Global Factors in the Term Structure of Interest Rates *

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Abstract

This paper introduces global factors within a FAVAR framework in an empirical affine term structure model. We apply our method to a panel of international yield curves and show that global factors account for more than 80 percent of term premia in advanced economies. In particular they tend to explain long-term dynamics in yield curves, as opposed to domestic factors which are instead more relevant for short-run movements. We uncover a key role for the third principal component of the global term structure in shaping risk neutral rates and term premia dynamics.

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1. INTRODUCTION

Why are there shifts in yield curves across countries? What makes a long-term bond riskier than a short-term bond? What are the elements which determine the variation over time of the "price of risk"? These questions lie at the heart of many monetary policy discussions held by policy makers, academics and bond market participants. Time variation in term premia can in fact greatly complicate the task of central banks. Recent empirical studies have undertaken the difficult task of estimating term premia from the yield curves of bond markets and have reached considerable success (Bauer, Rudebusch and Wu, 2012, 2014). This development was made possible by a new class of models (so called no-arbitrage "affine" models) which, by replicating the dynamics of the entire yield curves can provide accurate measures of the time-varying risk premia on long-term bonds (Wright, 2011, Abbritti et al, 2015). As a result, researchers have used them to back out this risk component associated with the pricing of long-term bonds (Wright, 2011, Bauer, Rudebusch and Wu, 2012, 2014, among others).

However, the effects of global forces on the dynamics of interest rates have been relatively less studied. Yet, there are compelling reasons to assert that global shocks impact cross-country government yield curves. The recent credit crisis, for instance, shows that macro-finance shocks can be crucially transmitted internationally. As a consequence of financial integration, a sizable amount of domestic government debt is held by foreigners in global capital markets. Thus, positions on foreign bonds are naturally affected by home macro-finance conditions, and vice-versa. Despite these important stylized facts, studies on the term structure of interest rates tend to pay very little attention to international spillovers in yield curves. This paper takes up this challenge and investigates the role of global factors in the yield curves of several industrialized countries.

We introduce a role for global factors by modeling the law of motion for the yield curves as a factor augmented VAR (FAVAR) similar to Bernanke, Boivin and Eliasz (2005), Stock and Watson (2005) and Moench (2008). In our model the traditional determinants of the yield curves - level, slope and curvature - are accompanied by a set of three global factors, extracted as principal components from the global term structure. Our sample covers the yield curves of eight economies: Canada, United Kingdom, Japan, Germany, Australia, New Zealand, Switzerland and the United States. Figure 1 plots the first three principal components across countries using zero coupon yields for each country (from 3 month to 10 year yields). If co-movement across yield curves is a dominant feature, we should then be able to gauge it by looking at the behavior of these three factors in different countries. The first factor indeed displays strong co-movement across countries. In all cases it has a strong downward trend and the correlation coefficient among these series ranges from 0.83 to 0.98. The second and third factors also display significantly positive cross-correlations, albeit lower, and these correlations become stronger starting around 2000. The strong co-movements across the level, slope and curvature factors of the different countries point towards the existence of global forces which may have a strong influence on the shape and evolution of the yield curves in general, and term premia in particular. What are they, and how important are these global forces?

Our estimated FAVAR term structure models show that global factors are the ultimate drivers of both yield curve and term premia dynamics across countries. Moreover, our global factors have a meaningful economic interpretation. The 1st global factor is global expected inflation and the 2nd global factor mimics global growth. Importantly, we uncover a key role for the third global factor, a factor completely ignored in the previous literature. We show that this factor follows the second moment of global inflation until 2007, while it seems to price deflation risk just before and during the recent financial crisis. In fact, the recent financial crisis is captured in our model as a shock to the third global factor, which leads to a substantial increase in the term premium. We link this finding to monetary policy responses, especially following the recent credit crisis shock. As Central Banks engaged in unconventionally persistent expansionary policies in a time of global liquidity scarcity, expected short-rates plummeted with respect to long-rates, giving rise to an increase in the risk component of long-term bonds.

This study relates to the rapidly growing literature on affine term structure models. This recent and lively area of research first included macro factors explicitly with the work of Ang and Piazzesi (2003), and was later enriched by studies which provided a more structural interpretation of latent yield curves factors (see Rudebusch and Swanson 2008 and Bekaert, Cho and Moreno 2010 among others). Common features of these models are a set of restrictions which impose non-arbitrage conditions across all the different assets. In general, they follow a closed-economy framework and the vast majority of them is estimated using only U.S. Treasury yield curve data. Only very recently have some studies analyzed the implications of these models for a broader set of countries. Wright (2011) for instance, shows that affine term structure models have a remarkably good fit also when applied to countries other than the US. Moreover he also shows that the model implied term premia display strikingly similar patterns across industrialized countries. Similarly, Spencer and Liu (2010) exploit international information to explain term structure dynamics in U.K., U.S. and Switzerland.

The introduction of global factors in an affine term structure model is also justified by a large and growing body of literature which points towards the importance of common sources of fluctuations across interest rates in advanced economies. As predicted by economic theory, progressive financial and economic integration implies global asset pricing determination and, as a result, macroeconomic and financial factors tend to co-move in response to a relatively small number of global shocks (see Modugno et al, 2009, Hellerstein, 2011, and Dell'Erba and Sola, 2013). For instance, Bauer and Díez de los Ríos (2012) and Díez de los Ríos (2011) assume complete markets and full financial integration and estimate affine term structure models imposing the uncovered interest rate parity. As a result, in their setting only global factors matter and exchange rate changes and stochastic discount factor ratios track each other very closely. Our approach is similar to Jotikashtira Le and Lundblad (2015) in that we do not impose these international finance restrictions and both global and local/idiosyncratic factors can potentially matter. Specifically, our model implies that financial markets are perfectly integrated domestically, but we do not impose any explicit assumption on the degree of integration of international financial markets, thus allowing for the possibility of segmented international bond markets. We select global factors that are shown to capture global macro-finance dynamics and study their impact across countries in the context of an affine term structure model.

Our work is closely related to Moench (2008) and Diebold, Li and Yue (2008). We borrow from Diebold, Li and Yue (2008) most of the building blocks necessary for a multi country affine term structure model, but we enrich the dynamics of the state variables by adopting a structure similar to the FAVAR presented by Moench (2008) to describe the U.S. term structure. Moench (2008) estimates an affine term structure model for the US where the interest rates are assumed to be a function of a large range of macroeconomic variables whose information is collapsed into a small number of unobserved latent factors. Diebold, Li and Yue (2008), instead, estimate a multi country affine term structure model with global and idiosyncratic factors. They show that two global factors - “global level and global slope” - are largely responsible for the co-movements of the yield curves in industrialized economies.

This article differs from Diebold, Li and Yue (2008) in many important aspects. First, and more importantly, we show that together with global level and global slope, a third factor is also important in explaining the dynamics of the interest rates. We show that this factor, which turns out to be especially important for explaining long run variations in interest rates and the term premium, is related to inflation uncertainty and precedes the financial instability of the 2007-2009 period. Second, we complete their analysis by analyzing the dynamic propagation of global shocks on both the dynamics of the yield curves and the term premia in different countries. As stated by Bernanke (2006), monetary policy makers closely watch term premium dynamics with a view to stimulating or restraining liquidity in the economy.

Third, following Bauer, Rudebush and Wu (2012, 2014), our model employs the inverse bootstrap bias correction in the estimation of the FAVAR. In their recent work, they have shown that the high persistence of the data in affine term structure models can severely worsen the small sample bias problem from which they are affected.[1,2]

This paper proceeds as follows. In Section 2 we present the data and some descriptive evidence in support of the presence of global factors. Section 3 describes the building blocks of our term structure model. Section 4 explains the estimation methodology and Section 5 discusses our main results. Section 6 briefly highlights some robustness checks that we conducted and Section 7 concludes.

2. DATA

We use the dataset constructed in Wright (2011). The data comprises yields to maturity on zero coupon yield curves for seven countries: United Kingdom, Canada, Germany, Japan, Australia, New Zealand and Switzerland starting in 1990 and ending in the first quarter of

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[1] There are also relevant methodological differences with respect to Diebold, Li and Yue (2008). For instance, they use a Nelson-Siegel framework, whereas we employ an affine-no arbitrage model. Additionally, we estimate the factors via principal components, while they obtain latent factors via Kalman filter estimation.

[2] The first and third aspects, among others, also differentiate our paper from Jotikashtira Le and Lundblad (2015).

2009.[3] We do not study the dynamics of the US yields or term premia, given that it is not a small open economy. However, as explained in the subsection on latent factor estimation, we make use of the US yield curve to construct the global factors affecting our set of countries. In this analysis we use quarterly frequency which we compute as simple averages of the monthly observations. Yields are available for maturities running from three months to ten years resulting in 40 series of zero coupon yields per country. These are the yields employed in the construction of the cross-country first three principal components shown in Figure 1.

A glance at the yield data helps us understand the importance of global factors in driving the co-movement of the yield curves across advanced economies. Figure 2 plots the dynamics of interest rates from short to long maturities over time for the set of countries in our sample. It shows that the cross-country term structures are strongly correlated. Across all maturities, the level of the yield curves displays a strong downward trend starting from the beginning of the nineties. While overall yield curves exhibit a positive slope, the actual degree of the slope varies from country to country. As shown in Figure 1, the first three factors do exhibit important cross-correlation, a fact we will use in this paper to characterize the importance of global factors in shaping the countries' term structures.

[3] Differently from Wright (2011) we exclude Norway and Sweden as the data are not available starting from the same date. The data can be downloaded at https://www.aeaweb.org/articles.php?doi=10.1257/aer.101.4.1514

3. A GLOBAL TERM STRUCTURE MODEL

3.1 Affine Model

Our model is a simple extension of a discrete-time affine term structure model of the sort employed by Ang and Piazzesi (2003), Cochrane and Piazzesi (2008) and Wright (2011). Let p_{it}^{n} represent the price at time t of an $n-$period zero coupon bond for country i, and let $y_{it}^{n} = -\log\left(p_{it}^{n}\right)/n$ denote its yield. If m_{it+1} denotes the nominal pricing kernel, bond prices can be recursively computed as:

$$p_{it}^{n} = E_t\left(m_{it+1} p_{it+1}^{n-1}\right).$$

We assume that the pricing kernel m_{it+1} is conditionally lognormal:

$$m_{it+1} = \exp\left(-r_{it} - \frac{1}{2}\lambda_{it}^{'}\lambda_{it} - \lambda_{it}^{'}u_{it+1}\right),$$

where r_{it} is the short-term interest rate, λ_{it} is the time varying price of risk and u_{it+1} is an i.i.d. shock which is normally distributed with mean zero.[4] Following the existing literature, we assume the price of risk to be an "affine" (linear) function of a vector of M latent state variables which we include in the vector Y_{it}:

$$\lambda_{it} = \lambda_{i0} + \lambda_{i1}Y_{it}. \tag{1}$$

[4] If $\lambda_{it} = 0$, the model generates the pure "expectational hypothesis".

