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DELOVNI ZVEZKI BANKE SLOVENIJE/
BANK OF SLOVENIA WORKING PAPERS:

A CHINESE SLOWDOWN AND THE US AND GERMAN YIELD CURVES

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6/2020

Title/*Naslov*: A Chinese slowdown and the US and German yield curves

No./*Številka*: 6/2020

Published by/*Izdajatelj*: BANKA SLOVENIJE
Slovenska 35
1505 Ljubljana
tel.: 01/+386 1 47 19 000
http://www.bsi.si

Kataložni zapis o publikaciji (CIP) pripravili v Narodni in univerzitetni knjižnici v Ljubljani
COBISS.SI-ID=305104384
ISBN 978-961-6960-40-3 (pdf)

A Chinese slowdown and the US and German yield curves

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This version: 16th of April 2020

Abstract

To measure the global spillovers of a Chinese slowdown on the 5y nominal interest rates in the US/Germany, I model the US/German yield curves jointly in the post financial crisis sample, including the Chinese leading indicator as a new factor. I use an affine term structure model and decompose changes in the 5y nominal interest rates into (1) changes in the 5y expected future nominal short rate, and (2) the 5y term premium. A drop in the Chinese leading indicator decreased the 5y Treasury yield and the compensation for bearing the duration risk (the 5y Treasury term premium). In Germany, the lower Chinese leading indicator moderately increased the 5y Bund yield by increasing the term premium attached to the 5y German Bunds. However, as such increases of the term premium could be driven by recessions I re-estimate a single country affine term structure model for Germany in the post sovereign debt crisis sample. Like in the US, I now find that in Germany, a lower Chinese leading indicator decreased the 5y Bund yield and its term premium.

Krivulji donosnosti v ZDA in Nemčiji ter upočasnitev gospodarske rasti na Kitajskem

Povzetek

Za merjenje vpliva upočasnitve gospodarske rasti na Kitajskem na petletne nominalne obrestne mere v ZDA in Nemčiji ocenim model ameriške in nemške krivulje donosnosti na vzorcu po finančni krizi. Pri tem vključim kot nov dejavnik v model, ki vključuje obe krivulji, kazalnik prihodnje rasti na Kitajskem. Z modelom afinitetne strukture obrestnih mer razčlenim spremembe v petletnih nominalnih obrestnih merah v ZDA in Nemčiji v (1) spremembo glede pričakovane prihodnje kratkoročne obrestne mere v naslednjih petih letih in (2) petletno terminsko premijo. Padec kazalnika prihodnje rasti na Kitajskem zmanjša donosnost petletne ameriške obveznice skozi nižjo terminsko premijo. V Nemčiji, sprva, nižji kazalnik prihodnje rasti na Kitajskem zmerno poveča donosnost petletne nemške obveznice in sicer tako, da poveča terminsko premijo. Povečanje slednje je lahko tudi posledica dolžniške krize v evrskem območju po finančni krizi. Zato ponovno ocenim model nemške krivulje donosnosti po dolžniški krizi. Tako kot v ZDA, sta sedaj tudi v Nemčiji, donosnost petletne nemške obveznice in njena terminska premija ob nižjem kazalniku prihodnje rasti na Kitajskem nižji.

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1. Introduction

The last decades have witnessed tremendous growth of the Chinese economy. In 2017, China accounted for 15 percent of global GDP, compared to only 3 percent in 1999. While the growth of the Chinese economy continues to outshine that of its global peers, the growth has dropped from double digits before the crisis to 7–8 percent after the crisis.

Existing work has investigated the impact of (changes in) Chinese growth on, amongst others, the global/US/EU growth and inflation dynamics, unequivocally finding the effects to be large[2,3]. To the best of my knowledge, this paper is the first to quantify the effects of a Chinese slowdown on the US and German yield curves. This is my main contribution.

I hypothesize that a Chinese slowdown can affect the US/German yield curves through two channels, in several (possibly opposing) ways.

First, changes in Chinese growth may affect the future expectations of fundamental drivers of the US/German yield curve, such as inflation and real growth rates in these respective countries. Gauvin and Rebillard (2015) and Metelli and Natoli (2017), for instance, show that a Chinese slowdown has substantial negative effects on the US and euro area (EA) growth and inflation rates[4]. The resulting drop in expected real short-term interest rates and inflation leads to a drop in expectations about future nominal short rates. Following Bauer and Rudebusch (2014), I call the future expected nominal short rate the "signaling channel."

Second, changes in Chinese growth may affect the US and German term premia attached to the nominal bonds. The lower Chinese growth could lower the expectations of the nominal interest rates by decreasing the compensation for bearing the duration risk (the term premium) through lower growth and inflation *risks*. First, deterioration of the economic outlook of the Chinese economy, and its consequences for the outlook of the global economy could imply that at the effective lower bound the Central banks will have to hold rates lower for longer. In such an environment, nominal bonds

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[2] Cashin, Mohaddes and Raissi (2017) find that a percentage decrease of the Chinese growth lowers the global growth by 23 basis points, while a surge in global financial market volatility decreases the global growth by 29 basis points.

[3] ECB (2017) estimates that if the Chinese GDP growth decreases by 3 percentage points cumulatively over three years commodity prices decrease by 6 percent over three years.

[4] Metelli and Natoli (2017) estimate that, without taking into account the Central Bank's responses, a negative shock to Chinese investments, and corresponding reduction in annual output growth equal to 2 percentage points over two consecutive years, decrease the US and EA inflation by 10 basis points in the first, and by 40 basis points in the second year. The shock decreases EA GDP by 30 basis points in the first year and by 20 basis points in the second year. US GDP decreases by 20 basis points in the first year and reverts back to 0 in the second.

hedge against the risk of lower growth while other instruments such as risky stocks do not. Second, lower Chinese growth could increase the risks of lower inflation through, i.e., Chinese lower demand for commodities[5]. The lower inflation increases the real value of fixed dollar payments that bondholders receive. To hedge against the risks of low growth and inflation investors are willing to accept low or even negative compensation for holding nominal bonds rather than short-term securities.

Albeit less likely, the lower Chinese growth could increase the risk premium attached to nominal bonds by increasing the uncertainty about the near-term outlook for the global economy or monetary policy. Such increases, however, are usually associated with recessions. In the euro area, the 5y Bund term premium increased during the sovereign debt crisis. In the US, the 5y Treasury term premium temporarily increased during “the taper tantrum” episode in 2013. Additionally, extremely low Chinese growth could be related to higher risk aversion (U-shaped pricing kernels) and could alter the term premium in a non-linear fashion. Baele et al. (2018) find that the model which accounts for the probability weighting (and loss aversion), namely that the investors attach higher probabilities to extreme events (disasters) explains the equity and the variance premia. Since for a global bond investor turmoil in China could represent a catastrophic event, she could correspondingly overweight such an event and given her loss aversion attach bigger term premium when Chinese growth decreases by a significant amount (i.e. more than 5 percent per year).

Figure 1 shows the development of the 5y Treasury and Bund yields, and of the Chinese leading indicator, in the post financial crisis sample. Actual 5y Bund yield decreased from 2.5 percent in 2009 to –18 basis points in 2017. After the sovereign debt crisis, the ECB initiated the QE programmes which depressed the 5y Bund yield. In 2013, the FED chairman Ben Bernanke signaled a decrease of the QE programmes (“the taper tantrum”). In December 2015, the FED began the hiking cycle. From December 2011 to December 2017 the actual 5y Bund yield decreased from 87 to –18 basis points while the actual 5y Treasury yield increased from 87 to 217 basis points.

[5] Gauvin and Rebillard (2015) notice that in 2011 China accounted for 11 percent of global oil, 41 percent of global copper, and 54 percent of global iron ore consumption.

