Global Factors in the Term Structure of Interest Rates*

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This paper introduces unspanned global factors within a FAVAR framework in a flexible reduced-form 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 premiums 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 premium dynamics, especially in the post-2007 period.

JEL Codes: C32, E43, F41, G12.

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 that determine the variation over time of the "price of risk"? These questions lie at the heart of many monetary policy discussions

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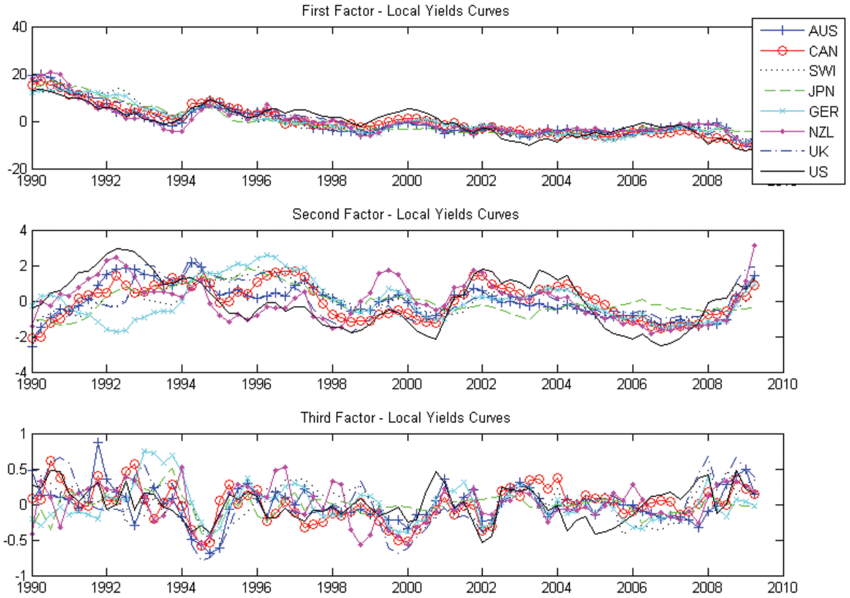
held by policymakers, academics, and bond market participants. Time variation in term premiums can in fact greatly complicate the task of extracting monetary policy expectations from interest rates. Recent empirical studies have undertaken the difficult task of estimating term premiums from the yield 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 macro-finance models which, by replicating the dynamics of the entire yield curves, can provide accurate measures of the time-varying risk premiums on long-term bonds (Wright 2011, Abbritti et al. 2016). As a result, researchers have used them to back out this risk component associated with long-term bond prices (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 affect 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 vector autoregression (FAVAR) similar to Bernanke, Boivin, and Eliasz (2005), Stock and Watson (2005), and Moench (2008).[1] 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

[1]While traditional FAVAR models are often used on a large cross-section of macro variables, we adopt the same estimation technique and apply it to a cross-section of bond yields.

Figure 1. National Yield Curves—First Three Factors



Notes: 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.

the United States. Figure 1 plots the first three principal components across countries using zero-coupon yields for each country (from three-month to ten-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 0.77 to 0.99. 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 premiums in particular. What are they, and how important are these global forces?

Our estimated FAVAR term structure model shows that global factors are the ultimate drivers of both yield-curve and term premium dynamics across countries. Moreover, our global factors have a meaningful economic interpretation. The first global factor is global expected inflation and the second 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 is highly correlated with the international term premiums, especially during the outset of the recent financial crisis. In fact, a shock to the third global factor has a large impact on risk-neutral rates (the expectations component of interest rates) and leads to a substantial and persistent increase in the term premium.

This paper proceeds as follows. In section 2 we discuss how our work relates to the recent literature. In section 3 we present the data and some descriptive evidence in support of the presence of global factors. Section 4 describes the building blocks of our term structure model. Section 5 explains the estimation methodology, and section 6 discusses our main results. Section 7 briefly highlights some robustness checks that we conducted, and section 8 concludes.

2. Literature Review

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 that provided a more structural interpretation of latent yield-curve factors (see Rudebusch and Swanson 2008 and Bekaert, Cho, and Moreno 2010, among others). Common features of these models are a set of restrictions that impose non-arbitrage conditions across all the different assets. In general, they follow a closed-economy framework, and the vast majority of them are 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 United States.

Moreover, he also shows that the model-implied term premiums display strikingly similar patterns across industrialized countries. Similarly, Spencer and Liu (2010) exploit international information to explain term structure dynamics in the United Kingdom, the United States, and Switzerland. Our framework is an international reduced-form affine term structure model without no-arbitrage restrictions. In our setting, the cross-section of yields is spanned by the three local factors. In turn, three unspanned global factors influence yields and term premiums through their impact on both local factors and the expectations of future short rates.

The introduction of global factors in an affine term structure model is also justified by a large and growing body of literature that 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 and Kleopatra 2009, Hellerstein 2011, and Dell'Erba and Sola 2016). For instance, Díez de los Ríos (2011) and Bauer and Díez de los Ríos (2014) assume complete markets and full financial integration and estimate affine term structure models imposing the uncovered interest rate parity under the risk-neutral measure (but not under the physical measure).[2] In their setting only global factors are priced. 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 be priced. Specifically, 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 Diebold, Li, and Yue (2008) and Moench (2008). We borrow from Diebold, Li, and Yue (2008) most of

[2]As shown in the appendix of Bauer and Diez de los Rios (2014), such a restriction naturally arises as a consequence of no-arbitrage pricing, and it has no consequence for the dynamics of the factors under the physical measure.

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 United States 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 the first and second global factors, 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 financial and policy risks and precedes the financial instability of the 2007–09 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 premiums in different countries. As stated by Bernanke (2006), monetary policymakers closely watch term premium dynamics with a view to stimulating or restraining liquidity in the economy. Third, following Bauer, Rudebusch, 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.[3,4]

[3]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 a reduced-form affine model. Additionally, we estimate the factors via principal components, while they obtain latent factors via Kalman-filter estimation.