The state vector determines the reaction of the short-term rate of country i, r_{it}, and this relationship is supposed to be linear:

$$r_{it} = y_{it}^{1} = \delta_{i0} + \delta_{i1}^{'} Y_{it}.$$

Hence, changes in the state variables affect the short-term interest rates and - through no-arbitrage relationships - the entire yield curve. The specification of the state vector allows us to distinguish the "global" versus the "local" determinants of the yield curves. In fact, we assume that the state vector is composed of two distinct sets of elements, a country specific state vector X_{it} and a "global" state vector F_t:

$$Y_{it} = \begin{pmatrix} X_{it} \\ F_t \end{pmatrix}.$$

The model is then completed by specifying the law of motion for the state variables. Alternatively to the existing literature, we assume the dynamics of the system are described by a Factor Augmented VAR (FAVAR) model. The "local" state variables X_{it} and the "global" ones F_t evolve according to:

$$X_{it} = \mu_i + \Lambda_i F_t + \Phi_i X_{it-1} + v_{it} \tag{2}$$

$$F_t = \Omega F_{t-1} + \eta_t,$$

where v_{it} and η_t are uncorrelated i.i.d. processes with mean zero. The implicit assumption behind this formulation is that there are a small number of global forces, F_t, that drive the comovements of country-specific states, X_{it}. For ease of exposition, global factors are demeaned. Notice that, as is standard in the international term structure literature, we assume that global factors affect domestic factors, but domestic factors do not affect global factors (see, for instance, Diebold et al, 2008). We believe that this assumption, a "small open economy" assumption, is reasonable for all our selected countries. In fact, our FAVAR nests the standard closed economy models, in which global factors do not affect domestic factors ($\Lambda_i = 0$), as in Wright (2011), as well as the case in which the evolution of X_{it} strictly follows that of the global factors ($\Phi_i = 0$). Standard likelihood ratio tests can be used to assess whether the set of global factors enters significantly into the evolution equation for the X_{it}. From a methodological point of view, this is not very different from standard affine term structure models, where the state vector is required to follow a VAR(1) process. The FAVAR model, in fact, can be easily rewritten in a VAR(1) form for each country *i* as:

$$Y_{it} = \tilde{\mu}_i + \Gamma_i Y_{it-1} + \Psi_i u_t \tag{3}$$

where $u_{it} = \begin{pmatrix} v_{it} \\ \eta_t \end{pmatrix}$ and the matrices $\tilde{\mu}_i$, Γ_i and Ψ_i are:

$$\tilde{\mu}_i = \begin{pmatrix} \mu_i \\ 0 \end{pmatrix}$$

$$\Gamma_i = \begin{pmatrix} \Phi_i & \Lambda_i \Omega \\ 0 & \Omega \end{pmatrix}$$

$$\Psi_i = \begin{pmatrix} I & \Lambda_i \\ 0 & I \end{pmatrix}.$$

Since the short term rate is linearly related to the state vector, bond prices are exponential linear functions of the state vector:

$$p_{it}^n = \exp(A_{i,n} + B_{i,n}^{'} Y_{it})$$

The scalar $A_{i,n}$ and the $m \times 1$ matrix of coefficients $B_{i,n}$ depend on time to maturity. Provided that no-arbitrage across maturities is guaranteed, Ang and Piazzesi (2003) and Bekaert, Cho and Moreno (2010) show that the coefficients can be computed using the following recursive equations:

$$A_{i,n+1} = -\delta_{i0} + A_{i,n} + B_{i,n}^{'}\left(\tilde{\mu}_i - \Psi_i \lambda_{i0}\right) + \frac{1}{2} B_{i,n}^{'} \Psi_i \Psi_i^{'} B_{i,n}$$

$$B_{i,n+1} = \left(\Gamma_i - \Psi_i \lambda_{i1}\right)^{'} B_{i,n} - \delta_{i1}$$

The recursion starts with $A_{i1} = -\delta_{i0}$ and $B_{i1} = -\delta_{i1}$. Hence, for an $n-$quarters to maturity zero coupon bond the yield will be given by:

$$y_{it}^n = -\log(p_{it}^n)/n = a_{i,n} + b_{i,n}^{'} Y_{it}$$

with $a_{i,n} = -\frac{A_{i,n}}{n}$ and $b_{i,n}^{'} = -\frac{B_{i,n}^{'}}{n}$.

Therefore, once we estimate the parameters of the FAVAR and the remaining model parameters, we will be able to generate yields at any given maturity, together with a series of forward rates. Using the generated yields we can compute term premia for all the countries in the sample.

3.2 Effects of Global Shocks

The dynamic structure of the FAVAR model allows us to analyze the propagation and the relative importance of global and local shocks in the dynamics of the yield curves. Hence in this section we show how to impose a structural identification and derive impulse responses to global and local shocks. Let us write out the FAVAR model in matrix form as:

$$\underbrace{\begin{bmatrix} I & -\Lambda_i \\ 0 & I \end{bmatrix}}_{\Xi_i} \underbrace{\begin{bmatrix} X_{it} \\ F_t \end{bmatrix}}_{Y_{it}} = \underbrace{\begin{bmatrix} \Phi_i & 0 \\ 0 & \Omega \end{bmatrix}}_{\Upsilon_i} \underbrace{\begin{bmatrix} X_{it-1} \\ F_{t-1} \end{bmatrix}}_{Y_{it-1}} + \underbrace{\begin{bmatrix} v_{it} \\ \eta_t \end{bmatrix}}_{u_{it}}.$$

Given that the shocks to the local and global factor equations are uncorrelated, $E(v_{it}\eta_t) = 0$, the variance-covariance matrix of the errors is given by:

$$E(u_{it}u_{it}^{'}) = \begin{bmatrix} \Sigma_{i\upsilon} & 0 \\ 0 & \Sigma_{i\eta} \end{bmatrix}.$$

Suppose that we can find matrices B_{i0} and C_{i0} such that $B_{i0}B_{i0}^{'} = \Sigma_{i\upsilon}$ and $C_{i0}C_{i0}^{'} = \Sigma_{i\eta}$, with those matrices having structural identification restrictions, then it is true that:

$$\underbrace{\begin{bmatrix} B_{i0} & 0 \\ 0 & C_{i0} \end{bmatrix}}_{\tilde{\Sigma}_i} \begin{bmatrix} B_{i0} & 0 \\ 0 & C_{i0} \end{bmatrix}' = \begin{bmatrix} \Sigma_{i\upsilon} & 0 \\ 0 & \Sigma_{i\eta} \end{bmatrix}.$$

The impulse responses to these identified structural shocks are therefore obtained by simply inverting the FAVAR:

$$Y_{it} = [I - \Xi_i^{-1}\Upsilon_i(L)]^{-1}\Xi_i^{-1}\tilde{\Sigma}_i.$$

Alternatively, a more operational expression for the impulse response functions can be obtained by rewriting the equations of the FAVAR in terms of the lag operator:

$$X_{it} = \Lambda_i F_t + \Phi_i(L) X_{it} + v_{it}$$

$$F_t = \Omega(L) F_t + \eta_t.$$

We can invert the expressions above to obtain:

$$X_{it} = [I - \Phi_i(L)]^{-1} \Lambda_i F_t + [I - \Phi_i(L)]^{-1} v_{it}$$

$$F_t = [I - \Omega(L)]^{-1} \eta_t.$$

These expressions imply that the response of the local factors X_{it} to " local shocks" can be computed from the moving average representation:

$$X_{it} = [I - \Phi_i(L)]^{-1} C_{i0} \varepsilon_{it}$$

were ε_{it} is a vector of structural " local shocks" . Similarly, the impulse responses of the local factors to " global shocks" can be computed from the moving average representation:

$$X_{it} = [I - \Phi_i(L)]^{-1} \{\Lambda_i [I - \Omega(L)]^{-1} B_{i0} \zeta_t\}$$

with ζ_t representing a vector of structural " global shocks".

4 ESTIMATION STRATEGY

The estimation of the model is undertaken in several steps (as in Joslin, Singleton and Zhu 2011, and Wright, 2011). The first step consists of estimating the two sets of global and local latent factors F_t and X_{it}. The second step is then to estimate the parameters of the FAVAR in (2), which can be obtained conditionally on estimates of the latent factors. The third step is to estimate the short-rate process parameters δ_{i0} and δ_{i1}. Finally with a last step we can back out estimates for the last set of parameters, λ_{i0} and λ_{i1}.

4.1 Estimation of the Latent Factors

The literature on affine term structure model often uses principal component analysis to find estimates of the state variables. Following Joslin, Priebsch and Singleton (2014), among others, we therefore define the set of domestic factors X_{it} as a vector containing the first three principal components extracted from the set of zero-coupon yields in country *i* of maturities running from three months to ten years. Because of their shape, these factors are generally called: level, slope and curvature respectively. Abiding by this convention, we will name the elements of X_{it} "local level", "local slope"and "local curvature".

The global factors, on the other hand, should be able to capture "global forces" that drive the co-movement or cross-correlation of the yields in different countries. As hypothesized in the literature on "factor models" (Geweke, 1977, Stock and Watson, 2005, Bernanke, Boivin Eliasz, 2005 among others) we can in fact think that yields across different countries are a function of a small number of global factors. Hence, F_t can be consistently estimated by extracting principal components from a matrix M_t which includes the term structures of all the N countries included in our sample, including the U.S. (320 series in total):

$$M_t = \{y_{1t}^1,...,y_{1t}^n,...,y_{Nt}^1...,y_{Nt}^n\}.$$

We also extract three global factors from all these interest rate series. From a methodological point of view, extracting latent factors from a set of variables taken from the different countries allows us to interpret the common factors F_t as "global". In particular the elements in F_t will be combinations of yields of different countries at different maturities which explain the highest proportion of correlation among interest rates in all countries over all maturities.[5] As a result, we have six factors in total: three local and three global.

[5] The literature has argued that extracting global factors through principal components from the pooled set of interest rates is subject to limitations. In particular, the principal components might still reflect idiosyncratic

(continued…)

4.2 Estimation of the Remaining Parameters

Following Bernanke et al. (2005), after estimating the global and the local factors F_t and X_{it} via principal components, we treat them as observable variables and estimate the parameters of the FAVAR (Γ_i, Ψ_i and $\tilde{\mu}_i$) via standard OLS.[6] Similarly, conditional on consistent estimates of the factors, we also obtain consistent estimates of the parameters δ_{i0} and δ_{i1} with a simple OLS regression of the short-term rate on Y_{it}.

Finally, the remaining parameters λ_{i0} and λ_{i1} which determine the evolution of the price of risk, are estimated, for instance, as in Cochrane and Piazzesi (2008) by minimizing for each country *i* the sum of squared differences between actual and fitted yields:

$$\left\{\hat{\lambda}_{i0}, \hat{\lambda}_{i1}\right\} = \arg\min_{\lambda_{i0}, \lambda_{i1}} \sum_t \sum_n (y_{it}^n - \tilde{y}_{it}^n)^2, \tag{4}$$

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factors (Perignon et al, 2007; Juneja, 2012). Some methodological alternatives have been provided, in particular the Inter-Battery Factor Analysis (IBFA) or the Common Principal Component (CPC). We have tried to adopt these methodologies in our context but, due to the dimension of our dataset, we run into estimation problems. We have nonetheless, as a robustness check, adopted the alternative estimation strategy for IBFA suggested by Bauer and Díez de Los Rios (2012). The results obtained are very similar to the ones we obtain by PCA.

