The role of global liquidity in the term structure of interest rates

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Abstract: As the global liquidity has emerged as an important factor in the global financial market since the global financial crisis in 2008, the global financial market has been interested in the effect of global liquidity on global yield dynamics. This paper examines the role of global liquidity in global yield dynamics based on the macro-finance model. The estimation results show that the global liquidity plays a more important role in explaining the global level factor than global inflation but such macro factors appear not to explain the global slope factor. We interpret that global liquidity has not only information on global commodity inflation but also global asset price inflation and future expected inflation and thus more explanatory power than global inflation.

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Key Words: Term structure, Global liquidity, Dynamic factor model, Global yield, Yield curve

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I. Introduction

Policymakers, academics, and bond market participants have shown great interest in the term structure of government bond yields and have generated a huge literature[1]. The key proposition is that the yield curve is driven by a number of latent factors. In particular, three latent yield factors were suggested and interpreted as level, slope and curvature in Andersen and Lund (1997), Diebold and Li (2006), and Diebold et al. (2008). Then, what are economic insights on underlying latent factors or forces that drive changes in interest rates? To provide insight into the fundamental drivers of the yield curve, macro variables and macro structure have been combined with the finance models, which are called as "Macro-finance models of interest rates"[2].

Diebold et al. (2008) provide a macroeconomic interpretation of the dynamic Nelson-Siegel representation of Diebold and Li (2006) by combining it with a vector autoregression representation for the macroeconomy. They show that latent global yield factors exist and the global yield factors are connected with the macroeconomic variables. In their estimation results, the global level factor is correlated with global inflation and the global slope factor is highly correlated with global business cycle (real activity).

This paper considers another macroeconomic factor, global liquidity. As the deepening of financial integration and cross-border lending has increased capital inflow and the financial dependence between economies, global liquidity has become a key focus of financial stability

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[1] Examples include Ang and Piazessi (2003), Ang et al. (2006), Bae and Kim (2011), Bekaert et al. (2010), Dewachter and Lyrio (2006), Dewachter et al. (2014), Diebold et al. (2005), Diebold and Li (2006), Diebold et al. (2006), Diebold et al. (2008), Paccagnini (2016), Rudebusch and Wu (2007, 2008), Wright (2011), and others.

[2] Please refer to Rudebusch (2010) for excellent summary on the macro-finance models of interest rates.

and goods and assets price inflation. This reflects a perception that global liquidity is an important driver of capital flows, global asset price dynamics and inflation. D'agostino and Surico (2009) show that global liquidity has more predictive power for forecasting U.S. inflation than U.S. money growth. Belke et al. (2012) support the hypothesis that there is a positive long-run relation between global liquidity and the development of food and commodity prices. Chen et al. (2012) show that global liquidity conditions matter for economic and financial stability. Eickmeier et al. (2014) emphasize that global liquidity has been a potentially important factor in the build-up of the pre-crisis financial imbalances and in the spill-over effects of accommodative monetary conditions from the core advanced to emerging market economies and suggest that global liquidity conditions are largely driven by three common factors—global monetary policy, global credit supply, and global credit demand[3]. Kang et al. (2016) find that the effect of global liquidity on commodity prices becomes more salient since the global financial crisis in 2008. Abbritti et al. (2018) show that global factors are the ultimate drivers of both yield curve and term premium dynamics across countries.

In this vein, global liquidity may play an important role in explaining the cross-border interest dynamics. In this paper, we tackle the question of whether global liquidity has an impact on global yield dynamics. For this end, we consider a dynamic factor Nelson-Siegel model of Diebold et al. (2008) and incorporate three macro variables—global inflation, global business cycle and global liquidity—into the model. In the empirical study, we consider the yield curves of 4 economies—Germany, Japan, U.K., and U.S.—covering the first quarter in 1985 to the second quarter in 2020.

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[3] Please refer to Ruffer and Stracca (2006), Sousa and Zaghini (2008), Belke et al. (2010), Domanski et al. (2011), CGFS (2011), Beckmann et al. (2014), Bruno and Shin (2015), and others for various issues related to global liquidity.

Our estimation results show that global liquidity plays an important role in the global level factor but not in the global slope factor. In particular, when we incorporate global liquidity into the dynamic Nelson-Siegel factor model, global inflation is not a key factor in explaining the global level factor any more. We interpret that global liquidity has not only the information on global commodity inflation but also the information on global asset price inflation and expected future inflation. However, global liquidity appears not to play an important role in global slope factor, indicating that only global business cycle is linked to the global slope factor as shown in existing literature.

The remainder of the paper is structured as follows. In Section II, we describe our estimation methodology. In Section III, we present the data and show estimation results. Section IV concludes.

II. Methodology

(1) Multi-country dynamic factor Nelson-Siegel model

There has been a significant development in extracting the global yield factors. Diebold et al. (2008) have tried to extend the dynamic factor Nelson-Siegel model (hereafter DFNS model; Diebold and Li 2006) for an individual country to the multi-countries model and Abbritti et al. (2018) have applied the FAVAR model (Factor Augmented VAR) to the Macro-Finance model. In this paper, we consider the generalized DFNS model of Diebold et al. (2008) and incorporate not only global inflation and global business cycle but also the global liquidity into the DFNS model. This modeling is similar with Ang and Piazessi (2003) and Diebold et al. (2008) who incorporated the macro factors into the Macro-Finance model. The key difference between these models and our model is that we consider the role of global liquidity in the macro factors whereas they do not.

Diebold and Li (2006)'s dynamic factorization of the Nelson-Siegel yield curve for a single country can be written as follows:

$$y_{it}(\tau) = l_{it} + s_{it}\left(\frac{1-e^{\lambda_{it}\tau}}{\lambda_{it}\tau}\right) + c_{it}\left(\frac{1-e^{\lambda_{it}\tau}}{\lambda_{it}\tau} - e^{\lambda_{it}\tau}\right) + v_{it}(\tau), \qquad (1)$$

where $y_{it}(\tau)$ denotes the continuously-compounded zero-coupon nominal yield on a τ month bond for a country i at time t, $l_{it}, s_{it}, and\ c_{it}$ are the three latent factors (slope, level, and curvature), λ_{it} is a parameter which determines the maturity at which the curvature loading is maximized, and $v_{it}(\tau)$ is a disturbance with standard deviation $\sigma_i(\tau)$. Following Diebold et al. (2008), we consider a simplified version of the yield curve (1) where the curvature factor (c_{it}) is left out[4]. Moreover, we assume that λ_{it} is constant over countries and time with little loss of generality from doing so. Then, the equation (1) can be rewritten as follows:

$$y_{it}(\tau) = l_{it} + s_{it}\left(\frac{1-e^{\lambda\tau}}{\lambda\tau}\right) + v_{it}(\tau). \qquad (2)$$

Note that equation (2) is effectively the measurement equation of a state space system with state vector $(l_{it}, s_{it})'$.

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[4] Diebold et al. (2008) focus on the model with level and slope factors only because the curvature factor is normally estimated with low precision due to missing data at very short and/or very long maturities in most of the countries used in their study and because curvature lacks clear links to macroeconomic fundamentals.

Now, following Diebold et al. (2008), we consider an *N*-country framework and introduce the global yields which depend on the global yield factors and thus the global yield can be expressed as follows:

$$Y_t(\tau) = L_t + S_t\left(\frac{1-e^{\lambda\tau}}{\lambda\tau}\right) + V_t(\tau), \tag{3}$$

where the $Y_t(\tau)$ are global yields and $L_t, and\ S_t$ are global yield factors (level and slope). We allow the dynamic movements of $L_t, and\ S_t$ which follow a first-order autoregressive process:

$$\begin{pmatrix} L_t \\ S_t \end{pmatrix} = \begin{pmatrix} \phi_{11} & \phi_{12} \\ \phi_{21} & \phi_{22} \end{pmatrix}\begin{pmatrix} L_{t-1} \\ S_{t-1} \end{pmatrix} + \begin{pmatrix} U_t^L \\ U_t^S \end{pmatrix}, \tag{4}$$

where the U_t^n are disturbances such that $\mathrm{E}\left(U_t^n U_{t'}^{n'}\right) = (\sigma^n)^2$ if $\mathrm{t} = \mathrm{t}'$ and $\mathrm{n} = \mathrm{n}'$, and 0 otherwise, $n = L, S$. In order to characterize the country common factors, $l_{it}, and\ s_{it}$, we allow $l_{it}, and\ s_{it}$ to load on the global factors $L_t, and\ S_t$ as well as country idiosyncratic factors:

$$l_{it} = \alpha_i^l + \beta_i^l L_t + \varepsilon_{it}^l, \tag{5}$$

$$s_{it} = \alpha_i^s + \beta_i^s S_t + \varepsilon_{it}^s, \tag{6}$$

where $\{\alpha_i^l, \alpha_i^s\}$ are constant terms, $\{\beta_i^l, \beta_i^s\}$ are loadings on global factors, and $\{\varepsilon_{it}^l, \varepsilon_{it}^s\}$ are country idiosyncratic factors, $\mathrm{i} = 1, \ldots, \mathrm{N}$. In equations (5) and (6), there are constant terms and so we assume that the country idiosyncratic factors have zero mean. In addition, following Diebold et al. (2008), because the magnitudes of global factors and factor loadings are not separately identified, we assume that innovations to global factors have unit standard deviation, that is, $\sigma^n = 1,\ n = L, S$.