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

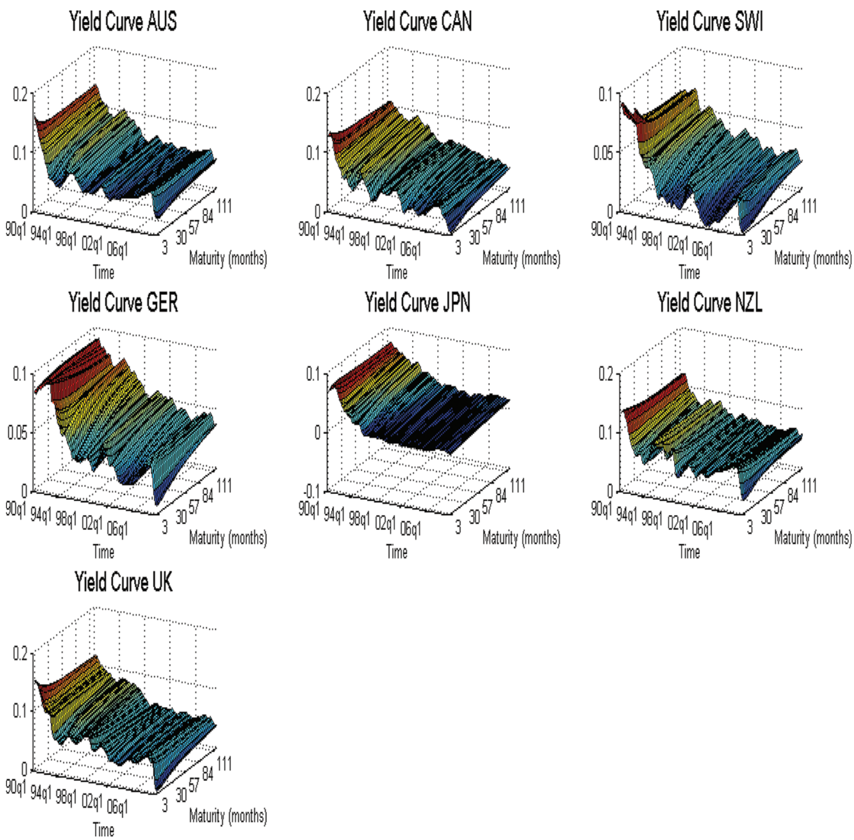
3. Data

We use the data set 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 2009.[5] We do not study the dynamics of the U.S. yields or term premiums, given that it is not a small open economy. However, as explained in the subsection on latent factor estimation, we make use of the U.S. 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 forty 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. While some studies point at the disconnection of Treasury bills (less then one year) from the rest of the yield curve (Duffee 1996), our subsequent results are robust to the exclusion of these yields from the analysis, i.e., including only yields with annual maturities starting at one year.

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.

[5]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.

Figure 2. National Yield Curves



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

4. A Global Term Structure Model

4.1 Affine Model

Our model is a simple discrete-time affine term structure model without no-arbitrage restrictions, as in Pericoli and Taboga (2012). 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, where the short-term rate is given for $n = 1\,(y_{it}^{1})$. In our reduced-form model, the cross-section of zero-coupon yields is a linear function of a vector of latent state variables:

$$y_{it}^{n} = a_i(n) + b_i'(n)X_{it}. \tag{1}$$

Importantly, since the estimation of the prices of risk is not relevant for our results, we do not impose in this paper the no-arbitrage restrictions. This allows us to consistently estimate the factor loadings $a_i(n)$ and $b_i'(n)$ by simple OLS and thus to avoid the computational burden of estimating a fully specified affine term structure model. In fact, in the absence of restrictions in the price of risk, the OLS and no-arbitrage estimates of $a_i(n)$ and $b_i'(n)$ are extremely close and, in consequence, there is no gain from using a term structure model.[6] Pericoli and Taboga (2012) show that the pricing accuracy of a fully specified affine term structure model is only slightly inferior to the one of the reduced-form model, and that the fitted yields almost coincide in the two cases. Moreover, the OLS-based estimation method affords a significant computational advantage, avoids the difficulties caused by local minima and flat surfaces, and is more robust to misspecification of the pricing kernel.

In equation (1), changes in the state variables affect both short-term interest rates and 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, both standardized to have zero means:

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

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

[6]See, e.g., Bauer and Díez de los Rios (2014), figure 1. Díez de los Rios (2015) derives an estimator where the no-arbitrage conditions can be easily tested. We thank an anonymous referee for this point.

VAR (FAVAR) model. The "local" state variables X_{it} and the "global" ones F_t evolve according to

$$X_{it} = \Lambda_i F_t + \Phi_i X_{it-1} + v_{it} \tag{2}$$
$$F_t = \Omega F_{t-1} + \eta_t,$$

where v_{it} and η_t are uncorrelated iid 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 co-movements of country-specific states, X_{it}. 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, Li, and Yue 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 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

$$Y_{it} = \Gamma_i Y_{it-1} + \Psi_i u_t, \tag{3}$$

where $u_{it} = \begin{pmatrix} v_{it} \\ \eta_t \end{pmatrix}$ and the matrices Γ_i and Ψ_i are

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

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 premiums for all the countries in the sample. All in all, our model can be seen as the reduced-form of a Gaussian affine no-arbitrage term structure model. Bauer and Díez de los Rios (2014) find that imposing the no-arbitrage constraints virtually does not change at all the factor loadings on the cross-section of yields.

4.2 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

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

Suppose that we can find matrices B_{i0} and C_{i0} such that $B_{i0}B'_{i0} = \Sigma_{iv}$ and $C_{i0}C'_{i0} = \Sigma_{i\eta}$, with those matrices having structural identification restrictions; then it is true that

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

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

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

where ψ_{it} is a vector of structural iid shocks (including both local and global shocks), with identity covariance matrix. 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:

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

where ε_{it} is a vector of structural iid "local shocks" with identity covariance matrix. Similarly, the impulse responses of the local factors to "global shocks" can be computed from the moving-average representation:

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

with ζ_t representing a vector of structural iid "global shocks" with identity covariance matrix.