[6] By observable factors we mean that the principal components obtained are used as data in FAVAR estimation of the term structure model. This is in contrast to other work where the factors are directly filtered in the estimation of the term structure model, for instance via Kalman filter techniques, as in Diebold, Li and Yue (2008). For simplicity, in the estimation all factors (domestic and global) are demeaned.

where $\tilde{y}_{it}^{n} = -(A_{i,n} + B_{i,n}^{'} Y_t)/n$ are the model implied yields of country *i*.

After having estimated these parameters, the model is able to generate the entire structure of the yields. It is therefore possible to compute the term premium associated with longer maturities. Following Wright (2011) and Bauer, Rudebusch and Wu (2014), we compute the term premium as the difference between the model implied 5-year forward rate 5 years from now and the average expected three-month rate 5 to 10 years from now.

Before moving on to the results of the paper, it is worth mentioning two methodological issues. The first issue refers to the possibility that some factors may be “unspanned”. Several recent papers (see e.g. Duffee, 2008, Ludvigson and Ng, 2009, Bauer and De los Ríos, 2012, Joslin, Priebsch and Singleton, 2014, among others) have considered the possibility that some factors in a term structure model can be important for forecasting future interest rates, but may not be needed to fit the cross-section of current bond yields. In this paper we follow Wright (2011) and we treat the first three country-specific factors X_{it} as “ spanned”, while the global factors F_t are treated as unspanned. Under this assumption, global factors do not enter directly in the cross-section determination of interest rates, where only local factors appear. Global factors however affect the term structure through two main channels. On the one hand, they have an indirect contemporaneous effect on the yield curve through their spillover effect on the domestic factors. On the other hand, they help to forecast future yields.

The second issue refers to the possibility that the estimated state process dynamics may be distorted by small-sample bias. As recently shown by Bauer, Rudebusch, and Wu (2012, 2014), the persistence in estimated term structure models can exhibit severe downward biases due to small-sample problems. This problem is likely to translate into an unrealistically low degree of volatility in long-run short-rate expectations due to fast mean reversion, which distort estimates of long maturity term premia. To address this issue, we use the indirect inference bias correction methodology laid out in Bauer, Rudebush and Wu (2012) to correct for the small sample bias.[7]

5 RESULTS

In this section we report the empirical results obtained for our FAVAR term structure model. First we show the three estimated global factors and provide an intuitive macroeconomic explanation for each of them. We then assess the specification of our FAVAR model and evaluate its fit in terms of how well it can replicate yield curves across different maturities for different countries. Finally, we investigate the dynamics of the term premia and quantify the relative importance of global versus domestic factors in explaining their behavior.

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[7] As in Bauer, Rudebush and Wu (2012), we impose the restriction that bias-corrected estimates are stationary using the stationarity adjustment suggested in Kilian (1998). Using a standard bootstrap bias correction instead of the indirect inference bias correction does not affect our results. Additionally, we also carried out all the estimations of the paper with a Monte Carlo procedure, performing draws from the distribution of the errors – instead of bootstrapping the empirical error terms- to construct the synthetic datasets and subsequently obtain the bias-corrected parameters. Results were very similar to those reported here.

5.1 Estimates of the Global Factors

In the first estimation step, we extract common factors from the large panel of international yields using the principal components approach of Stock and Watson (2002). Since the first three principal components together account for more than 96 percent of the total variance of all yields, we consider three global factors in the analysis, which are depicted in Figures 3 and 4.

As with any estimation methodology based on principal components, the main issue with latent factors is that they miss an economic interpretation. The existing literature on affine term structure models has shown that level and slope factors in a country's yield curves are generally related to expected inflation and real activity. We now develop an economic interpretation of the three global factors and discuss their relation with their local counterparts. Our results highlight that the behavior of the "global level" factor closely resembles a "global expected inflation factor" (Figure 3) which we compute as the first principal component extracted from a matrix containing one year ahead CPI inflation forecasts of the countries in our sample.[8] The two series look remarkably similar and present a correlation of 0.94.

Similarly we construct a "global real activity indicator" as the first principal component extracted from a matrix containing real GDP growth, industrial production and unemployment figures for the countries in our sample. The correlation between this index

[8] Data are taken from the Consensus Economic Forecasts and are quarterly averages of monthly figures.

and the second global factor is 0.77. The global real activity factor manages to capture the three downward movements experienced by the global slope factor between 1990 and 1995, then between 2000 and 2005 and finally during the Great Recession. For this last period however, the global real activity factor drops by less.

Regarding the third global factor, its correlation with the average of the local curvatures is 0.69. Finding an economic interpretation for the third global factor is however a novel task. The top panel in Figure 4 plots the third global factor together with uncertainty (the second moment) of inflation. This is measured as the two-sided smoothed series of inflation uncertainty (proxied by the standard deviation of one-year ahead inflation forecasts based on US consensus data). We can see that the two series show a very high degree of correlation up until the beginning of the 2007 recession (81%) and also quite high in the overall sample (70%). Interestingly, the bottom panel of Figure 4 shows that the third global factor peak precedes the financial stress index peak –published by the St. Louis Fed- and thus anticipates this financial/liquidity risk episode.

Interestingly, the top panel of Figure 4 shows that the third global factor and inflation uncertainty depart from each other during the recent financial crisis (2007-2009), characterized by both a higher inflation volatility and a significant drop in global inflation. To shed more intuition on this important period, Figure 5 describes the dynamics of a synthetic global (equally weighted by countries) yield curve during the financial crisis episode. Right before the crisis broke (2^{nd} quarter of 2007), the global yield curve was essentially flat at 4.5 percent. However, by the third and fourth quarter, it cleary becomes convex, with a marked hump-shape, as interest rates at intermediate maturities edge clearly lower, reflecting expectations of lower monetary policy rates. In hindsight, monetary authorities did not bring interest rates immediately down to the surroundings of the zero lower bound when the crisis broke (3rd quarter of 2007). It took some quarters. The right panel indeed shows that by the fourth quarter of 2008 the short-end of the yield curve was already at around 2 percent due to the global expansionary monetary policies. One possible interpretation is that as initial signs of the liquidity crunch appeared, some kind of deflation risk surfaced with a subsequent persistent expansionary reaction by international Central Banks. This move was understood by global bond investors and was thus reflected in both the third global factor and the global yield curve.[9] Despite these actions, the financial crisis could not be averted.

5.2 Model Performance

While there are many sound economic arguments to support the idea that global factors influence domestic term structures, it needs to be demonstrated that these effects are strong and statistically significant. One of the advantages of the FAVAR model (2) is that, by nesting the case in which global factors do not affect domestic factors ($\Lambda_i = 0$), it allows us to formally test the importance of global factors for the dynamics of the local level, slope and curvature factors.

[9] This evidence is consistent with the findings of Fleckenstein et al. (2013) who show that markets price very similarly deflation risk and other types of tail risk like systemic financial risk.

Table 1 shows the results of the likelihood ratio tests where we test formally whether the coefficients of the matrix Λ_i in the FAVAR are jointly statistically different from zero. Under the null hypothesis, the dynamics of domestic factors are independent from global factors. The degrees of freedom are corrected as in Sims (1980) for the number of parameters in each equation. For all the countries considered, the block exogeneity test very strongly rejects the null of no-effects of the global factors. We interpret these results as a validation of our empirical model and as an important starting point in uncovering the relationship between global forces and yield curve dynamics.

To evaluate the fit of the model, Table 2 shows the root mean square fitting error of yields, i.e. the square root of the minimum value of the objective function in equation (4). The fit of the model is excellent. The typical fitting errors range between 1.5 and 6 basis points, with New Zealand, Germany and Japan exhibiting the best fit.

5.3 How Important are Global Factors for Domestic Factors and Yields?

In our model, we have implicitly assumed a hierarchical structure, in which country yields depend only on country-specific factors, but these are in turn affected by the dynamics of global forces. Any influence of global factors on domestic interest rates can thus come only through their effect on the domestic level, slope and curvature factor. To understand the effect of global forces on country yields, in this section we use the FAVAR model to perform two exercises. We first analyze the impulse responses of domestic factors to global shocks. We then compute the variance decomposition exercise of the three local factors included in the vector X_{it}.

To perform these exercises, global shocks are identified with a simple Choleski decomposition. Using the macroeconomic interpretation of the global factors, we order the second global factor, capturing global real activity (slope), as first, the third global factor as second, and the global expected inflation (level) factor last. Notice however that alternative factor orderings resulted in very similar subsequent results.

Figure 6 shows the dynamic response of local yield factors to global forces in the case of the UK.[10] The unreported results for other countries give a similar picture.[11] Global forces are found to have a sizeable and persistent effect on domestic factors. A positive innovation to the global slope factor is found to have a positive effect on both the domestic level and slope factor, consistent with the idea that a global boom tends to induce both an improvement in the domestic cycle and an increase in the domestic inflation risk. Notice that both effects are delayed and very persistent. An increase in the third global factor instead is related to an increase in the domestic curvature and a reduction in the domestic level and slope factors. These last two effects can be caused by the aggressive expansionary monetary policy following the third global factor shock –see Figure 5-. The drop in slope is caused by a larger drop in the long-rate, due to the expected persistent lowering of the short-rate. Notice that the effect of this shock is small on impact but more persistent, as it remains significantly different from zero for more than 30 quarters. Finally, a shock to global level loads positively on the country's yield curve level factor (i.e. the country's inflation risk factor), while the

[10] Confidence intervals are obtained using the bootstrap-after-bootstrap method as described in Kilian (1998).

[11] All results are available upon request from the authors.

effect on local slope and curvature is small, and, more generally, may differ from country to country.

Table 3 shows the contribution of global shocks to the variance of the local factors at two forecasting horizons: 1 quarter and 40 quarters. At short horizons, country specific shocks explain most of the variance of the three local factors, but global factors are far from unimportant. Global factors explain, on average, 54 percent of the local level, 24 percent of the local curvature but only 3 percent of the local slope. The importance of global factors rapidly increase with the horizon. For most of the countries the level of interest rates is explained - at a 10 year-horizon - almost entirely by the global factors. The proportion of explained variance for the level factor in fact ranges between 94.8 percent in Japan and 99.3 in Germany. Global factors also explain more than 50 percent of the variance of the domestic slope and curvature.

Since global factors are important determinants of local factors, we expect them to have sizeable effects on domestic yield curves. Figure 7 shows the contribution of global shocks for the variance of domestic yields across maturities (left graph) and forecasting horizon (second graph). At a 40-quarters horizon, global shocks explain more than 80 percent of the variance of yields, across all maturities. This effect is found to increase with the maturity, and to reach a maximum between 10 and 25 quarters, depending on the country. Regarding the effect of the forecasting horizon considered, we find that on impact (h=1 quarter) domestic shocks explain, in most countries, most of the 10-year yield. Already after 4 quarters, however, global shocks dominate the variance decomposition of the 10-year yield, confirming the idea that the effect of global shocks tends to be large but delayed.