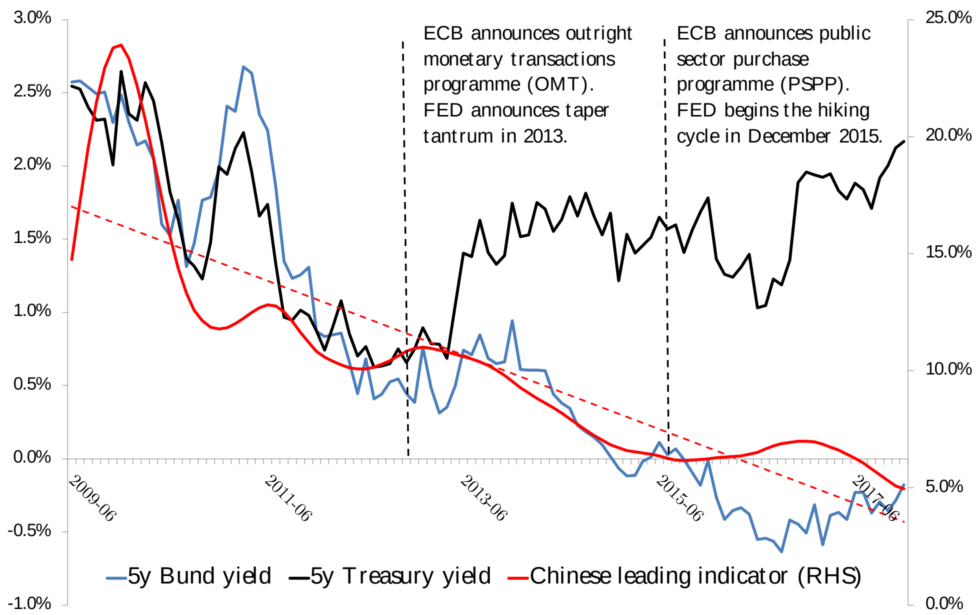

Figure 1: Chinese composite leading indicator (CLI) with trend-restored in twelve-month log differences and the actual 5-year Treasury and Bund yields. The dotted red line depicts a linear trend of the Chinese leading indicator after the crisis. Sample spans from June 2009 to December 2017. Source: BUBA, FED, and the OECD.

My main contribution is to measure the global spillovers of a Chinese slowdown on the US and German 5y nominal yields, the 5y risk-neutral yields, and the 5y term premia. I measure the slowdown with the difference between the GDP growth rates of the domestic economies (the US and Germany) and China. Empirically, I represent the growth rates at a monthly frequency with the leading indicators. To quantify the spillovers of a Chinese slowdown on the US/German 5y yields through the future 5y expected short rates and the 5y term premia, as well as to disentangle both channels, I proceed as follows.

I estimate the joint affine term structure model of the US and German yield curves with the unspanned macroeconomic variables in the post financial crisis sample. With an affine term structure model, I decompose the 5y nominal yields in (1) the expected future 5y nominal short rates, "the signaling channel," and (2) the estimated 5y term premia, "the portfolio balance channel." The alternative name for the first component, the expected future 5y nominal short rate, is the 5y risk-neutral yield. In the model I include, the six principal components extracted jointly from the US and German yield curves and the macroeconomic variables. For *each economy*, the vector-autoregression includes the six principal components, the unemployment rate, core inflation rate, the leading indicator, and the Chinese leading indicator.

In the affine term structure model with the unspanned macroeconomic variables, the macroeconomic variable such as the Chinese leading indicator affects the bond prices only indirectly through the principal components with a lag. In each economy, the US and Germany, I run a vector autoregression of the principal components and the macroeconomic variables. I increase the principal components by the significant estimated coefficients I find on the Chinese leading indicator. I interpret the changes in the means of the in-sample model implied 5y yields, the 5y risk-neutral yields, and the 5y term premia before and after the increase as the average effects of the Chinese leading indicator. These effects are measuring the economic importance of the Chinese leading indicator for the 5y yields, the 5y risk-neutral yields, and the 5y term premia.

My main empirical results yield several new findings.

I find that in the US, a one percentage point lower Chinese leading indicator lowers the 5y Treasury yield and the 5y Treasury term premium by 4.1 basis points over the short run. In the 5th month, the 5y Treasury yield decreases by 10.2 basis points, the 5y Treasury term premium by 9.2 basis points, and the 5y Treasury risk-neutral yield by 1 basis point. The responses of the 5y Treasury yield, the 5y Treasury term premium, and the 5y Treasury risk-neutral yield change by less than 1 basis point (in the absolute terms) in the 12th month. The lower Chinese leading indicator has an economically important negative impact on the 5y Treasury yield and its term premium[6].

At first glance, the Chinese leading indicator affects the 5y Bund yield in the opposite way as the 5y Treasury yield. The lower Chinese leading indicator *increases* the 5y Bund yield and the term premium attached to the 5y German Bunds. Over the short run, the 5y Bund yield increases by 3.8 basis points, the 5y Bund term premium by 3.3 basis points, and the 5y Bund risk-neutral yield by 0.5 basis points. In the 5th month, the 5y Bund yield increases by 5.9 basis points, the 5y Bund term premium by 4.7 basis points, and the 5y Bund risk-neutral yield by 1.2 basis points. However, as such increases are usually associated with recessions the effect could be driven by the ongoing sovereign debt crisis in the euro area. I find that the effects of the Chinese leading indicator on the 5y Bund yield and its term premium change direction and increase in the economic magnitude after the sovereign debt crisis. With the four-factor single country affine term structure model I find that in the 12th month, in the post sovereign debt crisis sample, the model implied 5y Bund yield decreases by 22.5 basis points, the 5y Bund term premium by 21.9 basis points and the 5y Bund risk-neutral yield by 0.6 basis points.

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[6] In my companion paper, Maletic (2018), I find that the lower growth of the Chinese foreign exchange reserves represents incremental information to the Chinese leading indicator and signals a lower 5y Treasury yield and decreases the compensation for bearing the duration risk (the 5y Treasury term premium).

The different direction of the effects in the US and Germany in a joint model after the financial crisis stems from two sources. First, although the principal components are extracted jointly from the US and German yield curves, I condition on a different set of domestic macroeconomic variables when I estimate the average effects of the Chinese leading indicator. Considering the link between the US/German unemployment rates and core inflations, and the difference between the leading indicators of the US/Germany and China is important when quantifying the effect of the Chinese leading indicator on the US and German yield curves. Second, and more importantly, after the financial crisis, we have witnessed the sovereign debt crisis in the euro area. The estimated effects change direction and strengthen in economic magnitude in Germany after the sovereign debt crisis.

My empirical findings suggest that the lower Chinese leading indicator mainly alters the term premia attached to the 5y nominal bonds. It signals lower 5y nominal interest rates and decreases the compensation for bearing the term (duration) risk in the US after the financial crisis, and in Germany after the sovereign debt crisis. The deterioration of the outlook about the Chinese economy provides a signal for lower longer-term nominal interest rates going forward. In an environment with low levels of growth, inflation and accommodative monetary policy constrained with the effective lower bound, investors are willing to accept lower compensation for holding nominal bonds instead of short-term securities, and are very sensitive towards signals about the future growth and inflation risks such as deterioration of the outlook about the Chinese economy.

The rest of this paper is organized as follows. Section 2 introduces an affine term structure model. Section 3 presents the data. Main results are presented in Section 4. Section 5 concludes.

2. Affine Term Structure Model

I estimate an affine term structure model. I use an estimator proposed by Diez de Los Rios (2015, 2018). His asymptotic least-square (ALS) estimator is internally consistent and has a limiting distribution which is asymptotically equivalent to the maximum likelihood. The evolution of the state variables (under the historical measure) follows the vector-autoregressive (VAR) process[7]

$$\begin{bmatrix} X_t^s \\ X_t^u \end{bmatrix} = \mu + \Phi \begin{bmatrix} X_{t-1}^s \\ X_{t-1}^u \end{bmatrix} + \begin{bmatrix} \upsilon_t^s \\ \upsilon_t^u \end{bmatrix} \quad (1)$$

Where

X_t^s – spanned pricing factors (principal components) $\in \mathcal{R}^{K_s \times 1}$

X_t^u – unspanned macroeconomic variables $\in \mathcal{R}^{K_u \times 1}$

[7] Adrian, Crump and Moench (2013) were among the first to propose the regression based estimation of an affine term structure model.

I use the principal component analysis and extract the principal components jointly from the US and German nominal term structures of interest rates (X_t^s). The macroeconomic variables (X_t^u) affect the bond prices merely through the principal components with a lag. In the US, in the model, I include the unspanned macroeconomic variables the US unemployment rate, the US core inflation, the US leading indicator, and the Chinese leading indicator. In Germany, in the model, I include the German unemployment rate, German core inflation, German leading indicator, and the Chinese leading indicator. The principal components which I extract jointly from the US and German yield curves *do not change*.

