}$	$\hat{\rho}_{(4)}$	$\hat{\rho}_{(10)}$	ADF
level	3.8205	1.9294	0.3235	1.8920	0.9555	0.8564	0.7660	-1.5636
slope	-1.2524	1.0790	0.0215	2.2710	0.9303	0.7370	0.4328	-1.7734
curv	-3.0991	1.4574	-0.1858	2.9174	0.8502	0.3809	-0.0481	-2.7375

U.K.

factor	mean	Std.Dev.	Skewness	Kurtosis	$\hat{\rho}_{(1)}$	$\hat{\rho}_{(4)}$	$\hat{\rho}_{(10)}$	ADF
level	7.2865	2.4391	0.1418	1.4383	0.9661	0.8977	0.8287	-1.4131
slope	-0.2054	2.0048	0.0520	3.6397	0.9192	0.5686	0.0122	-2.6400
curv	-0.1746	1.9176	0.1697	2.9090	0.7610	-0.0160	0.3697	-3.2687

U.S.

factor	Mean	Standard	Skewness	Kurtosis	$\hat{\rho}_{(1)}$	$\hat{\rho}_{(4)}$	$\hat{\rho}_{(10)}$	ADF
level	6.7758	1.7293	0.6281	2.8913	0.9122	0.7063	0.7886	-3.1029
slope	-2.0068	1.6229	-0.0951	1.8357	0.9070	0.4299	-0.2599	-3.3258
curv	-0.8723	1.8641	-0.8540	3.1599	0.7956	0.4346	-0.0564	-3.3837

Notes:
(1) Factors are from DNS estimation.
(2) $\hat{\rho}_{(\tau)}$is the autocorrelation coefficient with lag length τ periods.
(3)The lag length of ADF test is selected by SIC.

Table 3: Extraction of Global Yield Curve Factors

Kalman Filter*

	$\hat{\alpha}$	$\hat{\rho}$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\beta}_4$
level	0.2104	0.9608	0.6967	0.9412	0.9199	0.9955
	(1.01)	(31.77)	(8.42)	(27.22)	(15.59)	(62.97)
slope	−0.0988	0.9192	0.9313	0.9323	0.9250	0.9304
	(−0.63)	(8.74)	(19.26)	(27.60)	(19.56)	(16.59)
curv	−0.1890	0.8345	0.7909	0.8060	0.8885	0.9576
	(−0.99)	(4.90)	(7.71)	(9.91)	(15.60)	(30.42)

Principle Component Analysis

level	eigenvalue	3.6332	0.2135	0.1117	0.0416
	variance Prop.	0.9083	0.0534	0.0279	0.0104
	cumulative Prop.	0.9083	0.9617	0.9896	1.0000
slope	eigenvalue	1.9899	1.0556	0.8166	0.1379
	variance Prop.	0.4975	0.2639	0.2042	0.0345
	cumulative Prop.	0.4975	0.7614	0.9896	1.0000
curv	eigenvalue	1.5490	1.3123	0.7064	0.4341
	variance Prop.	0.3872	0.3281	0.1762	0.1085
	cumulative Prop.	0.3872	0.7153	0.8915	1.0000

Notes: (1)The statistics in the parentheses are t-values.
(2)The Japan factors used for extracting global factors consist of estimates of two samples from PACAP and Bloomberg.

Table 4: Summary Statistics for Global Factors

	mean	Std.Dev.	skewness	kurtosis	$\hat{\rho}_{(1)}$	$\hat{\rho}_{(4)}$	$\hat{\rho}_{(10)}$	ADF
level	6.6747	1.5292	0.1255	1.6824	0.9617	0.8567	0.8823	-1.5457
slope	-1.3509	0.4950	0.0201	2.8583	0.9164	0.5173	0.0742	2.8583
curv	-1.0614	0.4553	0.2233	2.8551	0.8095	0.2098	-0.1206	-3.3837

Note: $\hat{\rho}_{(\tau)}$is the autocorrelation coefficient with lag length τ periods

Table 5: Predicting the Year-Over-Year Real Growth Rate
Using Slope and Curvature Factors

		Germany		
	1 Year	2 Year	3 Year	4 Year
Slope	−0.0365	0.0234	0.0402	0.0750
	(−0.5132)	(0.3905)	(0.6665)	(1.1465)
Curvature	0.1579	0.1407	0.1088	0.0662
	(3.7185)	(3.9293)	(3.0232)	(1.6956)
R^2	0.3476	0.4990	0.4628	0.3624

		Japan		
	1 Year	2 Year	3 Year	4 Year
Slope	0.5246	0.5872	0.6088	0.5547
	(2.7882)	(3.7472)	(4.2023)	(3.5223)
Curvature	−0.0272	−0.0272	−0.0500	−0.0575
	(−0.1936)	(−0.2333)	(−0.4649)	(−0.4913)
R^2	0.2823	0.4984	0.6374	0.5994