Table 4 decomposes the contribution of global forces to long and short rates into the portions due to each of the three global factors. The global second and third global factors are found to explain together more than 70% of the 3 month rate each, while the first global factor only accounts for 10 percent of the forecasting variance of the short rate. At longer maturities, the importance of the global level factor increases, while the relevance of the other two factors is slightly reduced.

Overall, these results point towards a crucial importance of global factors in explaining domestic yields curves. Diebold et al. (2008) showed the importance of two global yield factors related to global inflation and economic activity. Our results suggest that a third global factor needs also to be taken into account, a factor related to the second moment of inflation until 2007 and which can proxy deflation risk during the recent financial crisis. We now show that this factor is also key in explaining term premium dynamics.

5.4 Term Premia Dynamics

One of the interesting properties of the affine term structure models is that they allow researchers to decompose long rates into the risk neutral rate and term premia. Term premia are the excess returns that investors ask to be indifferent between holding a short and a long-term instrument. In presence of risk aversion, in fact, investors need to be compensated for the risk of holding a long-term instrument with a return that is above the simple average of expected short term rates. In our default-free setting, term premia could reflect nominal and real risks, such as inflation (Gurkaynak, Sack and Swanson (2005)) and unemployment (Gil-Alana and Moreno (2012)), or potentially other macroeconomic and financial risks, such as policy risk (Bernanke, et al., 2004).

We therefore use our FAVAR model to estimate time varying term premia. Following Wright (2011) we compute them as the difference between the model-implied 5-to-5 year forward rate and the average expected one-year rates 5-to-10 year hence. Figure 8 shows the implied term premium of our FAVAR term structure across countries. To ease visualization, we divide the countries in two groups: the Pacific countries - Japan, Australia and New Zealand - and the Western countries - UK, Germany, Switzerland and Canada -.

In all countries, the term premium has declined from the beginning of the nineties until the early 2000s, but has started to increase afterwards, first quite smoothly, and then rapidly at the onset of the recent crisis. The Great Recession has been associated, in most countries, with an increase of the term premium of about 4 percentage points. Interestingly, the dynamics of term premia in Western economies is consistently more volatile than in the Pacific countries.

Notice that the dynamics of the term premia implied by the FAVAR term structure model are more volatile and countercyclical than the dynamics in Wright (2011) and Bauer, Rudebusch and Wu (2014). The higher volatility with respect to Wright (2011) was expected, because we correct the FAVAR estimates for the small-sample bias, which tend to make the estimated system less persistent. The higher volatility with respect to Bauer, Rudebusch and Wu (2014), instead, suggests that the presence of global factors further increases the volatility of the expectations of future short-term interest rates, especially at longer horizons. Notice also that the term premium can become negative for some countries, especially after the mid-1990s. As Campbell et al (2013) have shown, this situation can arise under a negative correlation between stock market and bond market returns. In this instance, long-term bonds can hedge against stock market losses and, in general, against the backdrop of recession times. As a result, investors are eager to accept lower returns on long-term bonds vis à vis short-term bonds.

In general, the dynamics of the term premia have been associated to the so called "inflation risk". The declining pattern in the early part in Figure 8 would therefore be evidence that central banks, with the adoption of an explicit target for inflation have managed to anchor inflationary expectations and therefore reduced term premia. The increase observed in the last part of the sample, however, suggests that there might be something more to it. Thus, it is important to ask whether these term premia dynamics are due to developments in the domestic economies or to global developments, because the implications for policy-makers may be strikingly different. This is a task that we perform in the following section.

5.5 Global Factors and Term Premium Dynamics

To get a first impression of the importance of global forces for term premia dynamics, Figure 9 shows the counterfactual term premia that would arise if countries were hit only by local or global shocks, respectively. Specifically, in this exercise we shut down all domestic (global) shocks to derive, conditional on the estimated parameters, counterfactual term premia due completely to global (local) shocks.

Term premia dynamics appear to be mainly determined by global factors. In particular, the patterns of term premia generated with only global factors, reflect both the steady decline of the first part of the sample and the steep increase associated with the Great Recession, and always move closely to actual term premia. When we include only local shocks, instead, the generated series sometimes depart significantly from the actual term premium, indicating that local shocks are less important in explaining their dynamics. The reason is that global factors explain most of the variance of local factors at longer horizons.

Table 5 reports the variance decompositions in term premia dynamics. The contribution of global factors to term premia variations ranges between 65 percent in the case of Germany to 91 percent in the case of the UK. The third global factor is, on average, the most important in explaining term premia variation, as it explains around 60 percent of the total variance at the 40 quarters horizon. This happens mainly because shocks to the third global factor explain most of the variance of the risk neutral rate (Table 6), which indicates that the third global factor has a large forecasting power for future short-term yields. This confirms the results in Dahlquist and Hasseltoft (2013), who also find that global shocks have an important effect on future expected short-term rates. We further refine their result and show that the shock to the third global factor is instrumental in this respect. Indeed, as Figure 5 shows, at the beginning of the recent crisis –when the third global factor peaks- the monetary policy authority aggressively and persistently lowered short-rates, thus lowering the risk neutral rate. The global level factor is instead the most important in explaining forward rates dynamics.

To get further intuition on the effect of global factors on term premia dynamics, Figure 10 shows the impulse responses of the term premium to each of the three global shocks. A positive shock to the second global factor induces in most countries a reduction in the term premium. This negative correlation between global growth shocks and movement in the term premium is consistent with Rudebusch et al. (2006). They show that a decline in the term premium is able to predict future growth. In our setting, we show that this is due to the second global factor which is associated with global growth. An increase in this factor induces both a decline in the term premium and an increase in future growth. The only exceptions are Australia and New Zealand, where the transmission mechanism is positive, due to an increase in the forward rate larger than the policy channel, which induces a small increase in the term premium.[12] [13]

[12] As in Jotikasthira et al. (2015), we decompose the impulse responses of the bond yields to global factors into those that operate through the policy channel (the expected average of future short-term rates) and the risk premium. For parsimony, Figure 10 shows only the response of the term premium to global factors, but the whole set of results is available upon request.

[13] The fact that the forward rate increases more for Australia and New Zealand could be related to either their role of commodity exporters or of investment currencies in carry trade positions. As a positive shock to the global growth occurs, a higher demand for commodities induce a larger expected depreciation, leading to an increase in the forward rate; also, as shocks to global growth induce an expectation of future increase in short-term rates, investors rebalance their portfolio away from investment currencies as return on investment in other

(continued…)

An increase in the third global factor, instead, produces an increase in term premia across countries. This effect is relatively large, especially in Western countries, and very persistent, as it usually lasts more than 30 quarters. Interestingly, Campbell et al (2013) have recently highlighted the potential importance of the yield curve curvature in shaping bond term premia. In particular, they show that the intermediate part of the term structure can react more than the long-end following macro shocks. In their model, this happens because the intermediate part of the yield curve reacts both to permanent and transitory shocks, whereas the long end only reacts to the permanent part. Under the light of our model during the 2007-2009 period, the yield curve became more convex by the beginning of 2008 –see Figure 5-. This event coincides with a peak in the third global factor –see Figure 4- which can be seen as apositive shock to that global factor resulting in a higher term premium across countries.[14]

currencies increase. Both circumstances lead to an increase in forward rates, which in the case of Australia and New Zealand leads to an increase in the term premium.

[14] The case of Japan bears particular attention. The term premium response is more muted compared to the other countries. The fact that Japan has experienced prolonged economic weakness and that monetary policy has been constrained by the Zero Lower Bound (ZLB) can explain the lower compensation investors require in the presence of global shock, compared to other countries. Also, while our model does not explicitely model the (ZLB), we observe a more-muted decline of the policy channel in response to a shock to the third global factor compared to the other countries whose monetary policy has not been affected by the ZLB. Results are available upon request.

An increase in global level -related to inflation- induces an increase in the term premium in all countries except Germany. In Germany, the term premium actually decreases following a shock to the global expected inflation factor because, even though long rates and the forward rate increase after the shock, the risk neutral rates increase by more on impact. The fact that the policy channel dominates in Germany is symptomatic of the high credibilityof its monetary policy stance. In the other countries, the policy channel response is relatively more muted on impact, compared to Germany, although it increases over time leading then to a subsequent reduction in term premia over the longer horizon.

6 Robustness Checks

We test the robustness of our results with three main exercises. First, to understand to what extent bias correction affects our conclusions, we compare the main results reported above (under bias correction) with analogs obtained without bias correction. As in Bauer, Rudebusch and Wu (2012 and 2014), we find that bias correction has important effects on the identification of the term premium. For all countries, the term premium identified with simple OLS presents a clearer downward sloping trend; it is less volatile/countercyclical and does not increase as much during the Great Recession. The conclusions about the importance of global factors, however, hold independently of the bias correction in the state process (Table 7). Bias correction slightly increases the total contribution of global shocks, but in the model estimated with simple OLS, global shocks still account, on average, for more than 70 percent of the total variance in the term premia. However, bias correction affects the relative contribution of the three shocks. Under OLS, the contribution to the total variance attributed to the first global factor almost doubles, from 16 to 29 percent, while the contribution of the third global factor is reduced. These results are consistent with the conclusions by Bauer, Rudebusch and Wu (2012 and 2014) and Abbritti, Alana, Lovcha and Moreno (2015), who show that, taking the term structure persistence correctly into account reduces the importance of expected inflation for term premia dynamics, while it increases the importance of real shocks.

In the second exercise, in order to assess the impact of the Great Recession on the estimation, we re-estimate the model for the 1990Q1-2007Q1 period, i.e. we leave out the last eight observations of our original sample. The average contribution of global factors to term premia dynamics is only slightly reduced, from 85 to 73 percent. In the shorter sample, the relative importance of the first global factor increases, explaining on average 35 percent of the variance of the term premia, while the third global factor only accounts for 21 percent of the total variance (Table 8). This exercise confirms previous papers which attribute the decline of term premia to expected inflation until the early/mid 2000s. It also shows that the importance of the third global factor is greatly diminished if we exclude the last part of the sample –the financial crisis period-. Thus, it is the financial crisis that brings to the scene the key relevance of the third global factor triggering international yield curve dynamics.

In the third exercise, we treat the US factors as the global ones. This is justified by the relevance of the US in the global economy as well as the importance of US monetary policy in global financial markets (see, for instance, Jotikashtira et al, 2015). In Table 9 we show the variance decomposition of the term premia across countries. We find that global factors are still key to explain term premia variations (above 80%) and that the third global factor is still very important, explaining almost 28% of the total variance. Nevertheless, with respect to the baseline model, it loses explanatory power in favor of the global cycle factor.

7 CONCLUSIONS AND EXTENSIONS

Recent term structure models have emphasized restrictions implied by no-arbitrage conditions in the market for government bonds of different maturities. In contrast, they have for the most part overlooked the implications of international financial linkages embedded in global financial markets free of restrictions to capital mobility. In this paper, we postulate a general framework to account for systematic international linkages among term structures while retaining the more traditional no-arbitrage structure.