As the case of the global factors, we allow the country idiosyncratic factors to follow a first-order autoregressive process:

$$\begin{pmatrix} \varepsilon_{it}^{l} \\ \varepsilon_{it}^{s} \end{pmatrix} = \begin{pmatrix} \psi_{11} & \psi_{12} \\ \psi_{21} & \psi_{22} \end{pmatrix} \begin{pmatrix} \varepsilon_{it-1}^{l} \\ \varepsilon_{it-1}^{s} \end{pmatrix} + \begin{pmatrix} u_{it}^{l} \\ u_{it}^{s} \end{pmatrix}, \tag{7}$$

where the u_{it}^{n} are disturbances such that $\mathrm{E}\left(u_{it}^{n} u_{it'}^{n'}\right) = (\sigma_i^n)^2\ if\ \ i = i', t = t' and\ \ n = n'$ and 0 otherwise, $n = l, s$. Moreover, we assume $\mathrm{E}\left(U_t^n u_{it-s}^{n'}\right) = 0,$ for all $n, n', i, and\ \ s,$ which means the shocks to the global factors and the shocks to the country specific factors are orthogonal. We restrict the dynamic matrices in the equations (5) and (7) are diagonal as in the case of Diebold et al. (2008).

We employ two step estimations in order to estimate the equations (1) ~ (7). In the first step, we consider four countries, US, Germany, Japan and UK and estimate $l_{it}, and\ \ s_{it}$ for each country in equation (2). We set $\lambda = 0.0609$.[5] Then, we can estimate the factor loading for the country *i* at time *t* by ordinary least squares regressions for each country as in Diebold and Li (2006). In the second step, given the estimate of $l_{it}, and\ \ s_{it}$, we estimate the global yield curve factor model by exploiting its state-space structure for both parameter estimation and factor extraction. In the state-space form, the equations (5) and (6) are measurement

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[5] Diebold and Li (2006) try to find an appropriate value of λ_{it} in the equation (1) by recalling that λ_{it} determines the maturity at which the loading on the medium-term, or curvature, factor achieves it maximum. They regard two- or three-year maturities as medium-term and thus simply pick the average, 30 months. They show that λ_{it} value that maximizes the loading on the medium-term factor at exactly 30 months is $\lambda_{it} = 0.0609$.

equations and the equations (4) and (7) are transition equations. Here, we can estimate the factor-by-factor model in the second step by assuming that the dynamic matrices in the equations (4) and (7) are diagonal. The all parameters to be estimated for each factor are one autoregressive coefficient of the global factor ($\phi_{nn}, n = 1, 2$), four constant terms ($\alpha_i^n, i = US, Germany, Japan$ & $UK, n = l, s$), four individual country loadings on the global factor ($\beta_i^n, i = US, Germany, Japan$ & $UK, n = l, s$) , four autoregressive coefficients on the country idiosyncratic factor (ψ_{ii}^n $i = US, Germany, Japan$ & $UK, n = l, s$) , and four standard deviations of the country idiosyncratic factor (σ_{ii}^n $i = US, Germany, Japan$ & $UK, n = l, s$) and so the total parameters are 17 for each factor. The state-space model for the level factor can be rewritten as follows:

$$\begin{pmatrix} l_{US,t} \\ l_{GM,t} \\ l_{JP,t} \\ l_{UK,t} \end{pmatrix} = \begin{pmatrix} \alpha_{US}^l \\ \alpha_{GM}^l \\ \alpha_{JP}^l \\ \alpha_{UK}^l \end{pmatrix} + \begin{pmatrix} \beta_{US}^l & 1 & 0 & 0 & 0 \\ \beta_{GM}^l & 0 & 1 & 0 & 0 \\ \beta_{JP}^l & 0 & 0 & 1 & 0 \\ \beta_{UK}^l & 0 & 0 & 0 & 1 \end{pmatrix} + \begin{pmatrix} L_t \\ \varepsilon_{US,t}^l \\ \varepsilon_{GM,t}^l \\ \varepsilon_{JP,t}^l \\ \varepsilon_{UK,t}^l \end{pmatrix}, \qquad (8)$$

$$\begin{pmatrix} L_t \\ \varepsilon_{US,t}^l \\ \varepsilon_{GM,t}^l \\ \varepsilon_{JP,t}^l \\ \varepsilon_{UK,t}^l \end{pmatrix} = \begin{pmatrix} \phi_L & 0 & 0 & 0 & 0 \\ 0 & \psi_{US}^l & 0 & 0 & 0 \\ 0 & 0 & \psi_{GM}^l & 0 & 0 \\ 0 & 0 & 0 & \psi_{JP}^l & 0 \\ 0 & 0 & 0 & 0 & \psi_{UK}^l \end{pmatrix} \begin{pmatrix} L_{t-1} \\ \varepsilon_{US,t-1}^l \\ \varepsilon_{GM,t-1}^l \\ \varepsilon_{JP,t-1}^l \\ \varepsilon_{UK,t-1}^l \end{pmatrix} + \begin{pmatrix} u_{L,t} \\ u_{US,t}^l \\ u_{GM,t}^l \\ u_{JP,t}^l \\ u_{UK,t}^l \end{pmatrix}, \; u_t \sim iidN(0, \Omega) \qquad (9)$$

where the equation (8) is a measurement equation and the equation (9) is a transition equation. Following Diebold et al. (2008), we set the valid initial value and estimate the parameters in the model by using the constrained MLE given the condition that the factor dynamics stationarity has to be satisfied[6].

(2) Multi-country dynamic factor Nelson-Siegel model with macro-variables

We extend the multi-country dynamic factor Nelson-Siegel model by incorporating the macro variables which are the global inflation, the global business cycle and the global liquidity. Diebold et al. (2008) consider only the global inflation and the global business cycle whereas we consider not only two macro variables but also the global liquidity. As in the case of the multi-country DFNS model, we employ two step estimation procedure. In the first step, we extract the level and the slope factors by using the OLS regression. Following Ang and Piazessi (2003), we apply the principal component analysis (PCA) to inflation, business cycles and liquidity variables for individual country and extract principal components. We regard the first principal component in each PCA as the global inflation factor (f_{INF}), the global business cycle factor (f_{BUSS}), and the global liquidity factor (f_{LIQ}) respectively[7]. In the second step, following Diebold et al. (2006), we consider the state-space model with the macro factors which are extracted from the PCA as follows:

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[6] Please refer to Kim and Nelson (1999) for the model specification and its estimation.

[7] After we regard the first principal component as the inflation factor in the inflation data, we regress the business cycle data on the inflation factor and consider the first principal component of the residual as the business cycle factor. Similarly, we regress the liquidity data on the inflation and business cycle factors and identify the first principal component of the residual as the liquidity factor. This process makes three factors orthogonal. The estimation result for the PCA is shown in the <Appendix 1>.