5. Estimation Strategy

The estimation of the model is undertaken in several steps (as in Pericoli and Taboga 2012). 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 parameters $a_i(n)$ and $b_i'(n)$ relating the state variables to the cross-section of yields.

5.1 *Estimation of the Latent Factors: Spanned (Local) and Unspanned (Global)*

The literature on affine term structure models often uses principal components analysis (PCA) 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, Bernanke, Boivin, and Eliasz 2005, and Stock and Watson 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 United States (320 series in total):

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

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.[7] As a result, we have six factors in total: three local and three global.

[7] 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 factors (Pérignon, Smith, and Villa 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 paper, we assume that the cross-section of yields is spanned by the local factors—the first three local principal components, which capture most of the cross-section of yields—whereas global factors are "unspanned." Several recent papers (see, e.g., Duffee 2008, Ludvigson and Ng 2009, Bauer and Díez de los Ríos 2014, and 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.

5.2 Estimation of the Remaining Parameters

Following Bernanke, Boivin, and Eliasz (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 and Ψ_i) via standard OLS.[8] Similarly, conditional on consistent estimates of the factors, we also obtain consistent estimates of the parameters $a_i(n)$ and $b_i'(n)$ with a simple OLS regression of the cross-section of yields on X_{it}.

After having estimated these parameters, the model is able to generate the entire structure of the yields. It is therefore possible to

in our context but, due to the dimension of our data set, 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 (2014). The results obtained are very similar to the ones we obtain by PCA.

[8]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.

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 five-year forward rate five years from now and the average expected three-month rate five to ten years from now.

The final parameter estimates are corrected for 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 distorts estimates of long-maturity term premiums. 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.[9]

6. Results

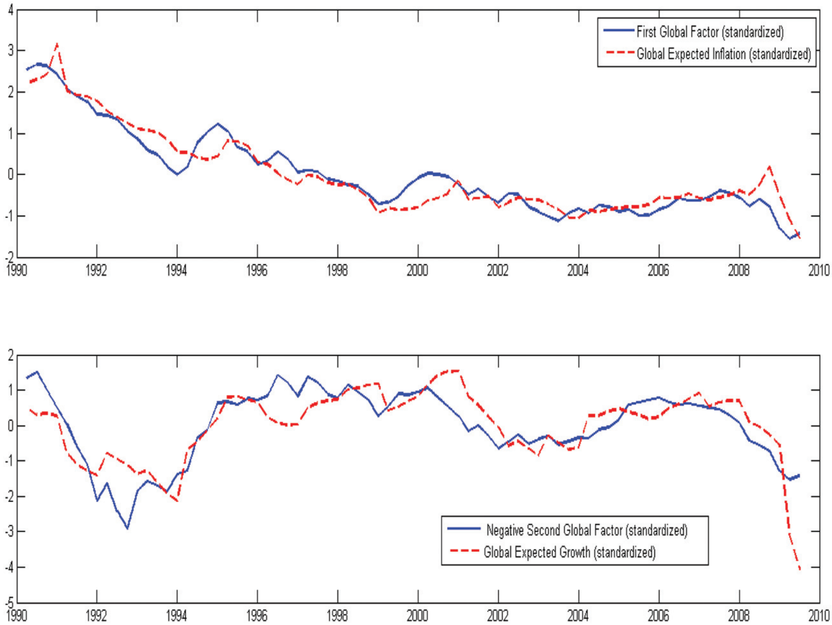
In this section we report the empirical results obtained for our FAVAR term structure model. First we show the three estimated global factors and provide an intuitive macroeconomic explanation for each of them. We then assess the specification of our FAVAR model and evaluate its fit in terms of how well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

6.1 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

[9]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.

Figure 3. First and Second Global Factors Dynamics

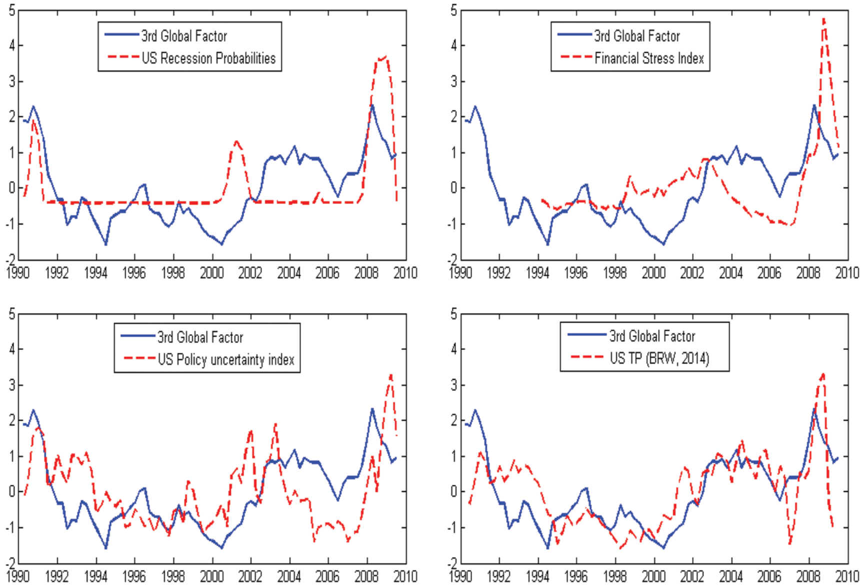


Notes: This figure shows the first two global factors plotted against their macroeconomic interpretations. The first global factor is plotted against the first principal component extracted from a matrix containing data on expected inflation for OECD countries. The negative of the second global factor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

variance of all yields (88.73 percent for the first, 4.42 percent for the second, and 2.98 percent for the third), 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 first global factor closely resembles a "global expected inflation factor" (figure 3), which we