Our results show that global factors explain an important share of fluctuations in the term premia of a panel of small-open economies, and they tend to be more important when explaining long-run trends as opposed to short-run fluctuations. Since 1990 to 2007 term premia dynamics exhibit a downward trend mostly explained by global expected inflation. Here we show the importance of a new factor explaining the yield curve and, especially, term premium dynamics: a global medium-run risk factor related to future macroeconomic and financial risks, which is filtered as the third principal component of the international yield curves. Interestingly, this factor takes the center place when explaining the dynamics of the recent crisis. During this time, monetary policy has been extraordinarily expansionary, sharply and immediately lowering interest rate expectations. In future work, we intend to examine the term structure implications of the zero –or near zero- interest rate lower bound in the years beyond the sample period in this paper. Analyzing the international spillovers of these ongoing unconventional policies is definitely a worthwhile exercise.

Table 1. Block Exogeneity Test

Likelihood Ratio Test		
Country	Stat.	p-value
JPN	40,11	0
UK	106,81	0
GER	128,17	0
SWI	96,06	0
CAN	74,20	0
AUS	95,26	0
NZL	153,67	0

Note: This table shows the p-values associated with the likelihood ratio statistics testing no-significance of global factors F_t on domestic factors X_{it}, as specified in our FAVAR term structure model. We apply the Sims (1980) correction on the likelihood ratio test, correcting degrees of freedom for the number of regressors per equation.

Table 2. Model Fit

Fit of Affine Term structure Model	
Country	RMSE
JPN	0,0211
UK	0,0599
GER	0,0214
SWI	0,0408
CAN	0,0370
AUS	0,0303
NZL	0,0146

Note: This table shows the root mean square fitting error (square root of the minimized value of the objective function of the affine term structure model) for each country, in percentage points.

Table 3. Variance Decomposition – Domestic Factors

Country	Horizon	Domestic Level				Domestic Slope				Domestic Curvature			
		GF2	*GF3*	*GF1*	Global	*GF2*	*GF3*	*GF1*	Global	*GF2*	*GF3*	*GF1*	Global
JPN	h=1	4,24	0,21	9,83	14,28	0,92	0,50	0,83	2,25	1,65	0,01	4,41	6,07
	h=40	48,14	32,09	14,59	94,82	22,03	10,45	42,06	74,53	6,44	38,75	12,38	57,57
CAN	h=1	17,41	7,66	19,24	44,30	2,22	0,17	1,44	3,83	9,31	6,84	8,16	24,31
	h=40	20,17	65,73	12,75	98,64	16,99	29,88	6,32	53,18	8,75	53,01	5,92	67,67
SWI	h=1	0,22	8,91	42,78	51,91	0,37	0,37	5,67	6,41	0,04	3,09	3,42	6,54
	h=40	17,31	61,79	17,84	96,93	7,73	22,89	27,04	57,65	1,43	54,45	1,79	57,67
GER	h=1	3,94	9,33	55,26	68,53	0,03	0,14	2,53	2,70	0,63	4,25	27,50	32,39
	h=40	17,08	55,93	26,23	99,25	2,75	25,01	2,64	30,40	9,21	36,89	15,47	61,57
AUS	h=1	32,26	3,08	32,09	67,43	3,12	1,75	0,23	5,10	23,42	1,70	23,15	48,27
	h=40	34,88	47,12	16,31	98,31	30,33	6,01	17,52	53,86	20,70	26,56	17,69	64,95
NZL	h=1	51,97	5,28	24,48	81,73	0,00	0,17	0,47	0,65	5,79	0,10	2,03	7,92
	h=40	44,24	42,09	11,96	98,29	11,20	40,53	4,16	55,89	7,35	7,62	2,25	17,22
UK	h=1	18,19	2,20	27,17	47,55	0,01	0,26	0,91	1,18	9,90	8,40	21,43	39,73
	h=40	24,13	58,74	15,90	98,77	5,73	56,05	1,42	63,20	4,24	70,02	12,90	87,16
Avg.	h=1	18,32	5,24	30,12	53,68	0,95	0,48	1,72	3,16	7,25	3,48	12,87	23,61
	h=40	29,42	51,93	16,51	97,86	13,82	27,26	14,45	55,53	8,30	41,04	9,77	59,12

Note: This table shows the contribution of shocks to the three global factors, to the variance of the three local factors (level, slope and curvature) contained in X_{it}. Results are reported for all countries in the sample and for selected horizons of 1 and 40 periods.

Table 4. Variance Decomposition – Yields

Country	Horizon	3 months yields					10 years yields				
		GF2	*GF3*	*GF1*	Global	Local	*GF2*	*GF3*	*GF1*	Global	Local
JPN	h=1	7,06	1,23	6,35	14,65	85,35	2,19	0,05	8,96	11,19	88,81
	h=40	68,85	12,44	6,13	87,42	12,58	24,81	39,38	30,37	94,55	5,45
CAN	h=1	8,18	1,71	8,74	18,63	81,37	11,70	5,76	14,38	31,84	68,16
	h=40	22,74	63,07	8,72	94,53	5,47	18,96	60,67	16,43	96,06	3,94
SWI	h=1	0,78	3,35	19,08	23,20	76,80	0,06	6,93	41,62	48,61	51,39
	h=40	20,83	58,82	3,78	83,43	16,57	11,09	38,46	46,36	95,91	4,09
GER	h=1	2,72	2,72	11,87	17,32	82,68	3,05	8,24	52,86	64,14	35,86
	h=40	12,27	54,70	13,53	80,50	19,50	17,03	35,88	25,94	78,85	21,15
AUS	h=1	26,28	4,82	18,44	49,53	50,47	47,81	37,13	10,47	95,41	4,59
	h=40	25,39	1,96	28,32	55,67	44,33	29,64	48,38	18,77	96,79	3,21
NZL	h=1	18,21	1,71	6,80	26,72	73,28	41,70	5,09	22,11	68,90	31,10
	h=40	37,75	51,03	3,36	92,14	7,86	42,08	28,85	19,12	90,05	9,95
UK	h=1	5,86	0,21	3,10	9,17	90,83	16,74	2,06	28,86	47,66	52,34
	h=40	22,00	65,01	5,68	92,70	7,30	28,28	41,89	24,33	94,50	5,50
Average	h=1	9,87	2,25	10,63	22,75	77,25	17,61	9,32	25,61	52,54	47,46
	h=40	29,98	43,86	9,93	83,77	16,23	24,56	41,93	25,90	92,39	7,61

Note: This table shows the contribution of shocks to the three global factors, their sum and the contribution of the three local factors (level, slope and curvature) contained in X_{it} to the variance of 3 months and 10 year yields. Results are reported for all countries in the sample and for selected horizons of 1 and 40 periods.

Table 5. Variance Decomposition – Term Premia

Country	Term Premia (h=40)				
	GF$_2$	*GF*$_3$	*GF*$_1$	Global	Local
JPN	8,95	9,70	66,65	85,31	14,69
CAN	1,54	85,51	1,70	88,75	11,25
SWI	5,99	69,57	9,81	85,37	14,63
GER	1,50	62,49	0,62	64,62	35,38
AUS	22,70	37,31	27,38	87,40	12,60
NZL	1,65	84,42	4,91	90,99	9,01
UK	0,41	90,86	1,84	93,11	6,89
Avg	6,11	62,84	16,13	85,08	14,92

Note: This table shows the contribution of shocks to the three global factors, their sum and the contribution of the three local factors (level, slope and curvature) contained in X_{it} to the variance of the term premia. Results are reported for all countries in the sample and for the 40 periods ahead horizon.

Table 6. Variance Decomposition – Forward and Risk Neutral Rates

Country	Forward rates (h=40)					Risk neutral rates (h=40)				
	GF$_2$	*GF*$_3$	*GF*$_1$	Global	Local	*GF*$_2$	*GF*$_3$	*GF*$_1$	Global	Local
JPN	8,47	37,32	44,38	90,17	9,83	30,63	53,68	11,96	96,26	3,74
CAN	17,34	50,41	20,84	88,60	11,40	5,39	90,29	4,29	99,97	0,03
SWI	1,89	4,28	67,94	74,12	25,88	8,23	84,44	0,82	93,49	6,51
GER	8,39	6,07	10,38	24,84	75,16	4,00	83,40	4,27	91,67	8,33
AUS	25,95	47,78	20,50	94,23	5,77	5,59	91,61	2,80	99,99	0,01
NZL	34,28	16,09	24,69	75,06	24,94	4,55	92,51	2,94	99,99	0,01
UK	29,64	19,12	31,22	79,98	20,02	4,41	91,59	3,92	99,92	0,08
Avg	17,99	25,87	31,42	75,29	24,71	8,97	83,93	4,43	97,33	2,67

Note: This table shows the contribution of shocks to the three global factors, their sum and the contribution of the three local factors (level, slope and curvature) contained in X_{it} to the variance of the forward interest rates and the risk neutral interest rates. Results are reported for all countries in the sample and for the 40 periods ahead horizon.

Table 7. Variance Decomposition – Robustness to Bias Correction

Term Premia: variance decomposition with and without bias correction

	horizon=40							
	GF2		*GF3*		*GF1*		*Global Shocks*	
	ols	bc	ols	bc	ols	bc	ols	bc
JPN	6,50	8,95	8,68	9,70	69,23	66,65	84,42	85,31
CAN	12,13	1,54	17,64	85,51	34,83	1,70	64,60	88,75
SWI	9,38	5,99	44,20	69,57	21,46	9,81	75,04	85,37
GER	5,15	1,50	41,05	62,49	2,19	0,62	48,38	64,62
AUS	26,36	22,70	17,76	37,31	41,49	27,38	85,60	87,40
NZL	15,21	1,65	36,84	84,42	17,16	4,91	69,21	90,99
UK	6,23	0,41	43,20	90,86	21,01	1,84	70,45	93,11
Avg.	11,57	6,11	29,91	62,84	29,62	16,13	71,10	85,08

Note: This table shows the contribution of shocks to the three global factors, and of their sum to the variance of the term premia. The table shows: (i) results obtained estimating the model through OLS and (ii) results obtained using the *inverse boostrap bias correction* as in Bauer , Rudebusch and Wu, 2012. Results are reported for all countries in the sample and for the 40 periods ahead horizon.