$$\begin{pmatrix} l_{US,t} \\ l_{GM,t} \\ l_{JP,t} \\ l_{UK,t} \\ f_{INF,t} \\ f_{BUSS,t} \\ f_{LIQ,t} \end{pmatrix} = \begin{pmatrix} \alpha_{US,t} \\ \alpha_{GM,t} \\ \alpha_{JP,t} \\ \alpha_{UK,t} \\ 0 \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} 0 & 0 & 0 & \beta^l_{US} & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & \beta^l_{GM} & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & \beta^l_{JP} & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & \beta^l_{UK} & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} f_{INF,t} \\ f_{BUSS,t} \\ f_{LIQ,t} \\ L_t \\ \varepsilon^l_{US,t} \\ \varepsilon^l_{GM,t} \\ \varepsilon^l_{JP,t} \\ \varepsilon^l_{UK,t} \end{pmatrix}, \tag{10}$$

$$\begin{pmatrix} f_{INF,t} \\ f_{BUSS,t} \\ f_{LIQ,t} \\ L_t \\ \varepsilon^l_{US,t} \\ \varepsilon^l_{GM,t} \\ \varepsilon^l_{JP,t} \\ \varepsilon^l_{UK,t} \end{pmatrix} = \begin{pmatrix} \theta_{11} & \theta_{12} & \theta_{13} & \varphi_{L,INF} & 0 & 0 & 0 & 0 \\ \theta_{21} & \theta_{22} & \theta_{23} & \varphi_{L,BUSS} & 0 & 0 & 0 & 0 \\ \theta_{31} & \theta_{32} & \theta_{33} & \varphi_{L,LIQ} & 0 & 0 & 0 & 0 \\ \varphi_{INF,L} & \varphi_{BUSS,L} & \varphi_{LIQ,L} & \phi_L & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \psi^l_{US} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \psi^l_{GM} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \psi^l_{JP} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi^l_{UK} \end{pmatrix} \begin{pmatrix} f_{INF,t-1} \\ f_{BUSS,t-1} \\ f_{LIQ,t-1} \\ L_{t-1} \\ \varepsilon^l_{US,t-1} \\ \varepsilon^l_{GM,t-1} \\ \varepsilon^l_{JP,t-1} \\ \varepsilon^l_{UK,t-1} \end{pmatrix} +$$

$$\begin{pmatrix} u^l_{INF,t} \\ u^l_{BUSS,t} \\ u^l_{LIQ,t} \\ u_{L,t} \\ u^l_{US,t} \\ u^l_{GM,t} \\ u^l_{JP,t} \\ u^l_{UK,t} \end{pmatrix}, \quad u_t \sim iidN(0, \mathbf{\Omega}), \tag{11}$$

where the equation (10) is a measurement equation and the equation (11) is a transition equation. Ang and Piazessi (2003) estimate the coefficients to show the relationship between macro factors, θ_{ij}, i & $j = 1,2,3$, and their variances by the OLS and fix these values in the model. Then, they estimate other parameters given these fixed values. Here, we employ Ang and Piazessi (2003)'s methodology. That is, we estimate θ_{ij}, i & $j = 1,2,3$ and three covariances of the macro-factors in Ω in the each model and then estimate other parameters give these values fixed. And we allowed the interaction between the global yield factors and the global macro factors, but assume that the country-specific yield factors are independent of the global macro factors. We also assume that the country-specific yield factors are orthogonal to each other.[8] In this estimation process, we have total 26 parameters to be estimated: 17 parameters in the multi-country global yield model, 6 coefficients on the relationship between the global yield and the global macro-factors, and 3 covariances between the global yield factor and the global macro-factors. Based on the estimation result of the multi-country global yield model, we set initial value and estimate all parameters by using the constrained MLE in order to satisfy the stationarity condition of the factor dynamics.

III. Estimation results

(1) Data

We consider four countries of US, Germany, Japan and UK and the data for the interest rate are the quarterly zero-coupon bond yield of 3, 6, 9, 2, 15, 18, 21, 24, 30, 36, 48, 60, 72, 84, 96, 108, and 120 months from the first quarter in 1985 to the second quarter in 2020[9]. The data for the global inflation are the CPI and GDP deflator of US, Germany, Japan and UK. The data

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[8] In the $\boldsymbol{\Omega}_{(8,8)} = \begin{pmatrix} \boldsymbol{Q}_{m,(4,4)} & \boldsymbol{0}_{(4,4)} \\ \boldsymbol{0}_{(4,4)} & \boldsymbol{Q}_{c,(4,4)} \end{pmatrix}$, $\boldsymbol{Q}_c$ is a diagonal matrix, the first (3×3) matrix in $\boldsymbol{Q}_m$ are the values to be pre-estimated, the variance of the global yield factor is an unity, and so total 7 parameters are estimated in $\boldsymbol{\Omega}$.

[9] The interest rate data from Q1 in 1985 to Q1 in 2009 are from Wright (2011) and the interest rate data from Q2 in 2009 to Q2 in 2020 are from Bloomberg. The reason is that the Wright's data are only available by May in 2009 and the Bloomberg's data is available from 1995. We compare the statistical characteristics of two different data over the common period of 1995 Q1 ~ 2008 May and find that two interest rates are almost same. Moreover, the interest rates of 9, 15, 18, 21, and 30 months in the Bloomberg are not available and so, we calculate the zero-coupon bond yields using the cubic spline interpolation.

on the global business cycle are the GDP and the industrial production index for four countries. We use OECD's data on the global inflation and the global business cycle.

Domanski et al. (2011) and Landau (2011) suggest to use the credit-to-GDP and the broad money to measure the global liquidity. In this study, we employ the credit-to-GDP ratio data for 4 countries which are collected from the BIS and the broad money data from OECD[10].

[Insert Table 1 here]

[Insert Table 2 here]

(2) Estimation results: Global yield only model

Following Diebold et al. (2008), we estimate yield only model and the estimation results are shown in the <Table 3>. As in the case of Diebold et al. (2008), the global level factor is highly serially correlated. The global level factor loadings in the country level factor equations are estimated with high precision. All level factors load positively on the global level factor. The country-specific level factors are also generally highly persistent. The UK level loading on the global level factor is larger relative to the US and Germany, and the persistence of the UK-specific level factor is much smaller, implying that the dynamics of the UK yield level match closely those of the global factor. Conversely, the Japanese level loading on the global level factor is smaller relative to the US and Germany. The persistence of the Germany-specific

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[10] Chen et al. (2012) suggested using the combination of price (eg. short-term rate) and quantity base variables to identify global liquidity. But in this study, we analyze the dynamics of yield factors that are price base variables, and interest rates are strongly correlated to each other. If we incorporate the price variables to identify global liquidity, this may cause spurious estimation results between the yield factors and global liquidity. So, we only use quantity base variables to identify global liquidity.

level factor is larger relative to other three countries, implying that the German yield level is comparatively divorced from the global level.

[Insert Table 3 here]

In the case of the country slope factor estimation, all slope factors load positively on the global slope factor, which is highly serially correlated in parallel with the estimation results for the level factors. The country-specific slope factors are also generally highly persistent. All slope factors load effectively on the global factor. The Japan slope loading on the global slope factor is smaller relative to the UK and US, as in the case of the Japan level results. Overall, the Japanese yield level and slope loadings on the global level and slope factor appear to be a little different from other three countries.

Figure 1.a and Figure 1.b show the estimated global yield factors and 4 countries' yield factors. The global level and country-specific level factors appear to comove roughly. Japanese level factor shows a slightly different movement from other countries, which seems to be due to its relatively small influence on the global level factor. We can find a similar implication from figure 1.b that the Japanese slope factor appears to be a little different from other countries.

[Insert <Figure 1> here]

In order to assess the commonality in country level and/or slope factor dynamics and the commonality of movements in country yield curves, we compare the global yield factor extracted with the first principal component which is estimated from a principal component analysis of the estimated level and slope factors. <Figure 2> plots the global level and slope factors extracted and the first PCA component. The correlations for the level factor and for the slope factor are 0.997 and 0.984 respectively. The global level factor extracted is almost identical to the first principal level component and this relation appears to be similar in the case of the global slope factor.

[Insert Figure 2 here]

(3) Estimation results: Global yield model with inflation and business cycle macro factors

Ang and Piazessi (2003), Diebold et al. (2006) and Diebold et al. (2008) show that latent country yield factors are linked to and interact dynamically with macroeconomic factors. In particular, Diebold et al. (2008) show that the extracted global level and slope factors reflect the major developments in global inflation and real activity. Diebold et al. (2008) and Bae and Kim (2011) show that the global level factor reflects the global inflation and Abbritti et al. (2018) state that the global level factor is closely related with the expected inflation. In addition, Diebold et al. (2008), Bae and Kim (2011), and Abbriti et al. (2018) show that the global slope factor has a close relation with the global business cycle. In order to examine the relationship between the global level and the slope factors and the global inflation and the global business cycle, we regard the first component of the PCA for 4 countries' inflation variables as the global inflation factor and the first component of the PCA for 4 countries business cycle variables as the global business cycle factor. The correlation between the extracted global level factor and the global inflation factor is 0.68 and the correlation between the extracted global slope factor and the global business cycle factor is 0.12, implying that the extracted global level factor is closely related with the global inflation but the relationship between the extracted global slope factor and the global business cycle appears to be weak.[11] In <Figure 3.a and 3.b>, we plot the

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[11] Diebold et al. (2008) show that the correlation between their extracted global level factor and average G-7

extracted global level and slope factors and the global inflation and the global business cycle factors.

[Insert <Figure 3> here]

Following Diebold et al. (2008), we consider two macro factors, global inflation and global business cycle, and then estimate the dynamic relationship between the global level and slope factors and global inflation and global business cycle. The estimation results are shown in the Table 4.