Shocks, $v_t = [v_t^s \quad v_t^u]'$, conditionally on lagged principal components and unspanned macroeconomic variables follow a Normal distribution, $v_t|\{X_s\}_{s=0}^{t-1} \sim N(0, \Sigma)$. μ, Φ, and Σ are partitioned according to the spanned and unspanned factors. Namely,

$$\mu = \begin{bmatrix} \mu_s \\ \mu_u \end{bmatrix}, \qquad \Phi = \begin{bmatrix} \Phi_{ss} & \Phi_{su} \\ \Phi_{us} & \Phi_{uu} \end{bmatrix}, \qquad and\ \Sigma = \begin{bmatrix} \Sigma_{ss} & \Sigma_{su} \\ \Sigma_{us} & \Sigma_{uu} \end{bmatrix}. \tag{2}$$

The bond pricing factors (principal components) and the nominal short-term interest rates in the US and Germany are related through the affine relation

$$r_{j,t} = \delta_0^{j,s} + \delta_1^{j,s'} X_t^s, \qquad for\ j = US\ and\ Germany. \tag{3}$$

The two-country affine term structure model allows for different loadings ($\delta_0^{j,s}$ and $\delta_1^{j,s'}$) on the US and German nominal short rates. When $\delta_0^{j,s}$ and $\delta_1^{j,s'}$ equal zero for $j = US\ or\ Germany$ the two-country model is reduced to a (usual) single country model[8].

Similarly as in the single-country case, under the risk-neutral probability measure, the spanned and unspanned factors follow the VAR (1) process

$$\begin{bmatrix} X_t^s \\ X_t^u \end{bmatrix} = \begin{bmatrix} \mu_s^\star \\ \mu_u^\star \end{bmatrix} + \begin{bmatrix} \Phi_{ss}^\star & 0 \\ \Phi_{us}^\star & \Phi_{uu}^\star \end{bmatrix} \begin{bmatrix} X_{t-1}^s \\ X_{t-1}^u \end{bmatrix} + \begin{bmatrix} v_t^{s\star} \\ v_t^{u\star} \end{bmatrix} \tag{4}$$

Shocks, $v_t{}^\star = [v_t^{s\star} \quad v_t^{u\star}]'$, conditionally on lagged principal components and unspanned macroeconomic variables follow a Normal distribution, $v_t{}^\star|\{X_s\}_{s=0}^{t-1} \sim N(0, \Sigma)$. Σ is the same matrix as in (2). The pricing (risk-neutral) transition matrices, $\mu^\star$ and $\Phi^\star$, can be written as

[8] $\delta_1^{j,s'}$ is a row vector so it equals a row of zeroes of appropriate dimension.

$$\mu^\star = \begin{bmatrix}\mu_s - \lambda_0^s \\ \mu_u - \lambda_0^u\end{bmatrix} = \begin{bmatrix}\mu_s - \lambda_0^s \\ \mu_u\end{bmatrix} = \begin{bmatrix}\mu_s^\star \\ \mu_u^\star\end{bmatrix}, \qquad \Phi^\star = \begin{bmatrix}\Phi_{ss} - \lambda_1^{ss} & \Phi_{su} - \lambda_1^{su} \\ \Phi_{us} - \lambda_1^{us} & \Phi_{uu} - \lambda_1^{uu}\end{bmatrix} = \begin{bmatrix}\Phi_{ss} - \lambda_1^{ss} & 0 \\ \Phi_{us} & \Phi_{uu}\end{bmatrix} = \begin{bmatrix}\Phi_{ss}^\star & 0 \\ \Phi_{us}^\star & \Phi_{uu}^\star\end{bmatrix}. \tag{5}$$

Because unspanned macroeconomic variables do not affect bond prices under the pricing measure following Adrian, Crump and Moench (2013), $\lambda_0^u = 0$, $\lambda_1^{us} = 0 \in \mathcal{R}^{K_u \times K_s}$, $\lambda_1^{uu} = 0 \in \mathcal{R}^{K_u \times K_u}$, the upper right $K_s \times K_u$ block of risk-neutral matrix $\Phi^\star$, $\Phi_{su}^\star = (\Phi_{su} - \lambda_1^{su})$ is zero, and therefore $\boldsymbol{\Phi_{su}} = \boldsymbol{\lambda_1^{su}} \in \mathcal{R}^{K_s \times K_u}$.
Given the assumptions (1) – (5), (log) bond prices of maturity n in country j at time period t are exponentially affine in the spanned factors (principal components)

$$lnP_{j,t}^{(n)} = A_n^{j,s} + B_n^{j,s'} X_t^s \tag{6}$$

The continuously compounded yield on a n-period zero-coupon bond in country j at time t equals $y_{j,t}^{(n)} = -\frac{1}{n} lnP_{j,t}^{(n)}$, and can be written as

$$y_{j,t}^{(n)} = a_n^{j,s} + b_n^{j,s'} X_t^s, \tag{7}$$

where $a_n^{j,s} = -\frac{A_n^{j,s}}{n}$ and $b_n^{j,s} = -\frac{B_n^{j,s}}{n}$.

Following Diez de Los Rios (2018) recursive linear restrictions $A_n^{j,s}$ and $B_n^{j,s'}$ are given as $(for\ n > 1)$

$$A_n^{j,s} = A_{n-1}^{j,s} + B_{n-1}^{j,s\ \prime}(\mu_s - \lambda_0^s) + \frac{1}{2} B_{n-1}^{j,s\ \prime} \Sigma_{ss} B_{n-1}^{j,s} - \delta_0^{j,s} \tag{8}$$

$$B_n^{j,s'} = B_{n-1}^{j,s\ \prime}(\Phi_{ss} - \lambda_1^{ss}) - \delta_1^{j,s'} \tag{9}$$

$$A_0^{j,s} = 0, \qquad A_1^{j,s} = -\delta_0^{j,s}, \qquad B_0^{j,s'} = 0, \qquad B_1^{j,s'} = -\delta_1^{j,s'}, \qquad for\ j = US\ and\ Germany. \tag{10}$$

When prices of risk parameters λ_0^s and λ_1^{ss} in (8) and (9) are set to zero, the recursions generate the risk adjusted bond pricing parameters

$$A_n^{j,s,RF} = A_{n-1}^{j,s,RF} + B_{n-1}^{j,s,RF'} \mu_s + \frac{1}{2} B_{n-1}^{j,s,RF'} \Sigma_{ss} B_{n-1}^{j,s,RF} - \delta_0^{j,s} \tag{11}$$

$$B_n^{j,s,RF'} = B_{n-1}^{j,s,RF'} \Phi_{ss} - \delta_1^{j,s'} \tag{12}$$

Risk-adjusted parameters imply that the model-fitted yields equal the time t expectation of the average future short rates over the next n periods, $E_t\left(-\left(\frac{1}{n}\right) lnP_{j,t}^{(n)}\right) = -\left(\frac{1}{n}\right)\left(A_n^{j,s,RF} + B_n^{j,s,RF'} X_t^s\right)$. The risk neutral yield (RNY), and the term premium (TP), the difference between the model-implied fitted yield and the risk neutral yield, can be written as[9,10]

$$RNY_{j,t}^{(n)} = -\left(\frac{1}{n}\right)\left[A_n^{j,s,RF} + B_n^{j,s,RF\prime} X_t^s\right] \tag{13}$$

$$TP_{j,t}^{(n)} = -\left(\frac{1}{n}\right)\left[\left(A_n^{j,s} - A_n^{j,s,RF}\right) + \left(B_n^{j,s} - B_n^{j,s,RF}\right)' X_t^s\right] \tag{14}$$

Diez de Los Rios (2018) notices that when the state variables are linear combinations of yields (i.e., $X_t^s = P' y_{j,t}^{(n)} = P'\left(a_n^{j,s} + b_n^{j,s\prime} X_t^s\right)$, for some full-rank matrix P) self-consistency implies[11,12]

$$P'a(\theta) = 0, \qquad P'b(\theta) = I,$$

where $\theta = (\theta_1', \theta_2', \theta_3')'$, $\theta_1 = vec(\Theta^\star)$, $\theta_2 = vec[(\mu\, \Phi)']$, $\theta_3 = vech\left(\Sigma^{1/2}\right)$, and

$$\Theta^{\star\prime} = \begin{pmatrix} \delta_0^{US,s} & \delta_1^{US,s\prime} \\ \delta_0^{GER,s} & \delta_1^{GER,s\prime} \\ \mu_s^\star & \Phi_{ss}^\star \end{pmatrix}. \tag{15}$$

Diez de Los Rios (2015) exploits conditions in (15) and proposes an asymptotic least squares (ALS) estimator. Estimator in Diez de Los Rios (2018) allows estimation of a multi-country affine term structure model with a large number of spanned factors (principal components).

To investigate how the Chinese leading indicator affects the spanned factors (X_t^s) and (log) bond prices ($lnP_{j,t}^{(n)}$) I focus on $\hat{\lambda}_{su}$. I increase principal components extracted from the US and German yield curves by the estimated coefficients $\hat{\lambda}_{su}$ which are statistically significantly different from zero

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[9] Campbell, Sunderam and Viceira (2009), Christensen, Lopez and Rudebusch (2010), Hördahl and Tristani (2012), and Rousselett (2017), amongst others, investigate the importance of variation in the estimated term premium for long-term nominal interest rates. They decompose the model implied term premium of the long-term nominal interest rates into the real term premium and the inflation risk premium. Abrahams, Adrian, Crump, Moench and Yu (2016) show that announcements of asset purchase programmes lower the long-term nominal interest rates mainly by lowering the model implied real term premium.