Table 8. Variance Decomposition – Term Premia – Subsample 1990Q1–2007Q1

Country	Term Premia (h=40)				
	GF2	*GF3*	*GF1*	Global	Local
JPN	4,80	52,57	35,98	93,35	6,65
CAN	16,06	11,39	39,54	67,00	33,00
SWI	2,93	1,22	59,65	63,80	36,20
GER	14,89	16,10	0,57	31,56	68,44
AUS	32,70	29,17	33,05	94,92	5,08
NZL	34,02	6,87	43,13	84,02	15,98
UK	8,98	29,39	36,30	74,66	25,34
Avg	16,34	20,96	35,46	72,76	27,24

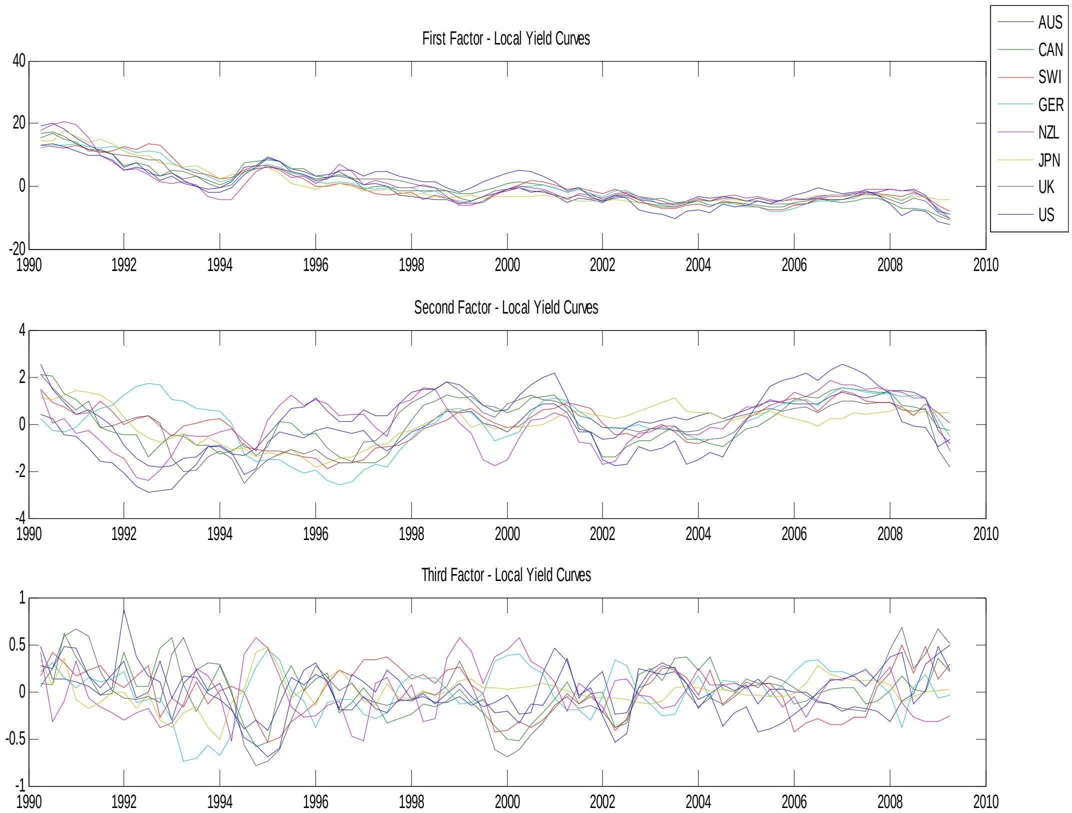
Note: This table shows the contribution of shocks to the three global factors, their sum and the contribution of the three local factors (level, slope and curvature) contained in X_{it} to the variance of the term premia when the model is estimated for the period 1990Q1-2007Q1 only. Results are reported for all countries in the sample and for the 40 periods ahead horizon.

Table 9. Variance Decomposition – Term Premia – US as Global Factor

Country	Term Premia (h=40)				
	GF_2	GF_3	GF_1	Global	Local
JPN	35,00	17,36	24,07	76,43	23,57
CAN	37,25	20,39	35,21	92,84	7,16
SWI	50,71	15,42	24,56	90,69	9,31
GER	3,73	51,32	2,97	58,02	41,98
AUS	19,97	40,61	26,09	86,67	13,33
NZL	27,42	26,54	29,21	83,17	16,83
UK	21,07	21,61	35,65	78,33	21,67
Avg	27,88	27,61	25,39	80,88	19,12

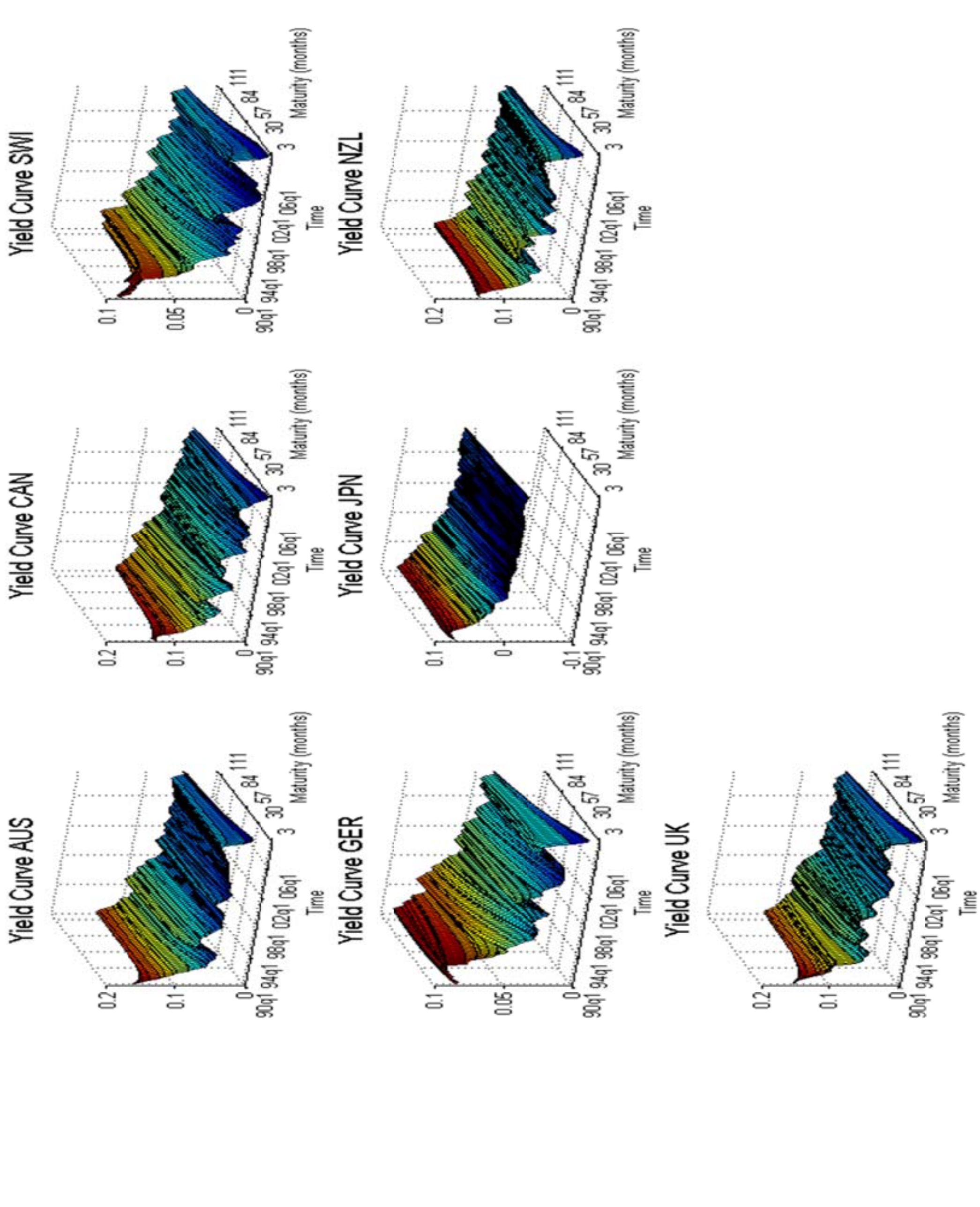
Note: This table shows the contribution of shocks to the three global factors, their sum and the contribution of the three local factors (level, slope and curvature) to the variance of the term premia when the global factors are substituted with the first three principal components of the US yield curve. Results are reported for all countries in the sample and for the 40 periods ahead horizon.

Figure 1. National Yield Curves – First Three Factors



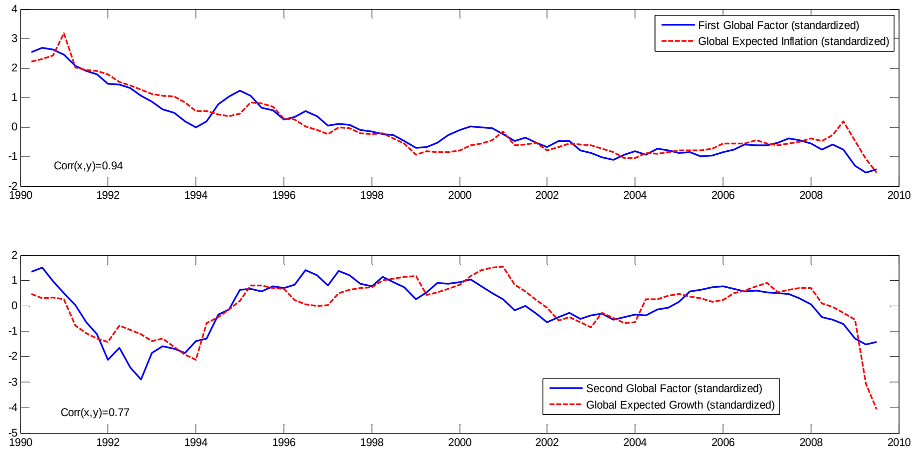
Note: This figure shows the "level", "slope" and "curvature" factors for all the countries in our sample. Level, slope and curvature are computed as the first, second and third principal components extracted from the cross-section of the yields of each country.