[Insert Table 4 here]

The global level factor is highly serially correlated. The estimated coefficient on the global inflation is positive and statistically significant in the global level factor dynamics whereas the estimated coefficient on the global business cycle is negative but not statistically significant. These results reassure that the global level factor is closely related with the global inflation. All four countries' level factors load positively on the global level factor. The country-specific level factors are highly persistent except UK. The persistence of the UK-specific level factor is much smaller than other three countries.

In the estimation results for the global and country slope factors, the global slope factor is highly serially correlated and the estimated coefficients on the global inflation and on the global business cycle are positive but only the coefficient on the global business cycle is statistically

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inflation over 1985.09~2005.08 is 0.75 and the correlation between the extracted global slope factor and average G-7 GDP annual growth is 0.27.

significant in the global slope factor dynamics. This result also confirms that the global slope factor is closely related with the global business cycle. All four country slope factors load positively on the global slope factor and the Japanese slope loading is smaller than other countries. The country-specific slope factors are generally highly persistent but the persistence of the UK-specific slope factor is smaller than other countries. Overall, the estimation results are similar with the case of the global yield only model except that the persistence of the UK-specific slope factor is lower in the global yield-macro model than in the global yield only model.

Based on the estimation results of the global yield-macro model with global inflation and global business cycle, we have impulse response analysis and the results are shown in Figure 4[12].

[Insert Figure 4 here]

The global level factor responds both to the shock of the global inflation and to the shock of the global business cycle. That is, the positive shock to the global inflation appears to have a positive impact on the global level factor. The reason is that since in the dynamic Nelson-Siegel factor model, the level factor reflects the nominal long-term rate and the nominal long-term rate reflects the inflation expectation, the shock to the global inflation is transmitted to the global level factor. This result is consistent with Ang and Piazessi (2003), Diebold et al. (2006) and Rudebusch and Wu (2008). In addition, the global level factor responds to the shock of the global business cycle. Diebold et al. (2006) and Rudebusch and Wu show that the shock to the

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[12] We employ Cholesky decomposition in the impulse response analysis and the order of variables is same with equation (10). For the robustness check, we have many different orders and find that the results are qualitatively similar with this paper.

global business cycle increases the US level factor with significant lags. We interpret that the increase in the expected inflation as the result of the business cycle expansion will have an impact on the long-term interest rate in the long run.

For the global slope factor, the shock to the global business cycle appears to have an impact on the global slope factor whereas the global slope factor hardly responds to the shock of the global inflation. Hamilton and Kim (2002) and Ang et al. (2006) state by using the relationship between the economic fluctuation and the yield spread that since the central bank tries to raise the short term rate in the economic expansion in order to cool down the economy, the yield spread reflects the business cycle state. That is, the slope factor is the difference between the short term interest rate and the long term interest rate and the change in the short term interest rate due to the change in economic status is reflected on the slope factor in the DNS model. This mechanism may work in the global factor context. The global economic expansion may result in the increase in overall interest rates and the higher increase in the short term rate relative to the long term rate would increase the global slope factor. While Hordahl et al. (2006) and Bekaert et al. (2010) show that the inflation factor has a significant impact on the slope factor, we do not find such evidence.

Following Diebold et al. (2008), we conduct variance decompositions. We decompose the variation in the global level and slope factors into parts driven by global inflation variation and global business cycle variation. The variance decompositions are shown in Table 5.

[Insert Table 5 here]

In the case of the global level variation, variation in the global inflation explains 14% fraction of the variation in global level factor only in the short run whereas variation in the global business cycle explains 45% fraction of the variation in global level factor only in the long run. The global inflation appears to be a significant component to explain the global level variation in the short run whereas the global business cycle does in the long run. In the case of the global slope variation, the variation in the global business cycle explains 30%~80% fraction of the variation in the global slope factor while the variation in the global inflation plays little role in the global slope variation. This result is consistent with Diebold and Li (2006), Diebold et al. (2006) and Diebold et al. (2008), where the slope factor is closely related with the yield spread and the yield curve slope is linked to the business cycle (real activity).

(4) Estimation results: Global yield model with inflation, business cycle, and liquidity macro factors

In this paper, we consider another global macroeconomic factor, which is global liquidity. Since the global financial crisis in 2008, there has been a significant increase in the interest of the global liquidity and many studies have shown that the global liquidity played an important role in the world macroeconomy. D'Agostino and Surico (2009) show that the global liquidity estimated from the PCA of the M2 growths of G7 countries has more predictive power in forecasting US inflation than the US M2 growth. Belke et al. (2013) and Beckmann et al. (2014) confirm that the shock to global liquidity has a significant impact on the global price level and Belke et al. (2010) show that the global liquidity has a long-run relationship with the global price. Eickmeier et al. (2014) examine the effect of the global liquidity on the financial variables and find that the interest rates in advanced countries are explained by the global liquidity significantly. Kang et al. (2016) find that the effect of the global liquidity on the price level has increased since the global financial crisis in 2008.

Given the possibility of the role of global liquidity in the global interest rate dynamics, we consider not only global inflation and global business cycle but also global liquidity and try to incorporate these three macro factors into the global yield model. In order to examine the relationship between the extracted global level and slope factors and the global liquidity factor, we estimate the first component of the PCA for 4 countries' credit-to-GDP ratios and broad money and regard it as the global liquidity factor. The correlation between the extracted global level factor and the global liquidity factor is 0.28 and the correlation between the extracted global slope factor and the global liquidity factor is 0.52, suggesting that the extracted global factors are related with the global liquidity. In Figure 5.a and 5.b, we plot the extracted global level and slope factors and the global liquidity factor. The global factors and the global liquidity factor appear to be correlated.

[Insert <Figure 5> here]

Following Diebold et al. (2008), we estimate the dynamic relationship between the global level and slope factors and three macro factors, global inflation, global business cycle, and global liquidity. The estimation results are shown in the Table 6.

[Insert Table 6 here]

As before, the global level factor is highly serially correlated. The estimated coefficients on the global inflation and global liquidity are positive but the coefficient only on global liquidity is statistically significant. The estimated coefficient on global business cycle is negative but not statistically significant. The interesting point to make is that only the coefficient on global liquidity factor is statistically significant and thus the global level factor appears to be closely related to global liquidity. The dynamics of all four countries' level factors and country-specific level factors are quite similar with the estimation results of the global yield model with two macro factors, global inflation and global business cycle. That is, all four countries' level factors load positively on the global level factor and the country-specific level factors are highly persistent except UK. These results imply that global liquidity factor plays an important role only in the global factor.

For estimation results of the global and country slope factors, the estimated coefficients on global inflation and global liquidity are positive but not statistically significant whereas the coefficient on global business cycle is positive and statistically significant. This result indicates that only global business cycle factor plays an important role in the global slope factor, confirming that the slope factor is closely related with business cycle. Furthermore, the global slope factor is persistent. The dynamics of all four countries' slope factors and country-specific factors are very similar with the case of the global yield model with two macro factors. This result imply that global liquidity has little impact on the global and country slope factors.

For the dynamic relationship between global level and slope factors and three macro factors, we have impulse response analysis. Figure 6 shows the results.

[Insert Figure 6 here]

The global level factor appears not to respond to the shock of global inflation whereas it does to the shock of global liquidity. Furthermore, the global level factor seems to respond to the shock to global business cycle only in the short run and such an effect appears to disappear in the long run. As in the case of previous estimation results, the information on global inflation is reflected in the global liquidity and thus only global liquidity has a significant impact on global level factor. In the impulse response analysis for global slope factor, only global business cycle has a significant impact on the global slope factor but the global slope factor appears not to respond to both shocks to global inflation and global liquidity.

Finally, we conduct variance decompositions of the global yield factors. The variance decompositions are shown in Table 7.

[Insert Table 7 here]

In the case of the global level variation, variation in the global inflation does not explain the variation in global level factor whereas variation in the global liquidity explains variation of the global level factor up to 34% fraction. The variation in the global business cycle still explains 36% fraction of the variation in global level factor in the long run. As before, global liquidity appears to not only have global inflation but also other information for global slope factor. In addition, the global business cycle is useful for explaining variation in the global slope factor in the long run. In the case of the global slope variation, the variation in the global business cycle explains 27%~73% fraction of the variation in the global slope factor while the variations in the global inflation and in the global liquidity play little role in the global slope variation. This result confirms that the slope factor is closely related with the yield spread and the yield curve slope is linked to the business cycle (real activity) as suggested in existing literature. In sum, global liquidity plays an important role in explaining the dynamics of global level factor but not global slope factor.

IV. Concluding remarks

Recently the dynamics of the interest rates were tried to explain in the Macro-Finance model framework and in the global context. That is, common global yield factors exist and are operative about the nature of dynamic cross-country bond yield interactions and macroeconomic factors play an important role in explaining global yield dynamics. In particular, global inflation and global business cycle have been emphasized as key macro factors to play an important role in the global level and slope factors.