		U.K.		
	1 Year	2 Year	3 Year	4 Year
Slope	−0.0274	0.0306	0.0812	0.1112
	(−0.3259)	(0.3896)	(1.2216)	(2.2067)
Curvature	0.0532	0.0276	0.0217	0.0053
	(0.5877)	(0.3262)	(0.3038)	(0.0980)
R^2	0.0374	0.0176	0.1130	0.2973

		U.S.		
	1 Year	2 Year	3 Year	4 Year
Slope	−0.0058	0.0574	0.0588	0.0659
	(−0.0933)	(1.0277)	(1.0608)	(1.2604)
Curvature	0.1316	0.1270	0.1299	0.0869
	(2.3293)	(2.5170)	(2.5956)	(1.8468)
R^2	0.1826	0.3478	0.4607	0.4302

Notes: (1) The statistics in the parentheses are t-values.
(2) Newey and West (1987) heteroskedasticity and autocorrelation consistent standard error are used for calculating t-values.

Table 6: Predicting the Year-Over-Year Inflation Rate Using Level and Slope Factors

	Germany	Japan	U.K.	U.S.
Level	0.1949	0.0691	0.1562	0.0989
	(3.5869)	(1.9427)	(2.8807)	(2.0164)
Slope	0.2316	0.1525	0.1804	0.0737
	(1.2343)	(2.3730)	(2.7926)	(1.4194)
R^2	0.5535	0.5019	0.4462	0.1628

Notes: (1) The statistics in the parentheses are t-values.
(2) Newey and West (1987) heteroskedasticity and autocorrelation consistent standard error are used for calculating t-values.

Table 7 Out-of-Sample 1 to 6-Quater-Ahead Forecasting Accuracy

		1 Quater	2 Quater	3 Quater	4 Quater	5 Quater	6 Quater
		Germany					
RMSE	factors	0.4729	0.5045	0.5299	0.5346	0.5334	0.5248
	spread	0.5089	0.5346	0.5589	0.5621	0.5468	0.5296
MAE	factors	0.4254	0.4493	0.4660	0.4660	0.4651	0.4617
	spread	0.5620	0.5700	0.5761	0.5811	0.5690	0.5689
		Japan					
RMSE	factors	0.7592	0.7621	0.7763	0.7751	0.7717	0.7556
	spread	0.6504	0.6436	0.6493	0.6397	0.6298	0.6212
MAE	factors	0.6423	0.6388	0.6596	0.6506	0.6406	0.6224
	spread	0.5562	0.5375	0.5360	0.5187	0.5016	0.4959
		U.S.					
RMSE	factors	0.5090	0.5312	0.5556	0.5736	0.5707	0.5739
	spread	0.5494	0.5480	0.5477	0.5388	0.5177	0.5046
MAE	factors	0.4037	0.4190	0.4411	0.4588	0.4459	0.4477
	spread	0.4392	0.4389	0.4500	0.4549	0.4411	0.4399

Notes: (1)the factor model uses slope and curvature factors from the yield curve.
(2) the spread model uses the yield spread between the 10-year yield and the short-term yields, respectively, for Germany and Japan, 1-year yield, for US, 3-month yield.

Table 8: Predicting the Year-Over-Year Real Growth Rate
Using Global Slope and Curvature Factors

	Germany			
	1 Year	2 Year	3 Year	4 Year
Slope	0.5904	0.5888	0.3994	0.1876
	(2.5450)	(2.4148)	(1.2536)	(0.7354)
Curvature	0.6026	0.3444	0.1570	−0.1235
	(2.3557)	(1.2809)	(0.5367)	(−0.4387)
R^2	0.3643	0.3684	0.1992	0.1368

	Japan			
	1 Year	2 Year	3 Year	4 Year
Slope	0.6450	0.8421	0.8923	0.7808
	(1.3615)	(1.9818)	(2.2186)	(1.9613)
Curvature	0.1144	0.2130	0.0746	0.0189
	(0.2190)	(0.4546)	(0.1682)	(0.0423)
R^2	0.1062	0.2649	0.3409	0.5994

	U.K.			
	1 Year	2 Year	3 Year	4 Year
Slope	0.1617	−0.1829	−0.0071	0.2015
	(1.3615)	(−0.6217)	(−0.0267)	(0.8959)
Curvature	−0.4554	0.3613	0.3998	0.2836
	(−1.5461)	(1.1136)	(1.3693)	(1.1434)
R^2	0.1617	0.0946	0.1384	0.1866

	U.S.			
	1 Year	2 Year	3 Year	4 Year
Slope	−0.3464	−0.1499	−0.0953	0.0597
	(−1.7313)	(−0.8700)	(−0.6797)	(0.3769)
Curvature	0.3910	0.6007	0.7141	0.4039
	(1.7719)	(3.1614)	(4.6167)	(2.3416)
R^2	0.1632	0.3058	0.5437	0.3100

Notes: (1) The statistics in the parentheses are t-values.
(2) Newey and West (1987) heteroskedasticity and autocorrelation consistent standard error are used for calculating t-values.