Figure 2. National Yield Curves



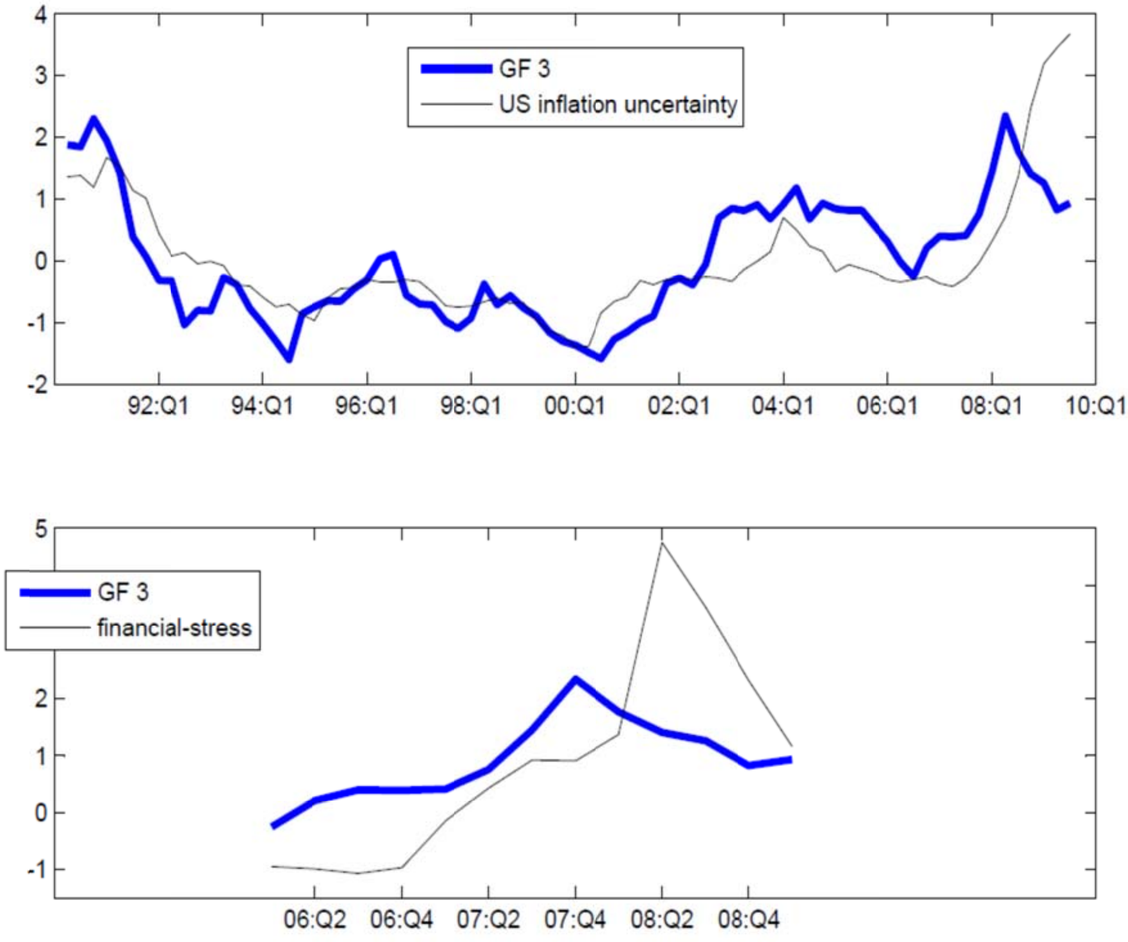
Note: This figure shows the evolution of the yield curves across countries.

Figure 3. First and Second Global Factors Dynamics



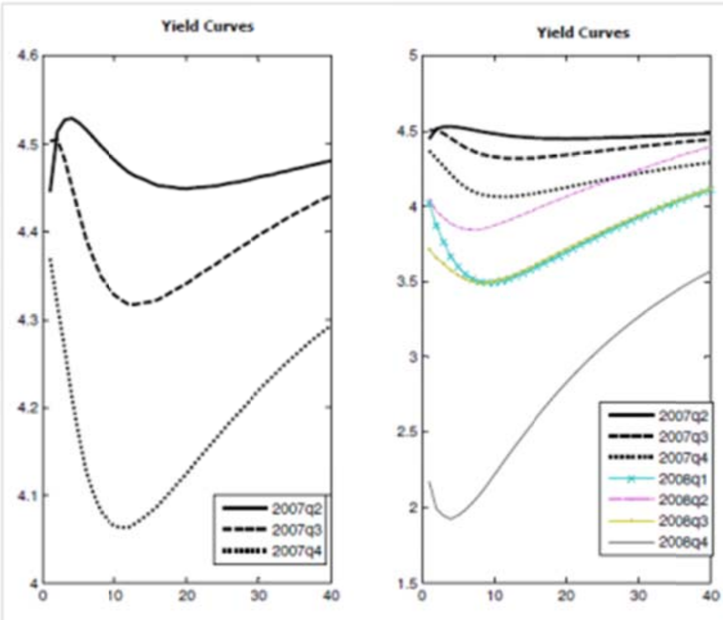
Note: This figure shows the first two global factors plotted against their macroeconomic interpretations. The first global factor is plotted against the first principal component extracted from a matrix containing data on expected inflation for OECD countries. The second global factor is plotted against the first principal component extracted from a matrix containing data on real activity for OECD countries. All series are standardized.

Figure 4. Third Global Factor Dynamics



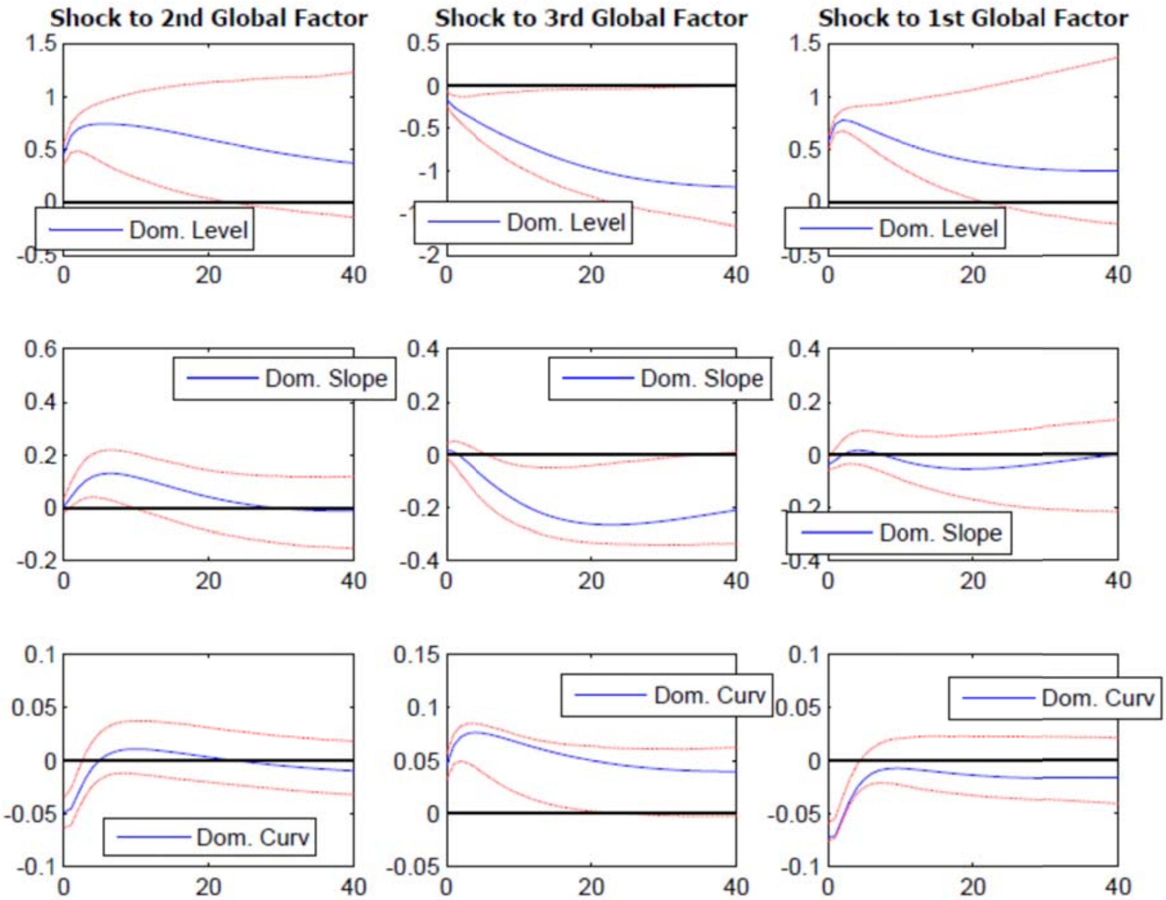
Note: The top panel of this figure plots the third global factor against the standard deviation of one year ahead forecasts of US CPI inflation, whereas the bottom panel plots the third global factor against the financial stress index published by the St. Louis Fed (left panel). All series are standardized.

Figure 5. Global Yield Curve (2007–08)



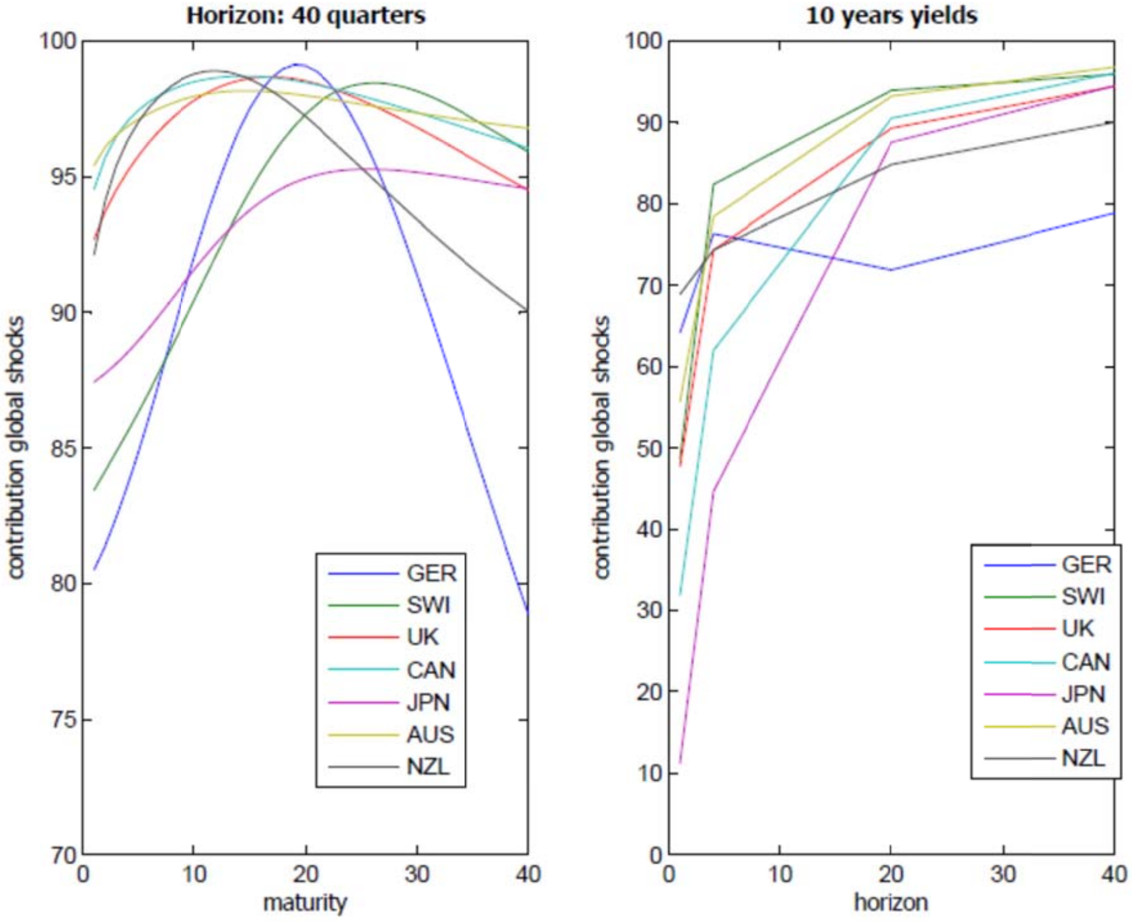
Note: This figure shows the global yield curves during 2007 and 2008. The global yield curve is constructed as the equally-weighted average of the country-yield curves in the sample. Yield maturities are in quarters.