As the deepening of financial integration and cross-border lending has increased capital inflow and the financial dependence between economies, global liquidity has become a key focus of financial stability and goods and assets price inflation. This reflects a perception that global liquidity is an important driver of capital flows, global asset price dynamics and inflation. In this vein, global liquidity may play an important role in explaining the cross-border interest dynamics. This paper tackles the question of whether global liquidity has an impact on global yield dynamics. In the empirical study, we consider the dynamic Nelson-Siegel model of Diebold et al. (2008) with three macro factors: global inflation, global business cycle and global liquidity. We consider the yield of four advanced economies— U.S., U.K., Germany and Japan— from the first quarter in 1985 to the second quarter in 2020.

We find that global liquidity plays an important role in the global level factor but not in the global slope factor. In particular, when we incorporate global liquidity into the dynamic Nelson-Siegel factor model, global inflation is not a key factor in explaining the global level factor any more. We interpret that global liquidity has not only the information on global commodity inflation but also the information on global asset price inflation and expected future inflation. However, global liquidity appears not to play an important role in global slope factor, indicating that only global business cycle is linked to the global slope factor as shown in existing literature. Therefore, global liquidity is economically important because it is not only a major determinant of goods price inflation but also is an important macro factor to have an impact on global yield curve dynamics.

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<Table-1> Descriptive statistics for bond yields

maturity(months)	Mean	Std. Dev	Minimum	Maximum	ρ(1)	ρ(4)	ρ(12)
US							
3	3.232	2.512	0.016	8.90	0.963	0.819	0.482
12	3.643	2.726	0.096	9.568	0.958	0.828	0.531
60	4.521	2.574	0.303	11.211	0.941	0.819	0.678
120	5.170	2.395	0.647	11.603	0.938	0.808	0.707
Germany							
3	3.026	2.867	-0.897	10.021	0.974	0.889	0.627
12	3.101	2.783	-0.872	9.076	0.977	0.888	0.629
60	3.793	2.747	-0.796	9.238	0.973	0.891	0.715
120	4.359	2.598	-0.584	9.222	0.973	0.889	0.733
Japan							
3	1.453	2.298	-0.339	8.010	0.973	0.855	0.619
12	1.458	2.201	-0.321	8.433	0.968	0.857	0.608
60	1.905	2.137	-0.366	8.001	0.961	0.868	0.679
120	2.425	2.103	-0.226	7.692	0.964	0.884	0.712
UK							
3	5.176	4.309	-0.002	15.125	0.970	0.868	0.642
12	4.861	3.859	-0.032	14.088	0.971	0.877	0.679
60	5.221	3.414	-0.048	12.389	0.966	0.884	0.730
120	5.488	3.113	0.183	11.669	0.966	0.882	0.720

All yield data are quarterly, 1985:1q ~ 2020:2q. $\rho(\tau)$ denotes the autocorrelation lag at τ.

<Table-2> Descriptive statistics for macro variables

	Mean	Std. Dev	Minimum	Maximum	$\rho(1)$	$\rho(2)$	$\rho(4)$
US							
GDP	2.554	1.890	-9.033	5.298	0.696	0.531	0.248
IP	1.878	3.908	-15.118	8.388	0.821	0.619	0.155
CPI	2.593	1.280	-1.607	6.276	0.841	0.647	0.324
Def	2.163	0.811	0.261	4.232	0.921	0.832	0.617
Credit	1.117	2.512	-4.916	6.382	0.943	0.865	0.705
Broad money	5.725	2.562	0.409	20.617	0.721	0.579	0.310
Germany							
GDP	1.690	2.377	-11.215	7.438	0.725	0.518	0.122
IP	1.485	5.660	-22.352	13.982	0.780	0.532	-0.033
CPI	1.735	1.181	-0.922	6.094	0.915	0.810	0.561
Def	1.683	1.204	-0.848	6.043	0.918	0.827	0.607
Credit	0.309	2.481	-7.762	7.129	0.880	0.725	0.360
Broad money	6.028	2.961	-1.549	12.126	0.947	0.860	0.648
Japan							
GDP	1.623	2.759	-10.334	9.369	0.751	0.566	0.192
IP	0.669	6.668	-30.802	23.192	0.753	0.398	-0.270
CPI	0.565	1.211	-2.213	3.709	0.874	0.747	0.432
Def	0.201	1.656	-3.149	4.965	0.749	0.669	0.441
Credit	0.129	3.186	-5.053	9.975	0.884	0.769	0.512
Broad money	3.466	3.222	-0.670	12.937	0.975	0.928	0.815
UK							
GDP	2.094	2.764	-20.800	6.974	0.546	0.386	0.186
IP	0.541	3.241	-18.927	7.974	0.689	0.497	0.166
CPI	2.831	1.789	0.334	9.219	0.947	0.861	0.687
Def	2.915	2.124	-1.767	9.946	0.815	0.743	0.594
Credit	2.298	4.324	-6.399	11.758	0.877	0.777	0.534
Broad money	8.255	5.679	-2.840	19.957	0.935	0.847	0.633

All macro data are quarterly, 1985:1q ~ 2020:2q. $\rho(\tau)$ denotes the autocorrelation lag at τ.

<Table – 3> Estimates of the global yield only model parameters

global level factor	
$L_t = 0.9679L_{t-1} + U_t^l$	
(0.0077)	
country level factors	
$l_{US,t} = 5.4760 + 0.4735L_t + \varepsilon_{US,t}^l$	$\varepsilon_{US,t}^l = 0.8841\varepsilon_{US,t-1}^l + 0.3825u_{US,t}^l$
(3.3576) (0.0442)	(0.0539) (0.0203)
$l_{GM,t} = 4.2020 + 0.4061L_t + \varepsilon_{GM,t}^l$	$\varepsilon_{GM,t}^l = 0.9669\varepsilon_{GM,t-1}^l + 0.1923u_{GM,t}^l$
(3.0541) (0.0299)	(0.0211) (0.0082)
$l_{JP,t} = 2.4890 + 0.3119L_t + \varepsilon_{JP,t}^l$	$\varepsilon_{JP,t}^l = 0.8433\varepsilon_{JP,t-1}^l + 0.3469u_{JP,t}^l$
(2.3301) (0.0299)	(0.0539) (0.0203)
$l_{UK,t} = 5.5816 + 0.5801L_t + \varepsilon_{UK,t}^l$	$\varepsilon_{UK,t}^l = 0.2861\varepsilon_{UK,t-1}^l + 0.2792u_{UK,t}^l$
(3.7849) (0.0380)	(0.1540) (0.0156)
global slope factor	
$S_t = 0.9191S_{t-1} + U_t^s$	
(0.0365)	
country slope factors	
$s_{US,t} = -2.3059 + 0.4435S_t + \varepsilon_{US,t}^s$	$\varepsilon_{US,t}^s = 0.9292\varepsilon_{US,t-1}^s + 0.5163u_{US,t}^s$
(0.7714) (0.0612)	(0.0335) (0.0437)
$s_{GM,t} = -1.6370 + 0.3896S_t + \varepsilon_{GM,t}^s$	$\varepsilon_{GM,t}^s = 0.9317\varepsilon_{GM,t-1}^s + 0.4125u_{GM,t}^s$
(0.6034) (0.0519)	(0.0317) (0.0315)
$s_{JP,t} = -1.1265 + 0.1467S_t + \varepsilon_{JP,t}^s$	$\varepsilon_{JP,t}^s = 0.9053\varepsilon_{JP,t-1}^s + 0.4099u_{JP,t}^s$
(0.3727) (0.0417)	(0.0360) (0.0209)
$s_{UK,t} = -0.4892 + 0.5848S_t + \varepsilon_{UK,t}^s$	$\varepsilon_{UK,t}^s = 0.9285\varepsilon_{UK,t-1}^s + 0.5410u_{UK,t}^s$
(0.8480) (0.0733)	(0.0438) (0.0638)

The table reports parameters and standard errors in parenthesis for the global yield-only model.