Figure 4. Third Global Factor Dynamics



Notes: This figure plots the third global factor against several macro-finance time series: Top left: U.S. recession probabilities, computed with the method in Chauvet and Piger (2008). Top right: Financial stress index published by the Federal Reserve Bank of St. Louis. Bottom left: U.S. policy uncertainty index computed by Baker, Bloom, and Davis (2016). Bottom right: U.S. term premium, computed by Bauer, Rudebusch, and Wu (2014). All series are standardized.

compute as the first principal component extracted from a matrix containing one-year-ahead CPI inflation forecasts of the countries in our sample.[10] 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 and the negative value of the second global factor is 0.77. That is, an increase in the second global factor is strongly related to a reduction

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

in expected growth. In fact, as shown in the bottom panel of figure 3, the global real activity factor manages to capture the three downward movements displayed by the negative value of the second global factor: These spells occur between 1990 and 1995, between 2000 and 2005, and finally during the Great Recession. For this last period, however, the global real activity factor drops by less.

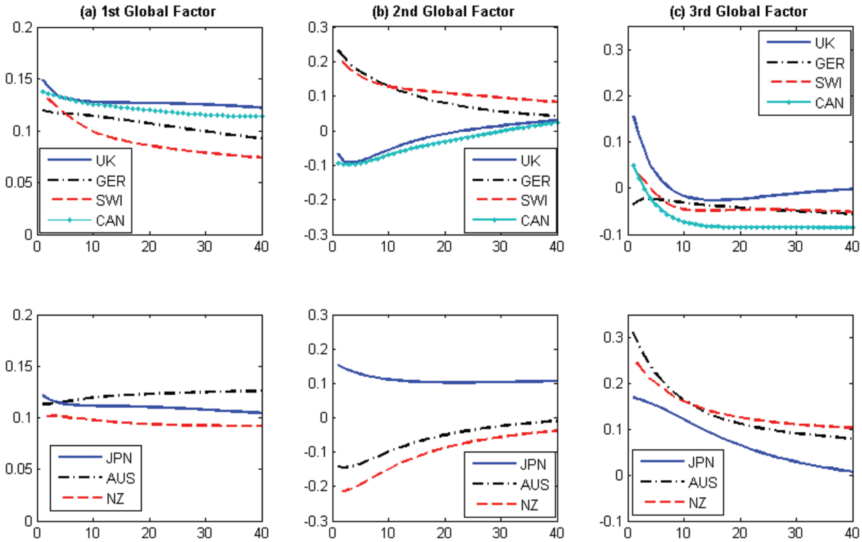
Regarding the third global factor, its correlation with the average of the local curvatures is 0.43. Finding an economic interpretation for the third global factor is, however, a novel task. Figure 4 plots the third global factor together with several related macro-finance series: probability of recession in the United States computed by Chauvet and Piger (2008) (top left), a financial stress index published by the Federal Reserve Bank of St. Louis (top right), the U.S. policy uncertainty index derived by Baker, Bloom, and Davis (2016) (bottom left), and the U.S. term premium computed by Bauer, Rudebusch, and Wu (2014). Overall, the dynamics of the third global factor show a decrease in the first part of the sample (up to 2000) and an increase in the second part, especially around 2007. The graphs show that the peak of the third global factor in 2007 coincides with a sharp increase in both the U.S. recession probability and the policy uncertainty index. It also precedes the peak in the financial stress index and thus anticipates this financial/liquidity risk episode. We later comment on the relation with the U.S. term premium.

As a last piece of interpretation of our global factors, we regress yields on the three global factors to gauge the shape of the implied loadings. As figure 5 shows, the loadings on the first global factor are relatively flat and persistent, resembling a classical global level factor. The loadings on the second global factor differ across countries, exhibiting either increasing or decreasing patterns. Finally, loadings on the third factor are all decreasing and, in most cases, convex. These results are consistent with those in Bauer and Díez de los Rios (2014). While not reported, we also find that a fourth global factor emerges as a global slope factor. Subsequent results in this paper are robust to the inclusion of a fourth global factor in our analysis.

6.2 Model Performance

While there are many sound economic arguments to support the idea that global factors influence domestic term structures, it needs

Figure 5. Loadings of Yields on Global Factors



Note: This figure plots the factor loadings of regression of all yields on the three estimated global factors.

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.

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.

Table 1. Block Exogeneity Test

Likelihood-Ratio Test		
Country	**Stat.**	**p-value**
JPN	40.11	0.00
UK	106.81	0.00
GER	128.17	0.00
SWI	96.06	0.00
CAN	74.20	0.00
AUS	95.26	0.00
NZL	153.67	0.00

Notes: 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.

To evaluate the fit of the model, table 2 shows the root mean square fitting error of yields, i.e., $\left(\sqrt{\frac{1}{T\times N}\sum_t\sum_n (y_{it}^n - \tilde{y}_{it}^n)^2}\right)$. The fit of the model is excellent. The typical fitting errors range between 1.4 and 4.2 basis points, with New Zealand, Germany, and Japan exhibiting the best fit.

6.3 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. First, we analyze the impulse responses of domestic factors to global shocks. Then, we compute the variance decomposition of the three local factors included in the vector X_{it}.

Table 2. Model Fit

Fit of Affine Term Structure Model	
Country	**RMSE**
JPN	0.0180
UK	0.0417
GER	0.0199
SWI	0.0316
CAN	0.0352
AUS	0.0278
NZL	0.0143

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.