[10] Bernanke (2015) points out that after 2013 the 10-year Treasury term premium is more important for low 10-year Treasury yield than the 10-year Treasury risk-neutral yield.

[11] Cochrane and Piazzesi (2005) pointed out that variables which are linear combinations of yields, state variables which come out of the model, should be equal to imposed observed pricing factors.

[12] To ensure the positivity of covariance matrix Σ Diez de Los Rios (2018) focuses on its Cholesky decomposition, $\Sigma = \Sigma^{1/2}\Sigma^{1/2\prime}$.

and correspond to the Chinese leading indicator. I compare the change in the mean of the model implied 5y Treasury/Bund yields, the 5y Treasury/Bund risk-neutral yields, and the 5y Treasury/Bund term premia before and after I increase the principal components by the estimated coefficients $\hat{\lambda}_{su}$. I interpret the difference in the means as the average effect of the Chinese leading indicator on the model implied 5y Treasury/Bund yields, the model implied 5y Treasury/Bund risk-neutral yields, and the model implied 5y Treasury/Bund term premia.

3. Data

I estimate the joint model of the US and German nominal term structure of interest rates in the post financial crisis sample, from June 2009 to December 2017. The parameters of the zero-coupon yield curve are retrieved from Deutsche Bundesbank (BUBA) and Gürkaynak, Sack and Wright (2007).

I focus on the maturities from 1 to 60 months (5 years). The rest of the data is as follows. Core inflation and unemployment rates for the US and Germany are from the FRED database of the Federal Reserve Bank of St. Louis and from Eurostat. I retrieve the leading indicators of the US, German and Chinese economies from OECD[13].

The leading indicator is constructed in such a way as to identify and predict the turning points in the business cycles. Reference series which is chosen to approximate the economic activity is the quarterly growth of the GDP. The OECD generates monthly estimates of the GDP based on the official quarterly estimates.

The database on the main economic indicators (MEI) provides the main source of variables that are included in the indicator. The variables can be grouped in (1) GDP and industrial production, (2) selected commodity output variables (crude steel, crude petroleum etc.), (3) business and consumer tendency survey series, (4) selected manufacturing variables (deliveries, stocks, new orders etc.), (5) construction, (6) domestic trade, (7) labor market series, (8) consumer and producer prices, (9) money aggregates, (10) interest rates, (11) financial variables, (12) exchange rates, (13) international trade and (14) balance of payments data.

I use the trend restored version of the index in 12-month log differences. This version of the index most closely tracks the yearly GDP growth rate and is available at a monthly frequency.

[13] Available at http://www.oecd.org/std/leading-indicators/

Figure 2 depicts the six principal components extracted jointly from the US and German term structures in the post financial crisis sample. The loadings on the yields of different maturities of the first and the second principal component are a mixture of level and slope. Loadings of the third to the sixth principal component do not have meaningful economic interpretation. That is why I decided to focus instead on the time-series dimension.

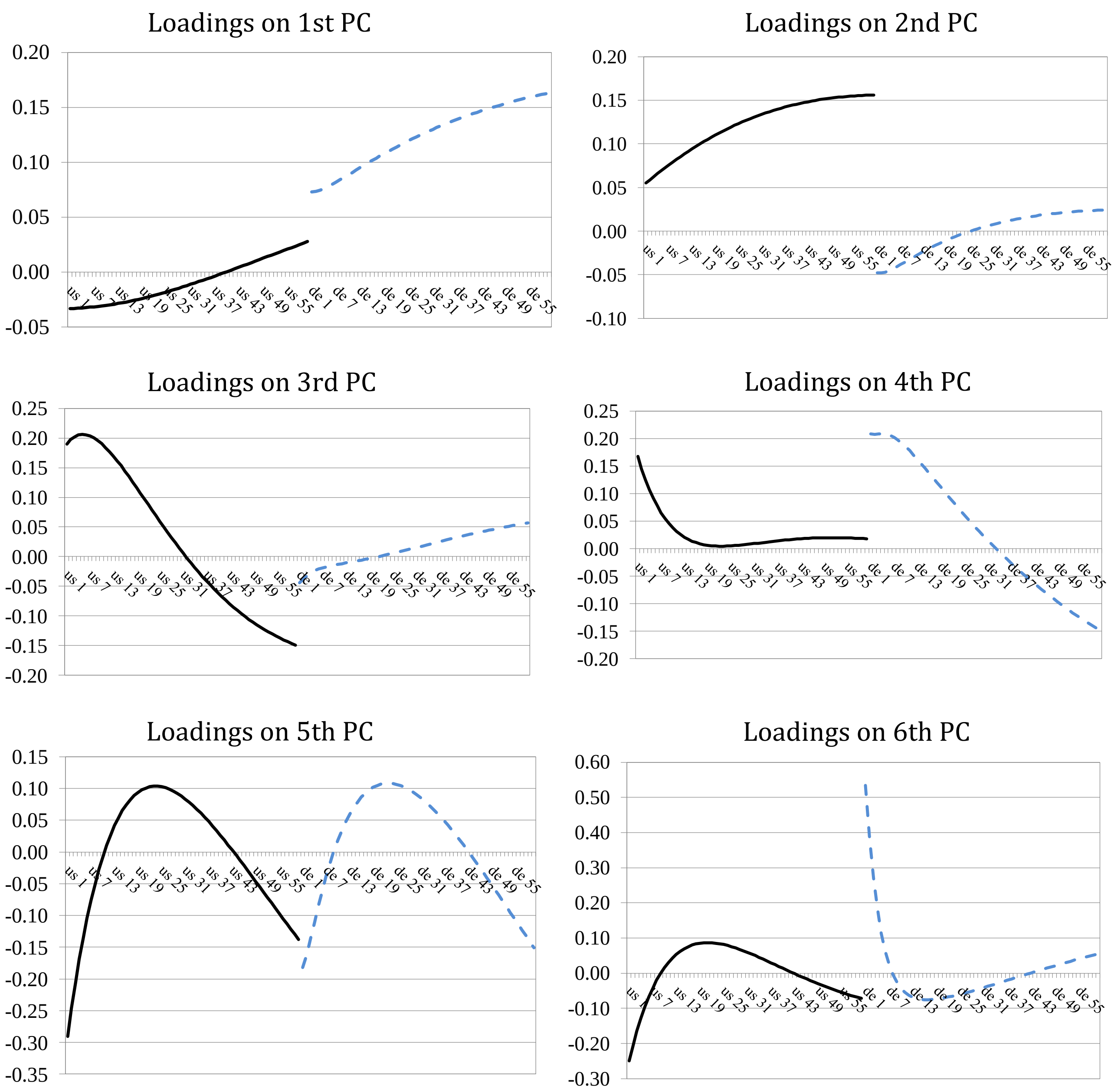

Figure 2: Loadings of US (black line) and German (dashed-blue line) monthly zero-coupon yields with maturities of one to sixty months (5 years) on the six global principal components. Sample spans from June 2009 to December 2017.

Figure 3 plots the first two principal components extracted jointly from the US and German nominal term structures in the post financial crisis sample. In the post financial crisis sample, the dynamics of principal component 1 are similar to the dynamics of the 5y Bund yield. The dynamics of principal component 2 are similar to the dynamics of the 5y Treasury yield. While principal components 1 and 2 do not have meaningful interpretations in the cross-sectional dimension (both are a mixture of levels and slopes), the principal components 1 and 2 in the time-series dimension show clear diverging patterns which are most probably due to the different monetary policy stances in the US and Germany in the post financial crisis sample.

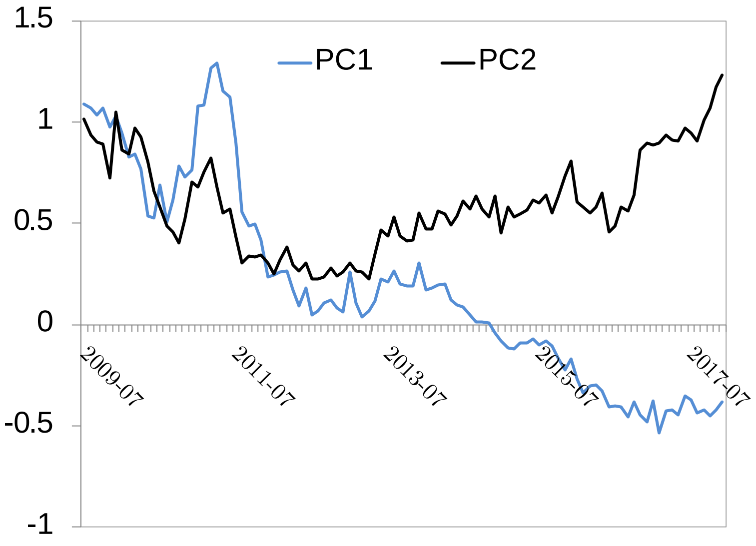

Figure 3: Principal component 1 and 2 in the post financial crisis sample (from June 2009 to December 2017).