Table 9: Predicting the Year-Over-Year Inflation Rate Using
Global Level and Slope Factors

	Germany	Japan	U.K.	U.S.
Level	N.A.	0.2256	0.3347	0.1577
		(4.3886)	(5.9508)	(4.1138)
Slope	N.A.	0.3982	1.0506	0.3924
		(2.5175)	(6.0713)	(3.3280)
R^2	0.5535	0.5396	0.7349	0.4813

Notes: (1) N.A. : the regression is nonstationary.
(2) The statistics in the parentheses are t-values.
(3) Newey and West (1987) heteroskedasticity and autocorrelation consistent standard error are used for calculating t-values.

Table 10: Predicting The Conditional Covariance of Real Growth Rate Across Countries Using Global Level, slope and Curvature Factors

	Germany and Japan					
	1 Quater	2 Quater	3 Quater	4 Quater	5 Quater	6 Quater
Level	0.0842	0.1316	0.1172	0.1110	0.1111	0.1131
	(9.6972)	(4.6989)	(4.1283)	(3.3358)	(3.6180)	(3.4330)
Slope	0.1557	0.3439	0.3440	0.4117	0.3850	0.3443
	(5.9042)	(4.0402)	(3.9885)	(4.0706)	(4.1270)	(3.4408)
Curv	−0.1346	−0.3069	−0.2106	−0.3196	−0.2461	−0.0968
	(−4.4860)	(−3.1707)	(−2.1471)	(−2.7783)	(−2.3198)	(−0.8508)
R^2	0.5772	0.3461	0.2322	0.2325	0.2649	0.2719
	U.K and U.S.					
	1 Quater	2 Quater	3 Quater	4 Quater	5 Quater	6 Quater
Level	0.0473	0.1479	0.0912	0.0854	0.0950	0.0817
	(3.2480)	(2.4114)	(1.8793)	(1.7486)	(1.8737)	(1.6667)
Slope	0.0453	0.3167	0.1873	0.1819	0.2056	0.1800
	(1.0244)	(1.6991)	(1.2701)	(1.2255)	(1.3341)	(1.2077)
Curv	−0.0542	−0.1885	−0.1136	−0.1087	−0.1520	−0.1592
	(−1.0785)	(0.2120)	(−0.6776)	(−0.6437)	(−0.8673)	(−0.9392)
R^2	0.2772	0.1356	0.1049	0.1130	0.1359	0.1199
	Germany and U.K.					
	1 Quater	2 Quater	3 Quater	4 Quater	5 Quater	6 Quater
Level	0.0288	−0.0100	−0.0736	−0.0752	−0.0887	−0.0889
	(2.3557)	(−0.3293)	(−2.3860)	(−2.1475)	(−1.9672)	(−2.0549)
Slope	−0.0577	−0.1494	−0.2107	−0.2420	−0.2467	−0.2118
	(−1.5517)	(−1.6184)	(−2.2465)	(−2.2758)	(−1.8004)	(−1.6118)
Curv	−0.0433	−0.0500	0.0725	0.0579	0.0515	0.0157
	(−1.0237)	(−0.4758)	(0.6800)	(0.4792)	(0.3305)	(0.1053)
R^2	0.1548	0.0467	0.1311	0.1601	0.1592	0.1768

Notes: (1) The statistics in the parentheses are t-values.
(2) Newey and West (1987) heteroskedasticity and autocorrelation consistent standard error are used for calculating t-values.

Table 11: Predicting The Conditional Covariance of Inflation Rate Across Countries Using Global Level, Slope and Curvature Factors

	G and J	G and U.K.	G and .US.	J and. U.K.	J and U.S.	U.K. and U.S.
Level	0.0932	0.7744	0.0336	0.2661	0.1124	0.1763
	(2.2289)	(2.4088)	(2.8868)	(4.1737)	(4.2492)	(4.4587)
Slope	0.1458	0.2794	0.1256	0.7943	0.3076	0.5329
	(1.1475)	(2.7678)	(3.5529)	(4.0996)	(3.8282)	(4.4344)
Curv	−0.2132	−0.0015	−0.0232	0.0211	−0.0849	−0.0905
	(−1.4753)	(−0.0137)	(0.0402)	(0.0957)	(−0.9288)	(−0.6623)
R^2	0.2820	0.3480	0.2631	0.5498	0.4632	0.5034

Notes: (1) The statistics in the parentheses are t-values.
(2) G: Germany, J: Japan;

Table 12: Predicting World Recession Synchronization Using Global Slope and Curvature Factors in a Possion Regression

	1 Quater	2 Quater	3 Quater	4 Quater
Slope	0.6084	0.7189	1.2125	1.3109
	(2.09)	(2.24)	(3.20)	(3.37)
Curvature	−0.6553	−0.8515	−1.6648	−1.5456
	(−1.85)	(−2.18)	(−3.57)	(−3.17)
	5 Quater	6 Quater	7 Quater	8 Quater
Slope	1.1275	0.6654	0.4341	0.4272
	(2.91)	(1.74)	(1.10)	(1.03)
Curvature	−1.3728	−0.6900	−0.6487	−0.6596
	(−2.86)	(−1.47)	(−1.38)	(−1.33)

Notes: (1) The statistics in the parentheses are t-values.
(2) 4-quater lagged slope factor and 2-quater lagged curvature factor are applied