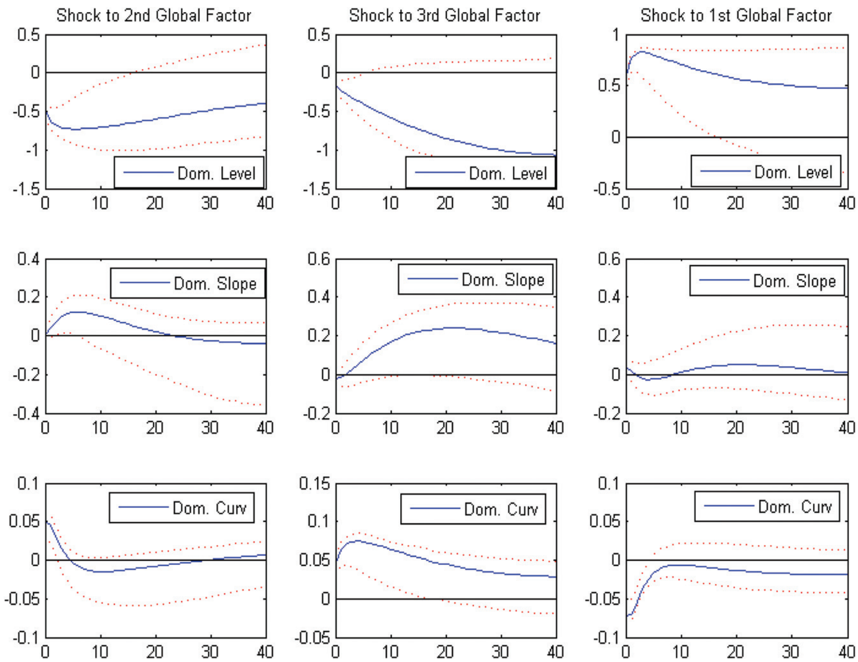
To perform these exercises, global shocks are identified with a simple Cholesky decomposition. Using the macroeconomic interpretation of the global factors, we order the second global factor, capturing global real activity, as first, the third global factor as second, and the global expected inflation factor last. Notice, however, that alternative factor orderings do not affect our results.

Figure 6 shows the dynamic response of local yield factors to global forces in the case of the United Kingdom.[11] The unreported results for other countries give a similar picture.[12] Global factors have a sizable and persistent effect on domestic factors. A positive innovation to the second global factor has a negative effect on the domestic level and a positive effect on the slope factor. This is 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 causes an increase in domestic curvature and slope and a reduction in the domestic level factor. This increase in domestic curvature is common across all countries. Notice that the effect of this shock is small on impact

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

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

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



Notes: 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 a horizon of forty periods. Dotted lines represent a $+/-1$ standard deviation confidence interval. Results are reported for the United Kingdom only.

but more persistent, as it remains different from zero for more than twenty quarters. Finally, a shock to the first global factor causes an increase in the countries' level factor (i.e., the countries' inflation risk factor), while it has a small and heterogeneous effect on countries' slope and curvature factors.

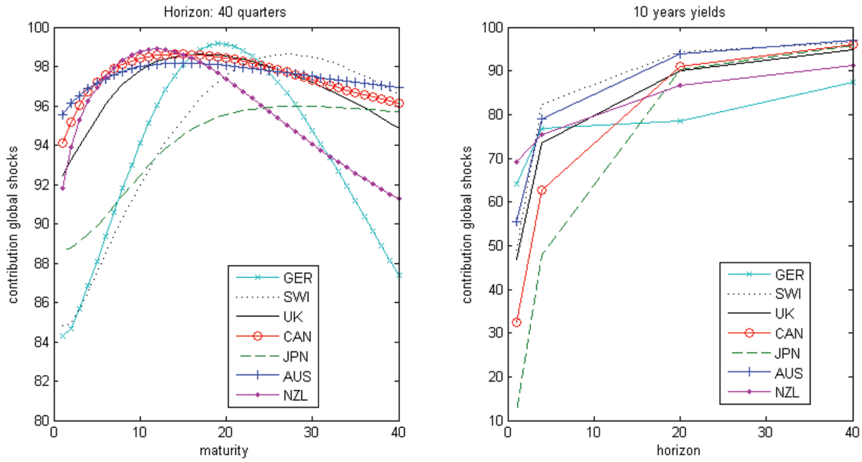
Table 3 shows the contribution of global shocks to the variance of the local factors at two forecasting horizons: one quarter and forty quarters. At short horizons, country-specific shocks explain most of the variance of the three local factors, but global factors are far from unimportant. Global factors explain, on average, 54 percent of the

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	$h = 1$	4.32	0.23	10.75	15.30	0.94	0.55	0.91	2.40	1.75	0.01	4.64	6.40
	$h = 40$	47.70	23.31	24.49	95.50	17.67	9.53	50.17	77.38	7.43	33.48	13.96	54.88
CAN	$h = 1$	17.51	7.38	20.20	45.08	2.29	0.16	1.59	4.05	9.43	6.88	8.09	24.40
	$h = 40$	20.88	54.79	22.89	98.56	16.68	24.43	9.87	50.97	8.75	49.05	6.35	64.15
SWI	$h = 1$	0.23	8.49	44.00	52.71	0.36	0.38	5.67	6.41	0.04	3.20	3.44	6.69
	$h = 40$	18.33	48.78	30.30	97.41	5.36	21.87	32.04	59.27	0.65	52.05	1.92	54.63
GER	$h = 1$	4.00	8.84	56.25	69.09	0.04	0.12	2.46	2.62	0.70	4.18	27.81	32.69
	$h = 40$	18.09	41.75	39.47	99.31	3.25	23.59	3.58	30.42	8.91	34.50	18.77	62.18
AUS	$h = 1$	32.25	3.23	32.56	68.03	3.22	1.89	0.28	5.39	23.94	1.75	22.67	48.35
	$h = 40$	35.94	36.57	25.82	98.34	29.59	6.23	22.00	57.82	21.64	22.05	18.72	62.41
NZL	$h = 1$	51.86	5.44	24.71	82.01	0.00	0.16	0.41	0.58	5.85	0.10	1.97	7.93
	$h = 40$	45.50	33.63	19.20	98.33	11.24	37.77	3.81	52.82	7.94	7.11	2.22	17.27
UK	$h = 1$	18.22	2.04	28.30	48.57	0.00	0.27	0.83	1.10	10.03	8.30	21.55	39.87
	$h = 40$	25.16	46.66	26.93	98.75	5.85	52.25	1.64	59.74	5.29	65.51	14.80	85.59
Avg.	$h = 1$	18.34	5.09	30.97	54.40	0.98	0.51	1.73	3.22	7.39	3.49	12.88	23.76
	$h = 40$	30.23	40.78	27.01	98.03	12.81	25.10	17.59	55.49	8.66	37.68	10.96	57.30

Notes: This table shows the contribution of shocks to the three global factors (GFs), 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 one and forty periods.