Table 1 shows the average percentage of explained variation of 60 yields with monthly maturities when I use one to six principal components. One factor model shows a clear disconnect between the US and German yields. While the first principal component extracted jointly from the US and German nominal term structures explains 97 percent of Bund yield variation, it explains only 11 percent of Treasury yield variation (up to the maturity of 5 years). The two-factor model already explains almost 90 percent of the variation of the US and more than 98 percent of the variation of German yields. However, the pattern of loadings on the yields of different maturities of the first two principal components in the US and Germany is not clear. Figure 4 depicts R^2s of the first six principal components on 120 yields with monthly maturities, 60 in the US and 60 in Germany. Model almost fully explains the yield variation.

Table 1: Average percentage of explained variation of 60 monthly maturity yields in the US and Germany when I use one, two, three, four, 5, or six principal components from June 2009 to December 2017.

	One Factor	Two Factors	Three Factors	Four Factors	Five Factors	Six Factors
U.S.	11.2%	89.8%	98.8%	99.2%	99.8%	99.9%
Germany	97.0%	98.4%	98.5%	99.6%	99.8%	99.9%

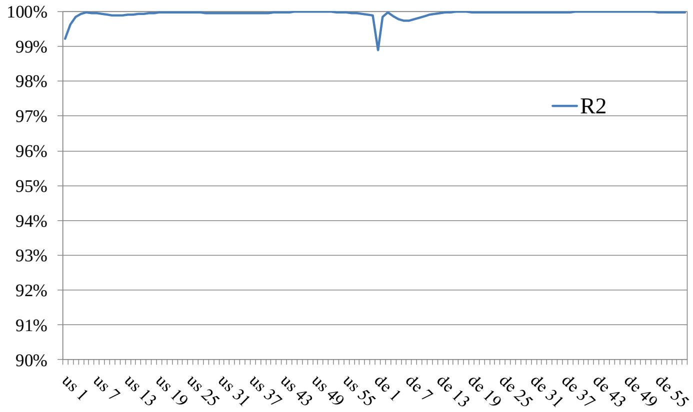

Figure 4: Percentage of explained variation of monthly yields with maturities of one to sixty months (5 years) in the US and Germany with the global six-factor model (which uses global PC1 to PC6). Sample spans from June 2009 to December 2017.

Figure 5 depicts the growth of the Chinese leading indicator before and after the financial crisis. The average growth of the Chinese leading indicator from 1998 to 2007, 14.2 percent, decreased to 10.3 percent in the post financial crisis sample. The growth of Chinese leading indicator after the financial crisis exhibits a clear downward trend. The yearly growth of the leading indicator in December 2017 decreased to 5 percent. From June 2009 to December 2017 the mean of the Chinese leading indicator is equal to 10.3 percent, and its standard deviation is equal to 4.5 percent.

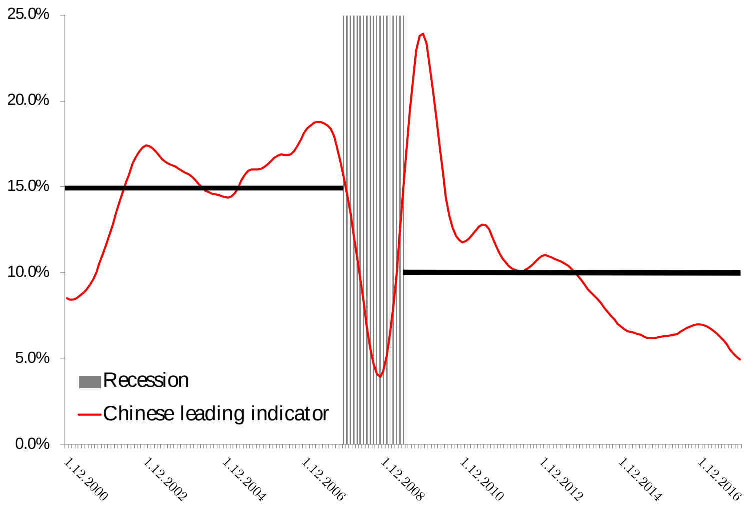

Figure 5: Average growth of the Chinese composite leading indicator before and after the financial crisis. Twelve-month log differences. Sample spans from December 2000 to December 2017. Source: OECD.

Figure 6 shows the US, Chinese and German leading indicators in the post financial crisis sample. Average yearly growth rates of the US and German leading indicators are similar. From June 2009 to December 2017, on average, US leading indicator increased by 2.1 percent. The German leading indicator increased by 2 percent. However, the German leading indicator seems to be exhibiting larger cyclical movements than the US leading indicator in the post financial crisis sample. Its standard deviation is 2.2 percent compared to 1.4 percent in the US. The growth of the Chinese leading indicator is converging towards the growth of German and the US leading indicator.

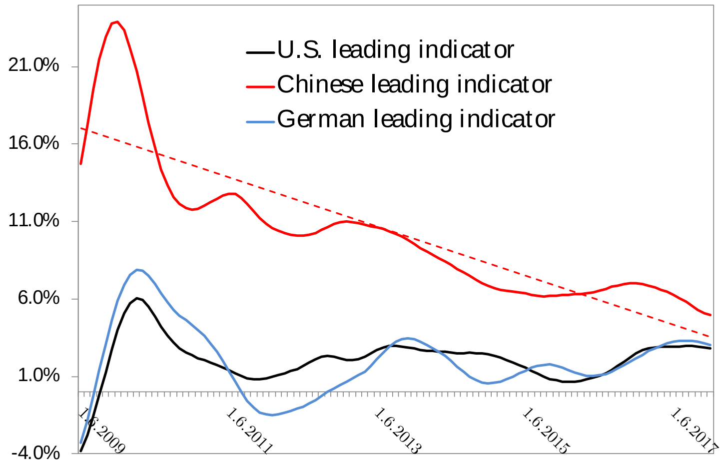

Figure 6: The US, German and Chinese composite leading indicators (CLIs) with trends-restored. Twelve-month log differences. Sample spans from June 2009 to December 2017. Source: OECD.

Figure 7 (left panel) presents the US and German core inflations. In the post financial crisis sample, the average German core inflation equals 1.1 percent. The average core inflation in the US equals 1.7 percent. Core inflations are below 2 percent, the policy target inflation rate. Figure 7 (right panel) shows the unemployment rates. In the US the unemployment rate decreased from 10 percent in September 2009 to 4.1 percent by December 2017. The German unemployment rate decreased from 7.9 percent in July 2009 to 3.6 percent by December 2017.

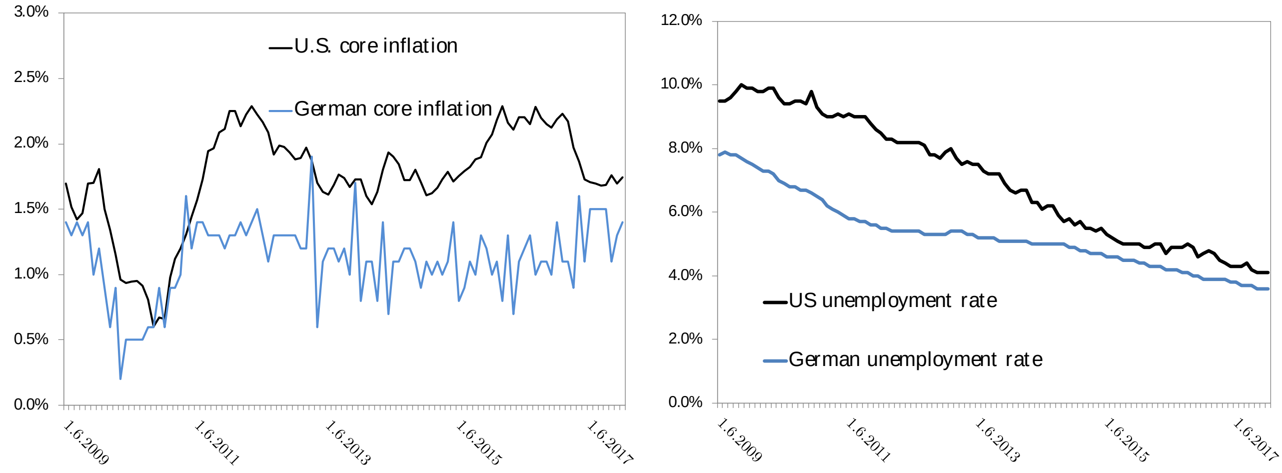

Figure 7: US and German core inflation rates (left panel) and unemployment rates (right panel). Sample spans from June 2009 to December 2017. Source: St. Louis FRED and Eurostat.