<Table – 4> Estimates of the global yield-macro model without global liquidity parameters

global level factor	
$L_t = 0.9679L_{t-1} + 0.0441f_{INF,t-1} - 0.0051f_{BUSS,t-1} + U_t^l$ (0.0237) (0.0351) (0.0680)	
country level factors	
$l_{US,t} = 4.5932 + 0.4752L_t + \varepsilon_{US,t}^l$ (1.2293) (0.0444)	$\varepsilon_{US,t}^l = 0.8840\varepsilon_{US,t-1}^l + 0.3789u_{US,t}^l$ (0.0538) (0.0203)
$l_{GM,t} = 3.4467 + 0.4077L_t + \varepsilon_{GM,t}^l$ (1.1185) (0.0302)	$\varepsilon_{GM,t}^l = 0.9669\varepsilon_{GM,t-1}^l + 0.1928u_{GM,t}^l$ (0.0210) (0.0082)
$l_{JP,t} = 1.9070 + 0.3131L_t + \varepsilon_{JP,t}^l$ (0.8129) (0.0301)	$\varepsilon_{JP,t}^l = 0.8430\varepsilon_{JP,t-1}^l + 0.3470u_{JP,t}^l$ (0.0498) (0.0155)
$l_{UK,t} = 4.6319 + 0.5104L_t + \varepsilon_{UK,t}^l$ (1.2891) (0.0384)	$\varepsilon_{UK,t}^l = 0.2922\varepsilon_{UK,t-1}^l + 0.2803u_{UK,t}^l$ (0.1543) (0.0157)
global slope factor	
$S_t = 0.9062S_{t-1} + 0.0174f_{INF,t-1} + 0.3423f_{BUSS,t-1} + U_t^s$ (0.0321) (0.0326) (0.0722)	
country slope factors	
$s_{US,t} = -2.6449 + 0.3858S_t + \varepsilon_{US,t}^s$ (0.7845) (0.0543)	$\varepsilon_{US,t}^s = 0.9409\varepsilon_{US,t-1}^s + 0.5270u_{US,t}^s$ (0.0313) (0.0430)
$s_{GM,t} = -1.9010 + 0.3222S_t + \varepsilon_{GM,t}^s$ (0.7264) (0.0440)	$\varepsilon_{GM,t}^s = 0.9488\varepsilon_{GM,t-1}^s + 0.4391u_{GM,t}^s$ (0.0261) (0.0285)
$s_{JP,t} = -1.2298 + 0.1339S_t + \varepsilon_{JP,t}^s$ (0.3919) (0.0358)	$\varepsilon_{JP,t}^s = 0.9125\varepsilon_{JP,t-1}^s + 0.4081u_{JP,t}^s$ (0.0329) (0.0206)
$s_{UK,t} = -1.0085 + 0.5904S_t + \varepsilon_{UK,t}^s$ (0.5613) (0.0619)	$\varepsilon_{UK,t}^s = 0.5753\varepsilon_{UK,t-1}^s + 0.4458u_{UK,t}^s$ (0.2641) (0.0692)

The table reports parameters and standard errors in parenthesis for the global yield-macro model without global liquidity.

<Table - 5> Variance decomposition of the global yield factors (%)

	horizon	inflation	business cycle	level
global level	4q	4.36	2.07	93.58
	8q	8.16	3.60	88.25
	12q	11.46	7.63	80.92
	20q	13.76	22.06	64.18
	40q	9.98	46.24	43.79
	horizon	**inflation**	**business cycle**	**slope**
global slope	4q	0.81	29.48	69.71
	8q	0.39	66.09	33.52
	12q	0.44	79.70	19.87
	20q	2.85	84.81	12.34
	40q	9.62	79.85	10.53

<Table – 6> Estimates of the global yield-macro model with global liquidity parameters

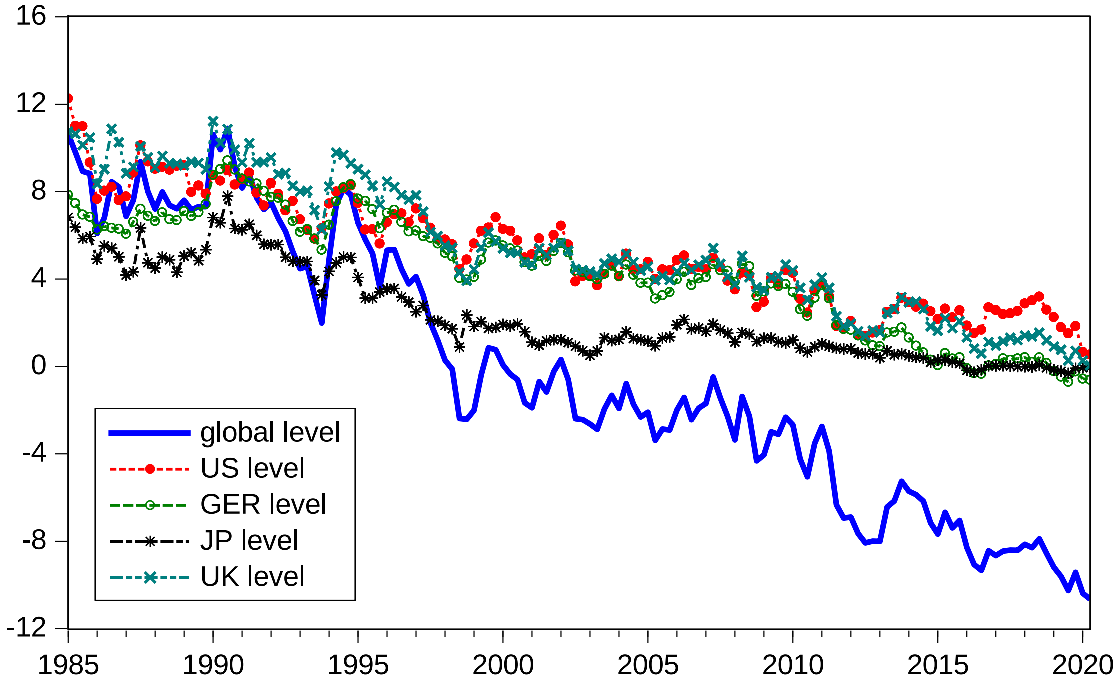
global level factor	
$L_t = \underset{(0.0196)}{0.9562} L_{t-1} + \underset{(0.0606)}{0.0348} f_{INF,t-1} - \underset{(0.0455)}{0.0524} f_{BUSS,t-1} + \underset{(0.0481)}{0.1040} f_{LIQ,t-1} + U^l_t$	
country level factors	
$l_{US,t} = \underset{(1.4809)}{4.2295} + \underset{(0.0430)}{0.4558} L_t + \varepsilon^l_{US,t}$	$\varepsilon^l_{US,t} = \underset{(0.0539)}{0.8868} \varepsilon^l_{US,t-1} + \underset{(0.0203)}{0.3786} u^l_{US,t}$
$l_{GM,t} = \underset{(1.3308)}{3.1246} + \underset{(0.0287)}{0.3923} L_t + \varepsilon^l_{GM,t}$	$\varepsilon^l_{GM,t} = \underset{(0.0210)}{0.9677} \varepsilon^l_{GM,t-1} + \underset{(0.0082)}{0.1903} u^l_{GM,t}$
$l_{JP,t} = \underset{(0.9742)}{1.6638} + \underset{(0.0287)}{0.3989} L_t + \varepsilon^l_{JP,t}$	$\varepsilon^l_{JP,t} = \underset{(0.0498)}{0.8408} \varepsilon^l_{JP,t-1} + \underset{(0.0155)}{0.3480} u^l_{JP,t}$
$l_{UK,t} = \underset{(1.5442)}{4.2483} + \underset{(0.0370)}{0.4858} L_t + \varepsilon^l_{UK,t}$	$\varepsilon^l_{UK,t} = \underset{(0.1550)}{0.2939} \varepsilon^l_{UK,t-1} + \underset{(0.0157)}{0.2829} u^l_{UK,t}$
global slope factor	
$S_t = \underset{(0.0375)}{0.8825} S_{t-1} + \underset{(0.0544)}{0.0294} f_{INF,t-1} + \underset{(0.0529)}{0.3387} f_{BUSS,t-1} + \underset{(0.0564)}{0.0302} f_{LIQ,t-1} + U^s_t$	
country slope factors	
$s_{US,t} = \underset{(0.7583)}{-2.5695} + \underset{(0.0540)}{0.3840} S_t + \varepsilon^s_{US,t}$	$\varepsilon^s_{US,t} = \underset{(0.0310)}{0.9396} \varepsilon^s_{US,t-1} + \underset{(0.0425)}{0.5303} u^s_{US,t}$
$s_{GM,t} = \underset{(0.6980)}{-1.8442} + \underset{(0.0438)}{0.3252} S_t + \varepsilon^s_{GM,t}$	$\varepsilon^s_{GM,t} = \underset{(0.0258)}{0.9495} \varepsilon^s_{GM,t-1} + \underset{(0.0280)}{0.4379} u^s_{GM,t}$
$s_{JP,t} = \underset{(0.3837)}{-1.2045} + \underset{(0.0358)}{0.1338} S_t + \varepsilon^s_{JP,t}$	$\varepsilon^s_{JP,t} = \underset{(0.0328)}{0.9122} \varepsilon^s_{JP,t-1} + \underset{(0.0206)}{0.4085} u^s_{JP,t}$
$s_{UK,t} = \underset{(0.4780)}{-0.8946} + \underset{(0.0617)}{0.5981} S_t + \varepsilon^s_{UK,t}$	$\varepsilon^s_{UK,t} = \underset{(0.2507)}{0.4932} \varepsilon^s_{UK,t-1} + \underset{(0.0672)}{0.4311} u^s_{UK,t}$

The table reports parameters and standard errors in parenthesis for the global yield-macro with global liquidity model.