Figure 7. Contribution of Global Shocks to the Yield-Curve Dynamics



Notes: 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.

local level, 24 percent of the local curvature, but only 3 percent of the local slope. The importance of global factors rapidly increases with the horizon. For most of the countries, the level of interest rates is explained—at a ten-year horizon—almost entirely by the global factors. The proportion of explained variance for the level factor in fact ranges between 95.5 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 sizable 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 (right graph). At a forty-quarter 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 ten and twenty-five quarters, depending on the country. Regarding the effect of the forecasting horizon considered, we find that on impact ($h =$ one quarter) domestic shocks explain, in most countries, most of the ten-year yield. Already after four quarters, however, global shocks dominate the variance decomposition of the ten-year yield, showing 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. At long forecast horizons, the second and third global factors are found to explain together more than 70 percent of the three-month rate, while the first global factor only accounts for 12 percent of the forecasting variance of the short rate. For longer-term yields (ten years), the importance of the first global factor increases, while the relevance of the other two factors is reduced.

Overall, these results point towards a crucial importance of global factors in explaining domestic yield curves. Diebold, Li, and Yue (2008) showed the importance of two global yield factors related to global inflation and economic activity. Our results suggest that a third global factor also needs to be taken into account. We now show that this factor is also key in explaining term premium dynamics.

6.4 Term Premium 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 premiums. Term premiums 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 premiums could reflect nominal and real risks, such as inflation (Gürkaynak, Sack, and Swanson 2005) and unemployment (Gil-Alana and Moreno 2012), or potentially other macroeconomic and financial risks, such as policy risk (Bernanke, Reinhart, and Sack 2004).

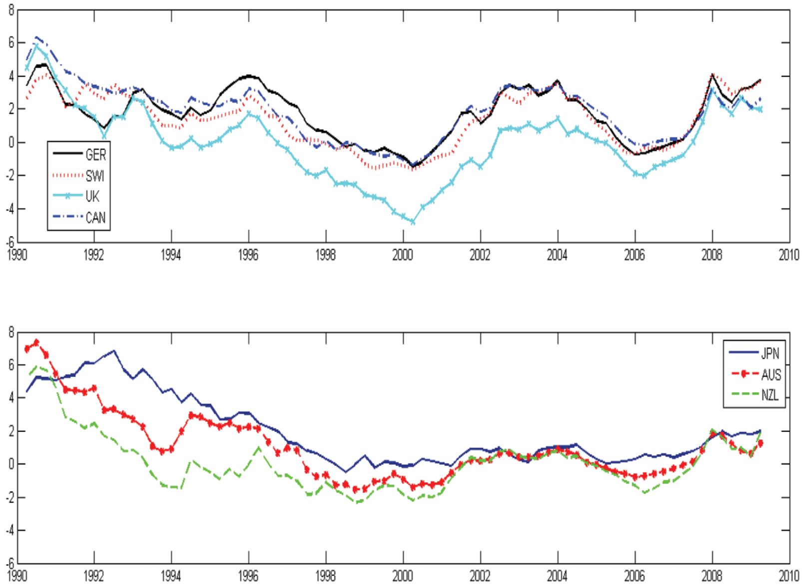
We therefore use our FAVAR model to estimate time-varying term premiums. Following Wright (2011), we compute them as the difference between the model-implied five-to-five-year forward rate and the average expected three-month rates five to ten years hence. Figure 8 shows the implied term premium of our FAVAR term

Table 4. Variance Decomposition—Yields

		Three-Month Yields					Ten-Year Yields				
Country	**Horizon**	**GF2**	**GF3**	**GF1**	**Global**	**Local**	**GF2**	**GF3**	**GF1**	**Global**	**Local**
JPN	$h = 1$	7.10	1.33	7.11	15.54	84.46	2.19	0.06	9.83	12.09	87.91
	$h = 40$	71.09	11.53	6.01	88.63	11.37	26.38	25.92	43.40	95.70	4.30
CAN	$h = 1$	8.33	1.60	9.59	19.51	80.49	11.77	5.52	15.17	32.46	67.54
	$h = 40$	23.65	54.97	15.49	94.11	5.89	19.77	47.54	28.81	96.12	3.88
SWI	$h = 1$	0.79	3.09	20.20	24.08	75.92	0.06	6.56	42.37	48.98	51.02
	$h = 40$	22.63	55.35	6.84	84.82	15.18	12.34	24.33	59.88	96.55	3.45
GER	$h = 1$	2.77	2.61	12.76	18.14	81.86	3.07	7.71	53.37	64.16	35.84
	$h = 40$	13.66	47.62	23.04	84.32	15.68	19.28	27.74	40.35	87.37	12.63
AUS	$h = 1$	26.27	5.11	19.53	50.92	49.08	25.00	2.03	28.56	55.59	44.41
	$h = 40$	49.34	30.58	15.62	95.54	4.46	30.46	36.37	30.12	96.95	3.05
NZL	$h = 1$	18.38	1.83	7.24	27.44	72.56	41.75	5.24	22.24	69.23	30.77
	$h = 40$	40.58	44.49	6.73	91.79	8.21	42.02	22.02	27.21	91.25	8.75
UK	$h = 1$	5.93	0.25	3.74	9.92	90.08	16.42	1.59	28.92	46.94	53.06
	$h = 40$	23.57	56.94	11.97	92.48	7.52	29.55	28.54	36.79	94.88	5.12
Avg.	$h = 1$	9.94	2.26	11.45	23.65	76.35	14.32	4.10	28.64	47.06	52.94
	$h = 40$	34.93	43.07	12.24	90.24	9.76	25.68	30.35	38.08	94.12	5.88

Notes: 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 three-month and ten-year yields. Results are reported for all countries in the sample and for selected horizons of one and forty periods.