In Figure 8 we can see that the 5y Bund term premium decreased from 2.4 percent in December 2009 to 1.2 percent by August 2010. The Chinese leading indicator decreased from 24 percent to 13 percent over the same period. During the sovereign debt crisis, the 5y Bund term premium temporarily increased to 2.5 percent in March 2011 but decreased to 80 basis points by December 2011. By September 2016, the 5y Bund term premium decreased to -40 basis points. It increased to 28 basis points by December 2017. The Chinese leading indicator, on the other hand, steadily decreased from 13 percent in August 2010 to 5 percent by December 2017. The in-sample correlation of the two series equals 0.86.

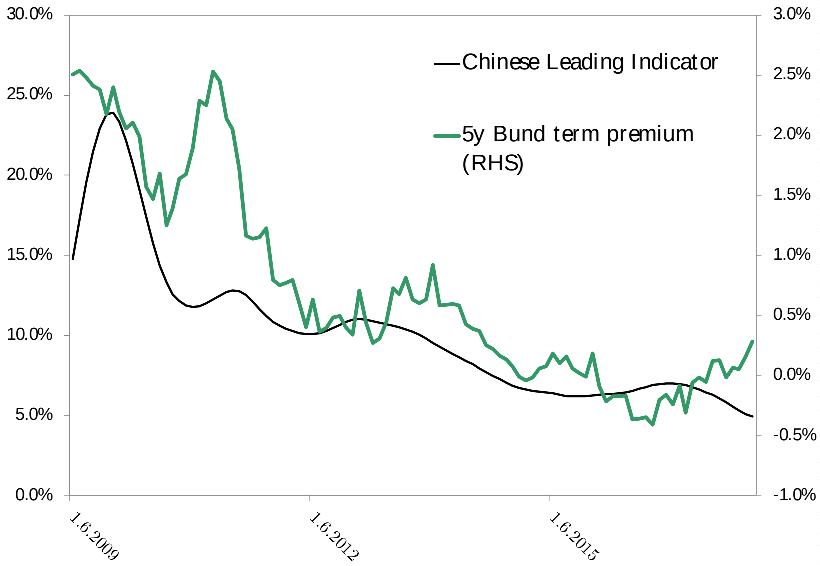

Figure 8: 5y Bund term premium and the Chinese leading indicator. Sample spans from June 2009 to December 2017. Source: OECD.

Table 2 presents descriptive statistics. After the crisis, the average German unemployment rate, 5.3 percent, is smaller than in the US, 7 percent. Average German nominal short rate is negative, –4 basis points. Its standard deviation is higher than in the US, 49 compared to 34 basis points. In the post financial crisis sample, the average 5-year Bund yield equals 69 basis points and is lower than in the US, 154 basis points.

Table 2: Descriptive statistics. Yearly growth of OECD leading indicators, core inflation rates, unemployment rates, nominal short rates (one-month government nominal yields), and the 5-year government nominal yields in the US and Germany. Sample spans from June 2009 to December 2017. Source: FRED database of the Federal Reserve Bank of St. Louis, ECB, Eurostat, OECD, Deutsche Bundesbank (BUBA).

	Mean		Standard deviation		Percentiles			
					US		GER	
	US	GER	US	GER	5th	95th	5th	95th
OECD leading indicator	2.1%	2.0%	1.4%	2.2%	0.7%	4.8%	-1.3%	6.9%
Core Inflation	1.7%	1.1%	0.4%	0.3%	0.9%	2.2%	0.6%	1.5%
Unemployment rate	7.0%	5.3%	1.9%	1.1%	4.3%	9.8%	3.7%	7.6%
Short rate	39	-4	34	49	3	125	-82	79
5-year yield	154	69	51	98	70	240	-50	250

4. Main Results

In this section, I present my main empirical results. Before I introduce the decomposition of the 5y Treasury and Bund yields in the 5y Treasury/Bund risk-neutral yields and the 5y Treasury/Bund term premia, I present the short and long-run effects of the Chinese leading indicator on the actual 5y Treasury/Bund yields.

Table 3 presents the estimated coefficients of the five-variable vector-autoregression for the US economy. All variables included in the regression are in percentage points. Estimated effects are for a percentage point increase, except for the Chinese leading indicator where the estimated effects are for a percentage point decrease. In the last column of Table 3, we can see that a percentage point lower Chinese leading indicator on average decreases the 5y Treasury yield by 4.3 basis points. In the first row of Table 3, we can see that the effects of the US macroeconomic variables are significant. A percentage point increase of the US unemployment on average decreases the 5y Treasury yield by 12.2 basis points. Higher US core inflation on average decreases the 5y Treasury yield by 28.9 basis points. Although significant at the 10% level, the effect of the US leading indicator is small in economic magnitude, on average 2.7 basis points.

Table 3: Estimated coefficients of a five-variable vector autoregression: $X_t = \mu + \Phi X_{t-1} + \varepsilon_t$. Variables included in the regression: 5y Treasury yield, US unemployment, US core inflation, US leading indicator, and Chinese leading indicator. Sample spans from June 2009 to December 2017. Bolded coefficients are significant at the 10% level.

Factor	$\boldsymbol{\Phi_{1,1}}$	$\boldsymbol{\Phi_{1,2}}$	$\boldsymbol{\Phi_{1,3}}$	$\boldsymbol{\Phi_{1,4}}$	$\boldsymbol{\Phi_{1,5}}$
	(5y Treasury Yield)	(ur_{us})	($CCPI_{us}$)	(CLI_{us})	(CLI_{ch})
5y Treasury Yield	**0.7092**	**-0.1222**	**-0.2890**	**-0.0269**	**0.0425**
(t-statistic)	11.21	-3.87	-3.50	-1.72	3.36
ur_{us}	-0.0607	**0.9438**	-0.0950	**-0.0311**	**0.0244**
(t-statistic)	-1.28	40.04	-1.54	-2.66	2.58
$CCPI_{us}$	0.0025	0.0103	**0.9131**	**-0.0224**	-0.0088
(t-statistic)	0.08	0.62	20.93	-2.71	-1.32
CLI_{us}	-0.0630	**-0.2065**	0.1231	**0.8412**	**0.1326**
(t-statistic)	-1.10	-7.20	1.64	59.18	11.56
CLI_{ch}	-0.0173	**-0.1374**	**-0.3702**	**-0.4144**	**1.0544**
(t-statistic)	-0.19	-3.04	-3.13	-18.48	58.28

Table 4 present the results for the German economy. Macroeconomic variables affect the 5y Bund yield in the opposite direction than in the US. A percentage point higher German unemployment increases the 5y Bund yield, on average by 19 basis points. The effect of German core inflation is positive but becomes insignificant. This suggests that in Germany, the 5y Bund yield was reacting more to the output gap than to inflation in the post financial crisis sample.

Estimated coefficients on the leading indicators are significant but of the opposite sign than in the US. A percentage point higher German leading indicator increases 5y Bund yield on average by 2.3 basis points. The economic magnitude is fairly similar to the Chinese leading indicator. A percentage point lower Chinese leading indicator increases the 5y Bund yield on average by 2.5 basis points.

Table 4: Estimated coefficients of a five-variable vector autoregression: $X_t = \mu + \Phi X_{t-1} + \varepsilon_t$. Variables included in the regression: 5y Bund yield, German unemployment, German core inflation, German leading indicator, and Chinese leading indicator. Sample spans from June 2009 to December 2017. Bolded coefficients are significant at the 10% level.