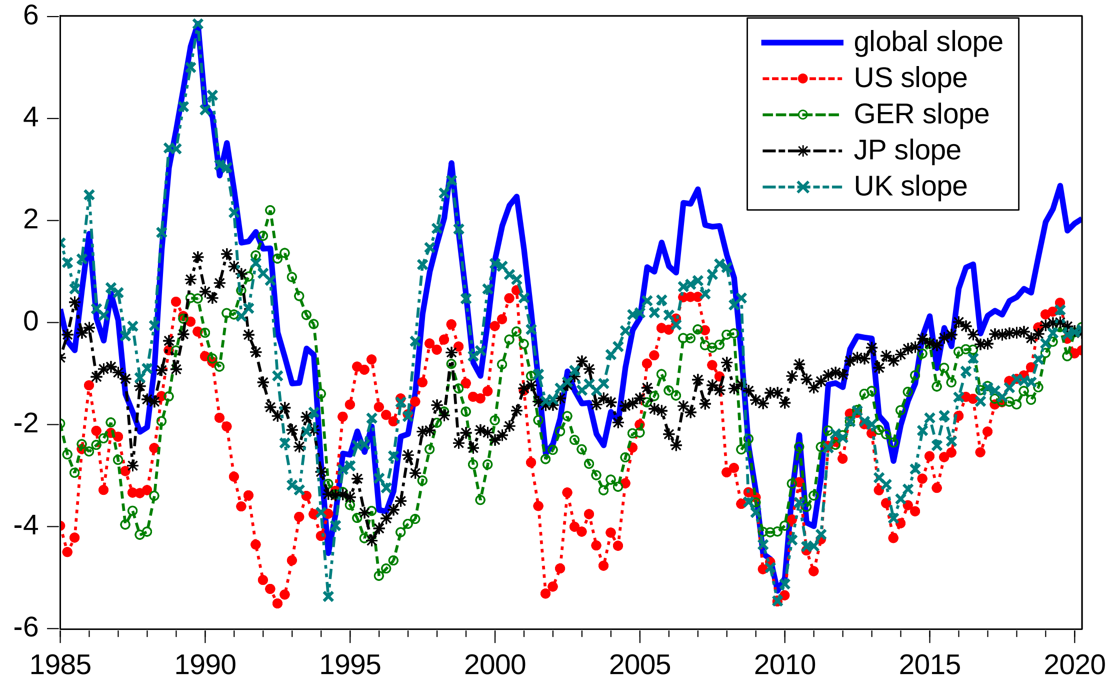
<Table – 7> Variance decomposition of the global yield factors

	horizon	inflation	business cycle	global liquidity	level
global level	4q	0.74	1.22	1.31	96.73
	8q	0.41	6.38	7.12	86.08
	12q	0.35	13.64	14.28	71.73
	20q	0.67	24.87	25.12	49.34
	40q	1.65	36.51	34.24	27.60
	horizon	**inflation**	**business cycle**	**global liquidity**	**slope**
global slope	4q	0.61	26.94	3.98	68.47
	8q	0.30	61.95	3.35	34.30
	12q	0.98	74.62	3.11	21.28
	20q	5.40	77.33	3.10	14.18
	40q	11.42	73.04	3.10	12.44

<Figure – 1> Global yield factors and country-specific yield factors

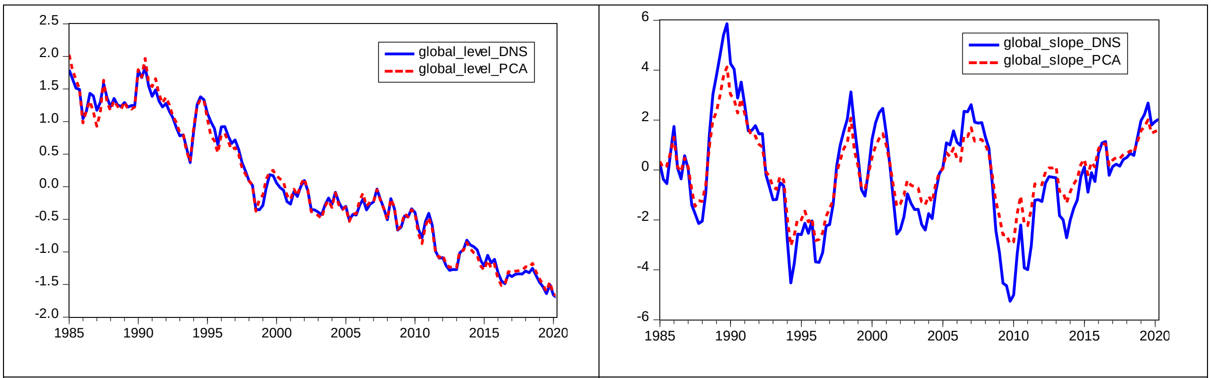


<Figure-1.a> global level factor and 4-country level factors



<Figure-1.B> global slope and 4-country slope factors

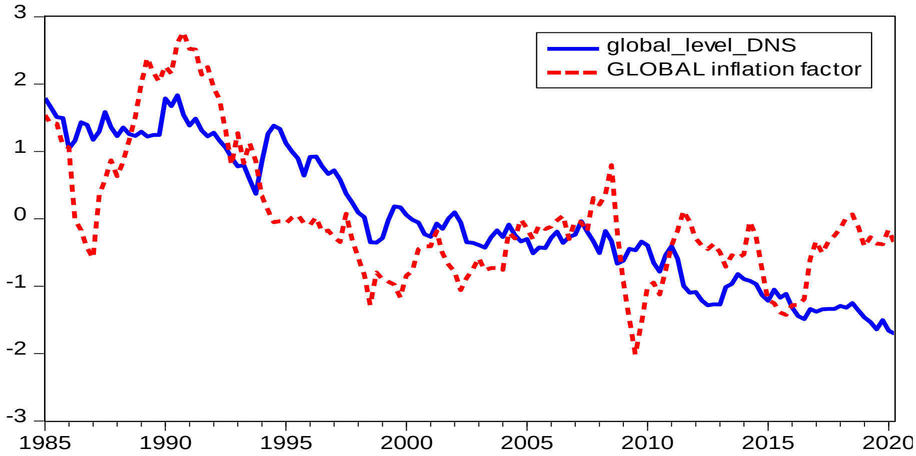
<Figure – 2> global yield factors from global yield model and PCA(normalized)



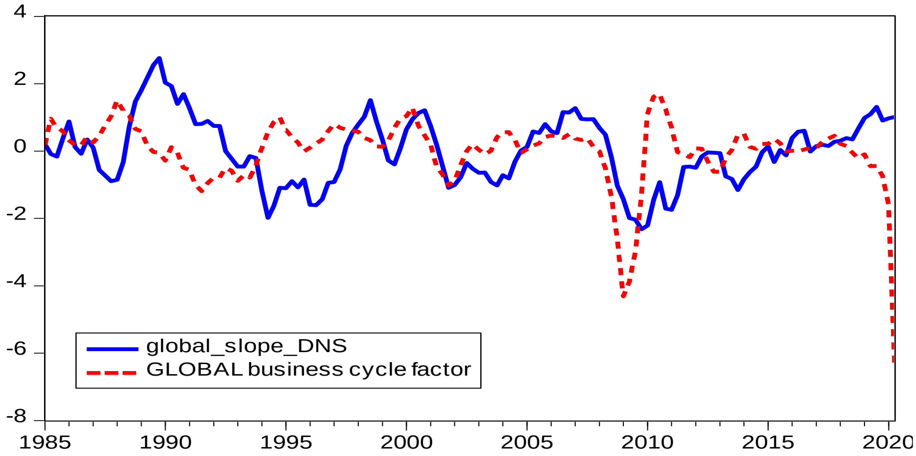
global level factor, correlation = 0.9969