Figure 8. Term Premium Dynamics



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

structure across countries. To ease visualization, we divide the countries into two groups: the Pacific countries (Japan, Australia, and New Zealand) and the Western countries (the United Kingdom, Germany, Switzerland, and Canada).

In all countries, the term premium has declined from the beginning of the 1990s 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 premiums in Western economies is consistently more volatile than in the Pacific countries.

Notice that the dynamics of the term premiums 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, Sunderam, and Viceira (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 episodes. 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 premiums have been associated with 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 premiums. 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 premium dynamics are due to developments in the domestic economies or to global developments, because the implications for policymakers may be strikingly different. This is a task that we perform in the following section.

6.5 Global Factors and Term Premium Dynamics

To understand the importance of global forces for term premium dynamics, table 5 reports the variance decompositions in term premium dynamics. The contribution of global factors to term premium variations ranges between 70 percent in the case of Germany and 92 percent in the case of the United Kingdom. The third global factor is, on average, the most important in explaining term premium variation, as it explains around 62 percent of the total variance at the forty-quarter 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

Table 5. Variance Decomposition—Term Premiums

	Term Premiums ($h = 40$)				
Country	**GF2**	**GF3**	**GF1**	**Global**	**Local**
JPN	10.43	9.63	69.20	89.27	10.73
CAN	3.47	79.08	2.37	84.91	15.09
SWI	5.02	73.16	8.57	86.75	13.25
GER	2.36	66.70	1.22	70.29	29.71
AUS	24.18	32.90	30.84	87.92	12.08
NZL	3.19	82.61	4.04	89.84	10.16
UK	1.37	89.68	0.94	91.99	8.01
Avg.	7.15	61.96	16.74	85.85	14.15

Notes: 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 premiums. Results are reported for all countries in the sample and for the forty-periods-ahead horizon.

forecasting power for future monetary policy and the expected path of the short-term yields. 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 premium dynamics, figure 9 shows the impulse responses of the term premium for all countries to each of the three global shocks. As in section 6.3, global shocks are identified with a simple Cholesky decomposition, ordering the global activity factor as first, the third global factor as second, and the global expected inflation factor as third.

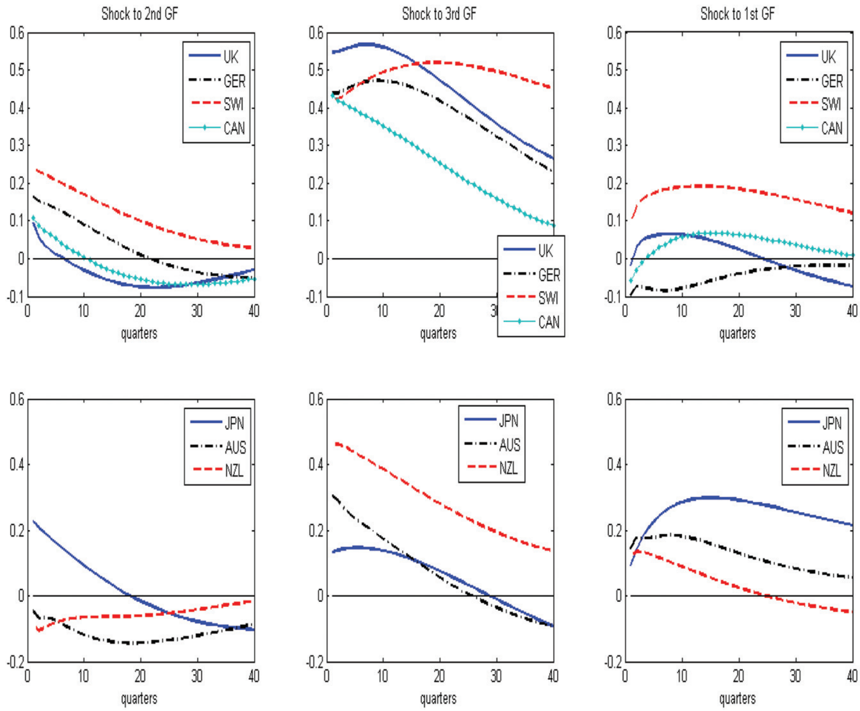
A positive shock to the second global factor induces in most countries an increase in the term premium. This positive correlation between shocks to the second global factor and movements in the term premium is consistent with Rudebusch, Sack, and Swanson (2006), which shows that a decline in the term premium predicts future growth. In our setting, we show that this is due to the second global factor, which is negatively associated with global growth. An increase in this factor induces both an increase in term premiums and a decline in future growth. The only exceptions are Australia and New Zealand, where the transmission mechanism is negative, due to

Table 6. Variance Decomposition—Forward and Risk-Neutral Rates

	Forward Rates (h = 40)					Risk-Neutral Rates (h = 40)				
Country	**GF2**	**GF3**	**GF1**	**Global**	**Local**	**GF2**	**GF3**	**GF1**	**Global**	**Local**
JPN	12.11	23.62	57.08	92.82	7.18	32.12	59.74	5.43	97.29	2.71
CAN	18.44	36.45	34.76	89.65	10.35	5.92	82.92	11.12	99.97	0.03
SWI	3.96	1.95	75.20	81.10	18.90	7.91	87.59	0.28	95.77	4.23
GER	14.35	9.11	25.23	48.68	51.32	5.36	79.95	11.22	96.53	3.47
AUS	26.66	34.83	33.01	94.49	5.51	6.79	85.26	7.95	99.99	0.01
NZL	34.34	12.67	32.20	79.22	20.78	4.80	87.66	7.54	99.99	0.01
UK	31.19	10.25	41.22	82.66	17.34	4.94	84.64	10.36	99.94	0.06
Avg.	20.15	18.41	42.67	81.23	18.77	9.69	81.11	7.70	98.50	1.50

Notes: 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 forty-periods-ahead horizon.