Factor	$\boldsymbol{\Phi_{1,1}}$	$\boldsymbol{\Phi_{1,2}}$	$\boldsymbol{\Phi_{1,3}}$	$\boldsymbol{\Phi_{1,4}}$	$\boldsymbol{\Phi_{1,5}}$
	(5y Bund Yield)	(ur_{ger})	($CCPI_{ger}$)	(CLI_{ger})	(CLI_{ch})
5y Bund Yield	**0.8568**	**0.1915**	0.1145	**0.0226**	**-0.0247**
(t-statistic)	18.80	3.22	1.48	2.17	-2.27
ur_{ger}	-0.0163	**0.9954**	-0.0064	**-0.0079**	0.0018
(t-statistic)	-1.13	52.68	-0.26	-2.40	0.53
$CCPI_{ger}$	**0.2839**	**-0.4714**	**-0.1853**	**-0.0988**	**0.0539**
(t-statistic)	5.07	-6.46	-1.95	-7.74	4.04
CLI_{ger}	**-0.5205**	0.1902	**0.3537**	**0.9278**	**0.1122**
(t-statistic)	-5.76	1.61	2.30	44.98	5.20
CLI_{ch}	0.0595	0.3001	**0.4879**	**-0.1329**	**0.9443**
(t-statistic)	0.50	1.93	2.41	-4.88	33.19

Figure 9 depicts the impulse response functions of the 5y Treasury yield (left panel) to one percentage point negative shock to the Chinese leading indicator. The response of the 5y Treasury yield strengthens from -4.2 basis points in the 1st month to -10.6 basis points in the 6th month. Afterwards, it reverts to -7.6 basis points and remains significantly different from 0 in the 12th month. In the right panel of Figure 9, we can observe that the economic magnitude of the response of the 5y Bund yield is smaller and goes in the opposite way than in the US. The response is significant only in the first month. The 5y Bund yield increases by 2.5 basis points.

Response of the 5y Treasury yield to 1% shock to Chinese leading indicator (orthagonalized IRF) (in bps)

Response of the 5y Bund yield to 1% shock to Chinese OECD leading indicator (orthagonalized IRF) (in bps)

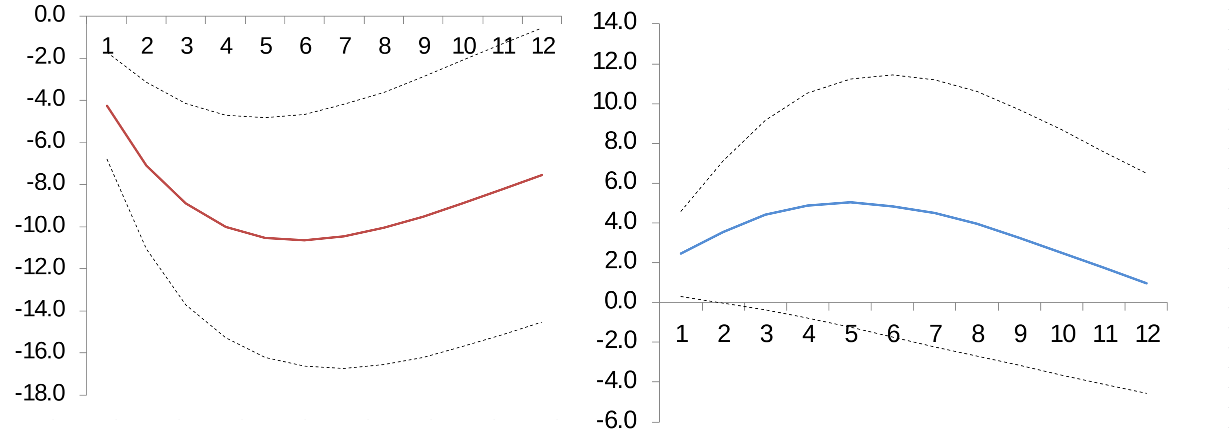

Figure 9: Orthogonalized impulse response functions of the 5y Treasury yield (left panel) and the 5y Bund yield (right panel) to 1 percentage point shock to Chinese OECD leading indicator. I estimate two structural vector auto-regressions with Cholesky identification scheme. Sample spans from June 2009 to December 2017. Variables included in the US model: 5y Treasury yield, US unemployment, US core inflation, US leading indicator, and Chinese leading indicator. Variables included in the German model: 5y Bund yield, German unemployment, German core inflation, German leading indicator, and Chinese leading indicator. Chinese leading indicator is ordered last and lower-triangular variance-covariance matrix of shocks is imposed.

Next, I estimate the two-country affine term structure model with the unspanned macroeconomic variables following Diez de Los Rios (2018). I use principal component analysis and extract principal components which are explaining the most of variation in the US and German yield curves. In the US, in the model, I include the six principal components, the US unemployment, US core inflation rate, the US leading indicator, and the Chinese leading indicator. In Germany, in the model, I include German unemployment, German core inflation, German leading indicator, and the Chinese leading indicator. I estimate the affine term structure model with the unspanned macroeconomic variables. I use the identity $\widehat{\Phi}_{su} = \hat{\lambda}_1^{su}$ to measure the effects of the macroeconomic variables on the six principal components, and bond prices.

Table 5 presents the estimated prices of risks of the six-factor model for the US economy. Average pricing error shrinks from 4.3 basis points to 1.4 basis points as I move from the five to the six-factor model (of the fitted 5y Treasury yield). The risk of the first principal component is affected significantly by itself, the sixth principal component, the US unemployment, US core inflation, and the US leading indicator. Risks of the second principal component are affected significantly by the second, the third principal component and all four macroeconomic variables: the US unemployment, US core inflation, US leading indicator, and the Chinese leading indicator. The risks of the third principal component are affected significantly by the first principal component, the second, the third and the fourth principal components. The US unemployment, US core inflation, and the Chinese leading indicator affect the risk of the third principal component significantly. The fourth principal component is affected significantly by the first, the fourth principal component, the US leading indicator, and the Chinese leading indicator. The fifth PC is affected significantly by itself and the US leading indicator. The sixth PC is affected significantly by the third, the fourth, the sixth PC, and the US and Chinese leading indicators.

Table 5: Estimated prices of risk, λ_0^s and $\lambda_1^{s\cdot}$ of the two-country affine term structure model using an estimator as outlined in Diez de Los Rios (2018). Sample spans from June 2009 to December 2017. Spanned factors: $X_t^s = [PC\ 1_t \quad PC\ 2_t \quad PC\ 3_t \quad PC\ 4_t \quad PC\ 5_t \quad PC\ 6_t]'$. Unspanned factors: $X_t^u = [ur_{US,t} \quad CCPI_{US,t} \quad CLI_{US,t} \quad CLI_{CH,t}]'$. Bolded coefficients are significant at the 10% level. I present the remaining estimated parameters in Appendix A.1. $ur_{US,t}$ – US unemployment rate, $CCPI_{US,t}$ – US core inflation rate, $CLI_{US,t}$ – US leading indicator, $CLI_{CH,t}$ – Chinese leading indicator.

Factor	λ_0	$\lambda_{1,1}$	$\lambda_{1,2}$	$\lambda_{1,3}$	$\lambda_{1,4}$	$\lambda_{1,5}$	$\lambda_{1,6}$	$\lambda_{1,7}$	$\lambda_{1,8}$	$\lambda_{1,9}$	$\lambda_{1,10}$
	(constant)	(PC1)	(PC2)	(PC3)	(PC4)	(PC5)	(PC6)	(ur_{us})	($CCPI_{us}$)	(CLI_{us})	(CLI_{ch})
PC 1	-0.0534	**-0.3268**	0.0464	-0.2144	0.0532	0.0530	**-0.9977**	**5.8453**	**-16.4305**	**-2.5910**	-0.1548
(t-statistic)	-0.251	-3.721	0.666	-1.605	0.161	0.128	-1.721	2.172	-4.507	-2.789	-0.236
PC 2	**0.5769**	-0.0391	**-0.2498**	**0.3264**	-0.1057	-0.4421	-0.8609	**-5.7030**	**-11.7262**	**-1.5982**	**1.7375**
(t-statistic)	2.656	-0.436	-3.511	2.389	-0.313	-1.046	-1.452	-2.077	-3.153	-1.686	2.594
PC 3	**-0.2106**	**-0.0493**	**0.0768**	**-0.0869**	**0.2320**	-0.0539	-0.0102	**2.5437**	**1.8737**	0.2622	**-0.5069**
(t-statistic)	-3.461	-1.958	3.757	-2.155	2.372	-0.434	-0.057	3.348	1.821	1.000	-2.735
PC 4	0.0973	**0.0524**	-0.0213	0.0203	**-0.4760**	-0.1031	0.1932	-0.6581	-0.7052	**0.8485**	**-0.6093**
(t-statistic)	1.649	2.144	-1.071	0.517	-4.998	-0.851	1.107	-0.895	-0.708	3.341	-3.394
PC 5	-0.0071	-0.0087	-0.0014	-0.0011	0.0528	**-0.2402**	-0.1820	-0.0269	-0.4523	**-0.5021**	0.0593
(t-statistic)	-0.195	-0.568	-0.108	-0.042	0.843	-2.941	-1.521	-0.060	-0.749	-3.264	0.546
PC 6	0.0163	0.0110	-0.0060	**0.0445**	**-0.1970**	0.1134	**-0.1896**	0.0338	0.1168	**0.3071**	**-0.1999**
(t-statistic)	0.454	0.738	-0.506	1.925	-3.471	1.586	-1.862	0.075	0.191	1.969	-1.813

Figure 10 depicts the estimated 5y Treasury risk-neutral yield (left panel) and 5y Treasury term premium (right panel). The 5y Treasury risk-neutral yield increased from 47 basis points in June 2009 to 3.4 percent by December 2017. From December 2014 to December 2017 the 5y Treasury risk-neutral yield increased from -5 basis points to 3.4 percent. The 5y Treasury term premium (upper right panel, Figure 10) decreased from 2.1 percent in June 2009 to 1 percent by October 2010, from where it increased to 2.2 percent in March 2011. Volatile 5y Treasury term premium can be at least in some part explained by the ongoing sovereign debt crisis in the Euro Area. The 5y Treasury term premium decreased to 71 basis points by April 2013 from where it increased to 2 percent in December 2013. After 2014, the 5y Treasury term premium decreased to -1.2 percent by December 2017.