global slope factor, correlation = 0.9841

<Figure – 3> global yield factors and global macro factors

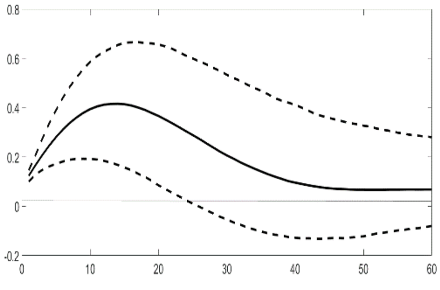
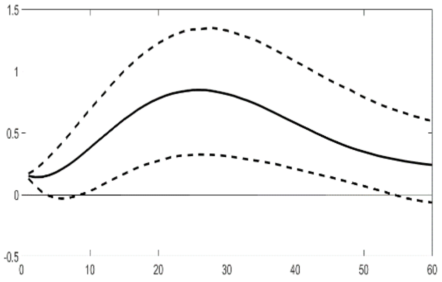
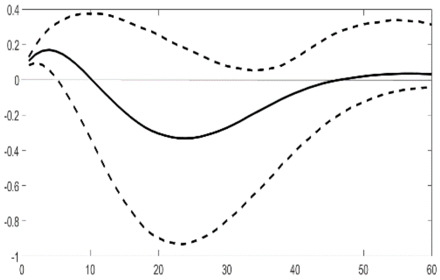
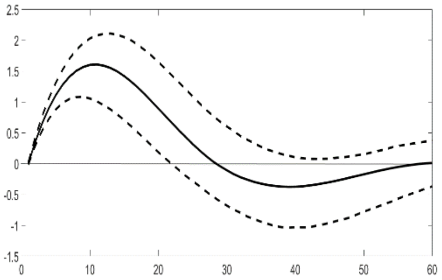


<Figure-3.a> global level and macro factors(normalized)



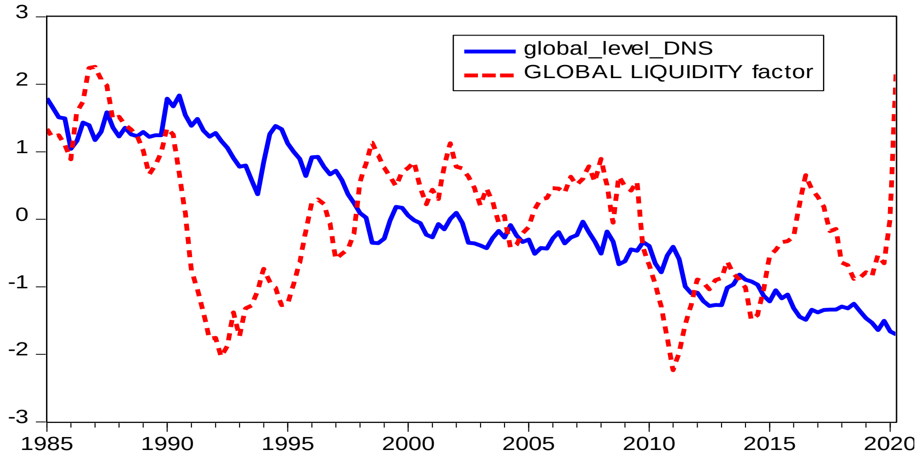
<Figure-3.B> global slope and macro factors(normalized)

<Figure – 4> Response of the global yield factors

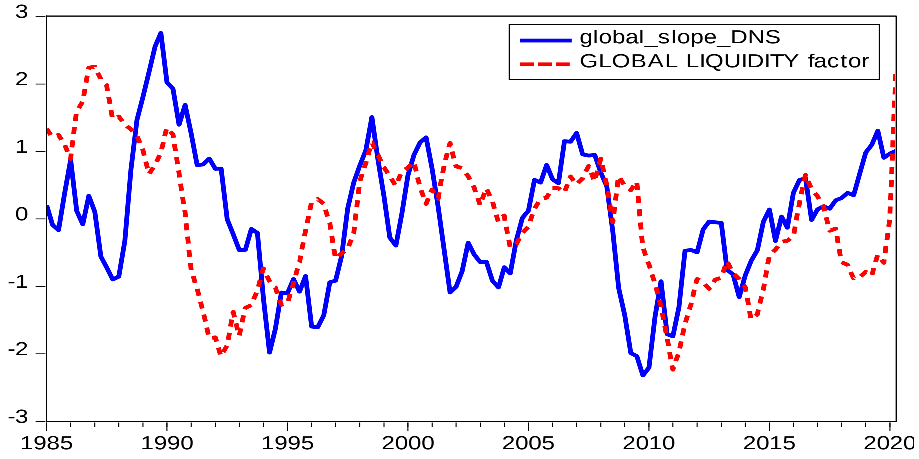
responses of the global level factor	
	
global inflation shock	global business cycle shock
responses of the global slope factor	
	
global inflation shock	global business cycle shock

The solid line and the dotted lines indicate the impulse response and 90% confidence interval

<Figure – 5> global yield factors and global liquidity



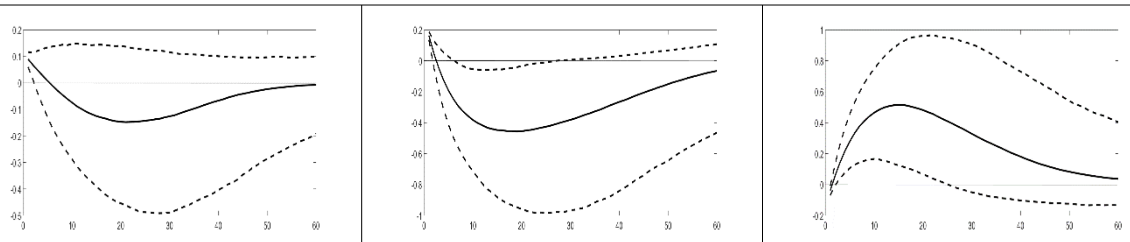
<Figure – 5.a> Global level and liquidity factors(normalized)



<Figure – 5.b> Global slope and liquidity factors(normalized)

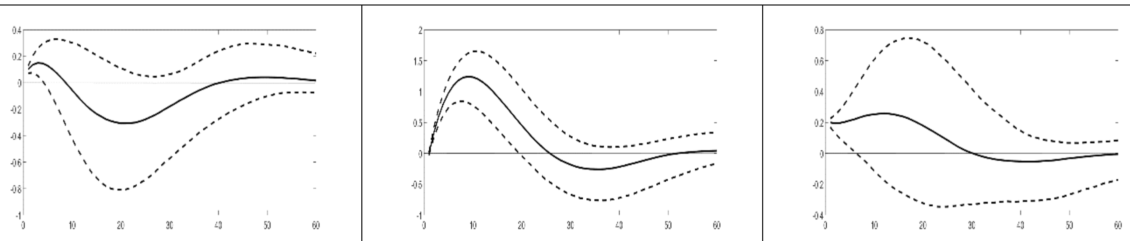
<Figure - 6> Responses of the global yield factors

responses of the global level factor



global inflation shock | global business cycle shock | global liquidity shock

responses of the global slope factor



global inflation shock | global business cycle shock | global liquidity shock

The solid line and the dotted lines indicate the impulse response and 90% confidence interval

<Appendix – 1> Cumulated variance shares explained by principal components

principal component	global inflation	global business cycle	global liquidity
1st	54.27%	70.78%	45.55%
2nd	69.04%	82.45%	62.56%
3rd	78.67%	89.00%	76.53%
4th	87.28%	94.06%	85.95%
5th	93.51%	96.25%	91.00%
6th	96.40%	87.68%	95.53%
7th	98.47%	98.99%	98.87%
8th	100%	100%	100%

<Appendix – 2> VAR estimates for yield-macro model without global liquidity

	$f_{INF,t-1}$	$f_{BUSS,t-1}$	$\text{adj} - R^2$
$f_{INF,t}$	0.949*** (0.024)	0.230*** (0.058)	0.919
$f_{BUSS,t}$	-0.038* (0.024)	0.961*** (0.058)	0.668

Note: a. In parentheses are OLS standard errors. b. *** and * denote statistically significant at the 1% and 10% levels respectively.

<Appendix – 3> VAR estimates for yield-macro model with global liquidity

	$f_{INF,t-1}$	$f_{BUSS,t-1}$	$f_{LIQ,t-1}$	$\text{adj} - R^2$
$f_{INF,t}$	0.948∗∗∗	0.218∗∗∗	0.054∗	0.920
	(0.024)	(0.058)	(0.031)	
$f_{BUSS,t}$	-0.038	0.958∗∗∗	0.014	0.666
	(0.024)	(0.058)	(0.041)	
$f_{LIQ,t}$	-0.018	-0.057	0.948∗∗∗	0.873
	(0.024)	(0.058)	(0.031)	

Note: a. In parentheses are OLS standard errors. b. ∗∗∗ and ∗ denote statistically significant at the 1% and 10% levels respectively.