Figure 9. Impulse Responses of the Term Premiums to Global Shocks



Notes: This figure shows the dynamic responses of the term premiums 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 forty quarters.

a reduction in the forward rate larger than the policy channel, which induces a small reduction in the term premium.[13]

A positive shock to the first global factor—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

[13] As in Jotikasthira, Le, and Lundblad (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 9 shows only the response of the term premium to global factors, but the whole set of results is available upon request.

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 credibility of its monetary policy stance. In the other countries, the policy channel response is relatively more muted on impact, compared with Germany, although it increases over time, leading then to a subsequent reduction in term premiums over the longer horizon.

Finally, a positive shock to the third global factor produces an increase in term premiums across all countries. The effect is relatively large, especially in Western countries, and quite persistent, as it usually lasts more than thirty quarters. Interestingly, these results are consistent with the bottom-right panel of figure 4, which plots the third global factor against the U.S. term premium implied by the model in Bauer, Rudebusch, and Wu (2014). It reveals that the third global factor captures the dynamics of the term premium very closely. This is especially the case at the end of the sample, coinciding with the onset of the financial crisis. In the next section we further explore the role of the third global factor during this latter subperiod.

7. Robustness Checks

We test the robustness of our results with three 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, 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 premiums. However, bias correction affects the

Table 7. Variance Decomposition—Risk Premium—Robustness to Bias Correction

	Horizon = 40							
	GF2		GF3		GF1		Global Shocks	
Country	**OLS**	**BC**	**OLS**	**BC**	**OLS**	**BC**	**OLS**	**BC**
JPN	6.98	10.43	8.75	9.63	68.93	69.20	84.66	89.27
CAN	12.12	3.47	17.39	79.08	34.97	2.37	64.48	84.91
SWI	9.67	5.02	42.34	73.16	21.42	8.57	73.43	86.75
GER	5.09	2.36	40.23	66.70	2.40	1.22	47.73	70.29
AUS	25.92	24.18	17.61	32.90	41.42	30.84	84.96	87.92
NZL	15.24	3.19	37.00	82.61	17.13	4.04	69.36	89.84
UK	5.57	1.37	48.58	89.68	17.09	0.94	71.24	91.99
Avg.	11.51	7.15	30.27	61.96	29.05	16.74	70.84	85.85

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

relative contribution of the three shocks. Under OLS, the contribution to the total variance attributed to the first global factor almost doubles, from 17 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, 2014) and Abbritti et al. (2016), who show that taking the term structure persistence correctly into account reduces the importance of expected inflation for term premium dynamics, while it increases the importance of real shocks.

Second, in order to assess the impact of the Great Recession on the estimation, we reestimate the model for the 1990:Q1–2007:Q1 period. The average contribution of global factors to term premium dynamics is only slightly reduced, from 86 to 82 percent. In the shorter sample, the relative importance of the first global factor increases, explaining on average 45 percent of the variance of the term premiums, while the third global factor only accounts for

Table 8. Variance Decomposition—Term Premiums—Subsample 1990:Q1–2007:Q1

Country	Term Premiums (h = 40)				
	GF2	**GF3**	**GF1**	**Global**	**Local**
JPN	12.53	34.06	49.64	96.22	3.78
CAN	30.45	4.78	49.51	84.74	15.26
SWI	4.29	0.54	71.84	76.67	23.33
GER	17.73	14.91	5.36	38.00	62.00
AUS	39.52	12.86	44.70	97.07	2.93
NZL	38.17	1.60	53.40	93.17	6.83
UK	22.52	23.24	40.83	86.59	13.41
Avg.	23.60	13.14	45.04	81.78	18.22

Notes: 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 premiums when the model is estimated for the period 1990:Q1–2007:Q1 only. Results are reported for all countries in the sample and for the forty-periods-ahead horizon.

13 percent of the total variance (table 8). This exercise confirms previous papers that attribute the decline of term premiums 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.

Third, we treat the U.S. factors as the global ones. This is justified by the relevance of the United States in the global economy as well as the importance of U.S. monetary policy in global financial markets (see, for instance, Jotikashtira, Le, and Lundblad 2015). In table 9 we show the variance decomposition of the term premiums across countries. We find that global factors are still key to explain term premium variations (around 90 percent) and that the third global factor, the U.S. curvature factor, is still the most important, explaining around 57 percent of the total variance. Nevertheless, with respect to the baseline model, it loses explanatory power in favor of the U.S. cycle factor.

Table 9. Variance Decomposition—Term Premiums—United States as Global Factor

Country	Term Premiums (h = 40)				
	GF2	**GF3**	**GF1**	**Global**	**Local**
JPN	37.70	41.61	10.67	89.98	10.02
CAN	24.49	71.12	2.83	98.44	1.56
SWI	36.33	56.34	3.40	96.07	3.93
GER	5.25	53.89	3.44	62.58	37.42
AUS	34.41	31.01	28.71	94.13	5.87
NZL	25.91	68.31	2.00	96.22	3.78
UK	11.85	77.84	3.08	92.77	7.23
Avg.	25.13	57.16	7.73	90.03	9.97

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 premiums when the global factors are replaced with the first three principal components of the U.S. yield curve. Results are reported for all countries in the sample and for the forty-periods-ahead horizon.

8. 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 reduced-form linear framework to account for systematic international linkages among term structures.

Our results show that global factors explain an important share of fluctuations in the term premiums 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 premium 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 factor capturing the dynamics of global term premiums, which is filtered as the third principal component of the international yield curves. Interestingly, this factor takes center stage 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.

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