Figure 6. Responses of Local Yield Factors to Global Factors in the UK



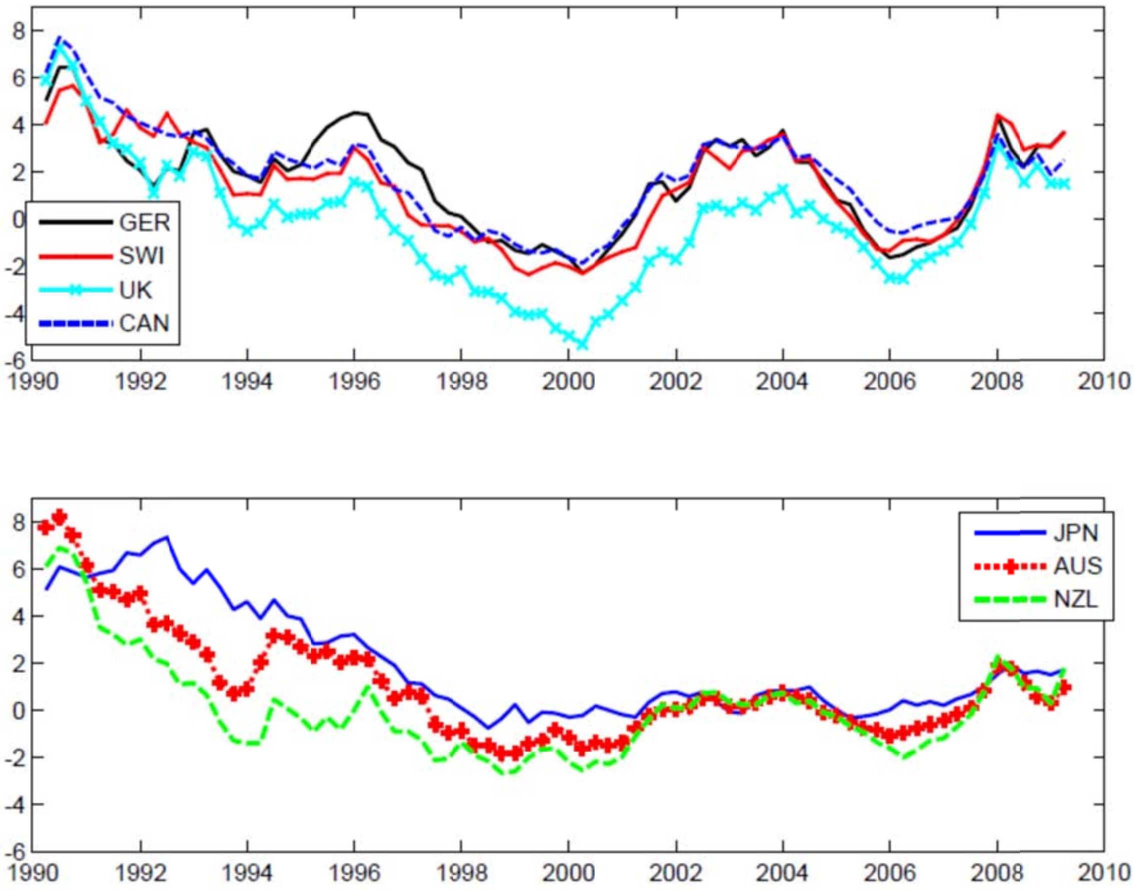
Note: This figure shows the responses of the three local factors (level, slope and curvature) contained in X_{it} to shocks to the three global factors. Impulse responses are plotted for an horizon of 40 periods. Dashed lines represent a +/- 1 standard deviation confidence interval. Results are reported for the UK only.

Figure 7. Contribution of global shocks to the yield curves dynamics



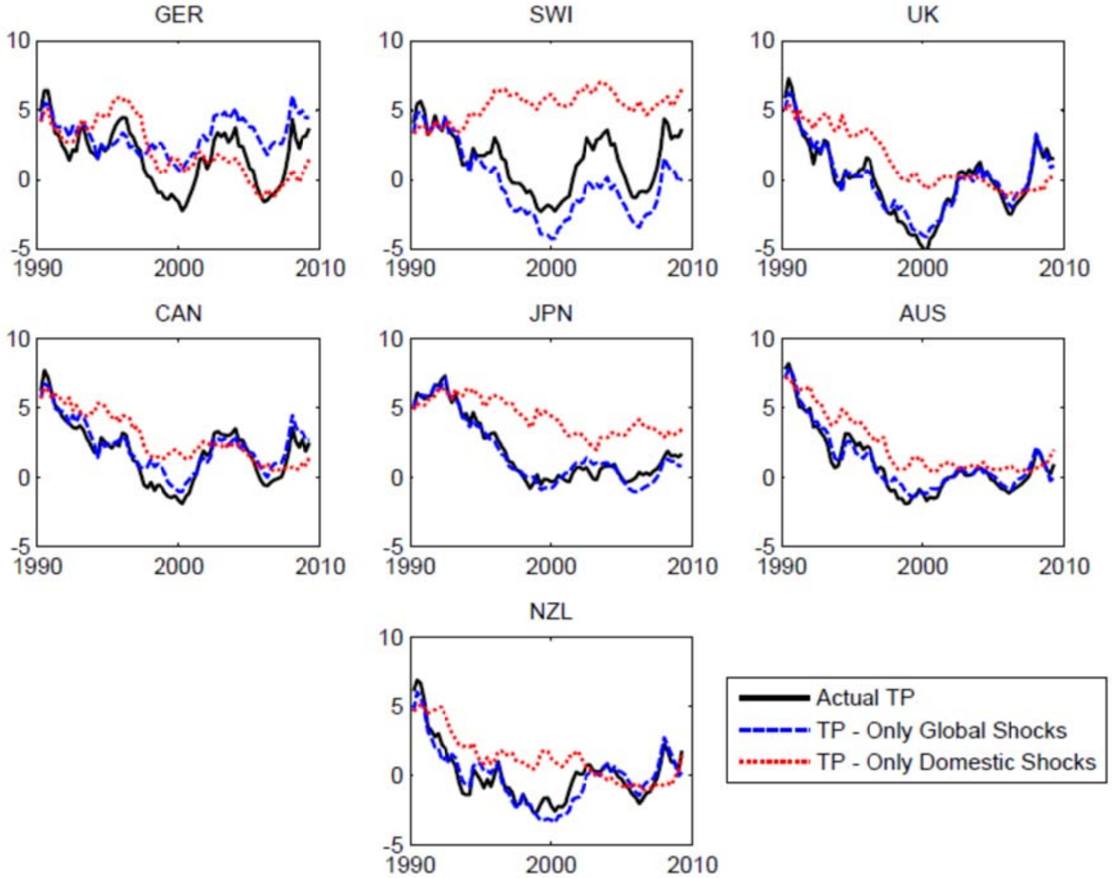
Note: This figure shows the contribution of global shocks to the variance of domestic yields across both maturities (left panel) and forecasting horizon (right panel). Results are shown for all the countries in our sample.

Figure 8. Term Premia Dynamics



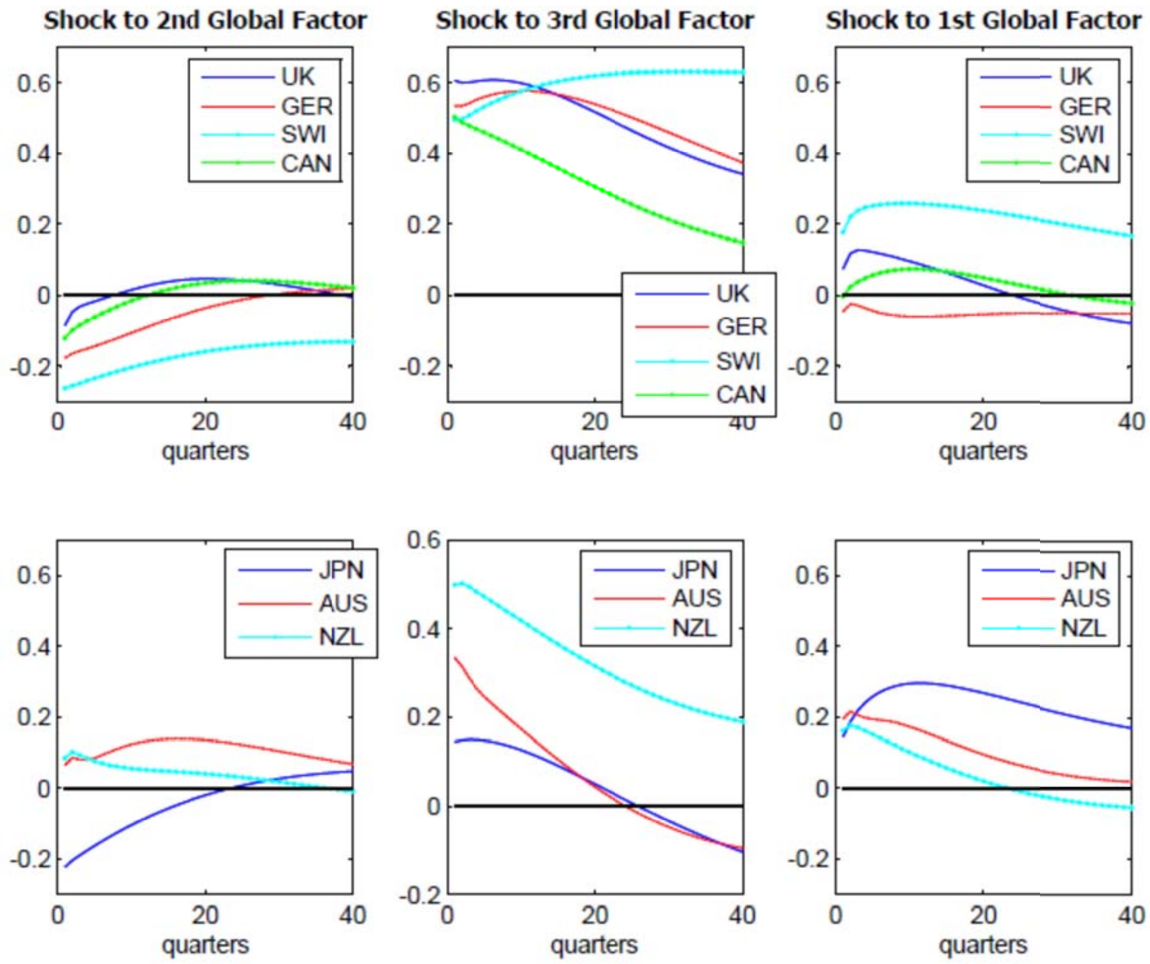
Note: This figure shows the dynamics of the term premia for all of the countries in our sample. Term premia are computed as the difference between the model implied 5-year forward rates 5 years from now and the average expected three-month rate 5 to 10 years from now.

Figure 9. Historical Decomposition: Contribution of Local and Global Shocks to Term Premia Dynamics



Note: This figure shows the dynamics of the estimated term premia plotted together with two counterfactual term premia derived under the assumptions that: (i) the only existing shocks are those to the global factors F_t and (ii) the only existing shocks are those to the local factors X_{it} .

Figure 10. Impulse Responses of the Term Premia to Global Shocks



Note: This figure shows the dynamic responses of the term premia to shocks to the three global factors contained in F_t. Results are reported for all of the countries in the sample and for forecasting horizons of up to 40 quarters.

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