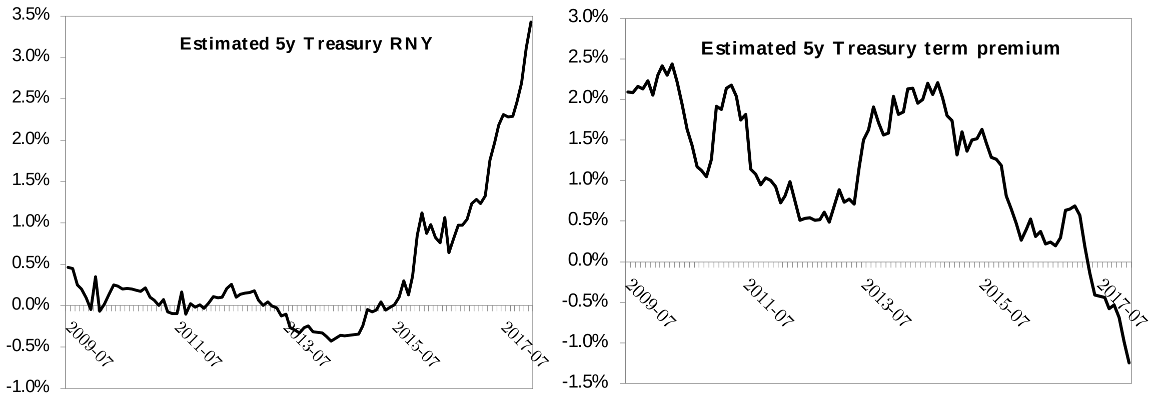

Figure 10: Model implied 5-year Treasury risk-neutral yield (expected future nominal short rate) (left panel) and the 5y Treasury term premium (right panel) estimated with the six-factor model (which uses PC1 to PC6) and unspanned macroeconomic variables: US unemployment, US core inflation, US leading indicator, and the Chinese leading indicator. I use an estimator as outlined in Diez de Los Rios (2018). Sample spans from June 2009 to December 2017.

To measure the effect of the Chinese leading indicator on the US yield curve, I increase the principal components by the significant coefficients $\hat{\lambda}_{1,10}$ which are estimated in Table 5. I calculate the change of the in-sample mean of the 5y Treasury yield, the 5y Treasury risk-neutral yield and the 5y Treasury term premium which are presented in Figure 10. The mean of the model implied 5y Treasury yield increases by 4.1 percent. The mean of the 5y Treasury term premium increases by 4.1 percent and the mean of the model implied 5y Treasury risk-neutral yield remains unchanged. However, the estimated coefficients represent an increase of the Chinese leading indicator by “a unit”. This implies that the Chinese leading indicator would increase by 100 percent. I divide the estimated effects by 100 and premultiply them by -1.

A one percentage point decrease of the Chinese leading indicator decreases the model implied 5y Treasury yield by 4.1 basis points and the model implied 5y Treasury term premium by 4.1 basis points while leaving the model implied 5y Treasury risk-neutral yield unchanged[14].

The 95 percent confidence interval (in basis points) for a percentage points decrease of the Chinese leading indicator of the model implied 5y Treasury yield is (**−7.1, −1**), the model implied 5y Treasury term premium is (**−6.9, −1.3**) and of the model implied 5y Treasury risk-neutral yield is (**−0.2, 0.3**).

Figure 11 presents the impulse response functions of the six principal components to "a unit" shock to the Chinese leading indicator in the model which includes the US macroeconomic variables. The estimated effect on the second principal component, 1.7375 (estimated coefficient in the 10th column of Table 5) decreases to 0.0027 (upper-middle panel in Figure 11, the effect is pre-multiplied by −1). The response of the second principal component increases to 0.0065 by the 5th month from where it reverts back to 0. In Figure 11, we can observe that the responses of the third, the fourth, and the fifth principal components are significant as well.

To measure the long-run effects of the Chinese leading indicator on the US yield curve, I proceed as follows. First, I compute average 5y Treasury yield, average 5y Treasury term premium and average 5y Treasury risk-neutral yield with the principal components (X^s) which I extract from the yield curves. Second, I increase the principal components by responses in the 5th month when the responses of the 2nd, the 3rd, and the 4th PCs are significant and the highest (please refer to Figure 11). Third, I re-compute average 5y Treasury yield, average 5y Treasury term premium and average 5y Treasury risk-neutral yield with the new principal components.

In particular, let P denote the Cholesky decomposition of Σ, such that $PP' = \Sigma$. Furthermore, let $u_t \in \mathcal{R}^{K\times 1}$ be such that I can write shocks in (1) as $u_t = P^{-1}v_t$. Orthogonalized impulse responses can be written as[15]

[14] When I do not condition on the US unemployment, US core inflation and the US leading indicator, average estimated effects in the US decrease to (in absolute terms): the model implied 5y Treasury yield decreases by 0.8 basis points, the model implied 5y Treasury term premium by 0.6 basis points, and the model implied 5y Treasury risk-neutral by 0.2 basis points.

[15] And interpreted as one standard-deviation impulse to u_t.

$$\begin{bmatrix}\widehat{X}_0^s\\ \widehat{X}_0^u\end{bmatrix} = I_K\widehat{P}$$

$$\begin{bmatrix}\widehat{X}_1^s\\ \widehat{X}_1^u\end{bmatrix} = \widehat{\Phi}\widehat{P}$$

$$\begin{bmatrix}\widehat{X}_2^s\\ \widehat{X}_2^u\end{bmatrix} = \widehat{\Phi}^2\widehat{P} \tag{16}$$

$$\vdots$$

$$\begin{bmatrix}\widehat{X}_T^s\\ \widehat{X}_T^u\end{bmatrix} = \widehat{\Phi}^T\widehat{P}$$

To scale the orthogonalized impulse of the Chinese leading indicator to a unit shock, I divide the responses by the standard deviation of the Chinese leading indicator (which I order last). The standard deviation corresponds to the element in the last row of the last column of $\widehat{P}$. I multiply the responses by 10.000 to scale them to basis points responses.

Next, I collect significant responses of the 6 principal components in the fifth month in a row vector which I denote ϕ_{LR}, and add the ϕ_{LR} to the principal components, which I extract from the yield curves

$$\widetilde{X}_t^s = X_t^s + \widehat{\phi}_{LR} \tag{17}$$

I re-estimate the 5y yield, the term premium and the risk-neutral yield with the new principal components, $\tilde{X}_t^s$. I interpret the changes in the 5y yield, the term premium and the risk-neutral yield, which are estimated with X_t^s and $\tilde{X}_t^s$, as average effects of a one percentage point increase of the Chinese leading indicator on the 5y yield, the term premium, and the risk-neutral yield.

In the 5th month, a one percentage point decrease of the Chinese leading indicator decreases the in-sample average of the model implied 5y Treasury yield by 10.2 basis points, the 5y Treasury term premium by 9.2 basis points and the 5y Treasury risk-neutral yield by 1 basis point. In the 12th month, the model implied 5y Treasury yield decreases by 0.77 basis points, the 5y Treasury term premium by 0.33 basis points and the 5y Treasury risk-neutral yield by 0.44 basis points.

The 95 percent confidence interval (in basis points) for a percentage points decrease of the Chinese leading indicator of the model implied 5y Treasury yield in the 5th month is ($\mathbf{-17, -3.5}$), the model implied 5y Treasury term premium is ($\mathbf{-16.6, -1.9}$) and of the model implied 5y Treasury risk-neutral yield is ($\mathbf{-0.4, -1.6}$).

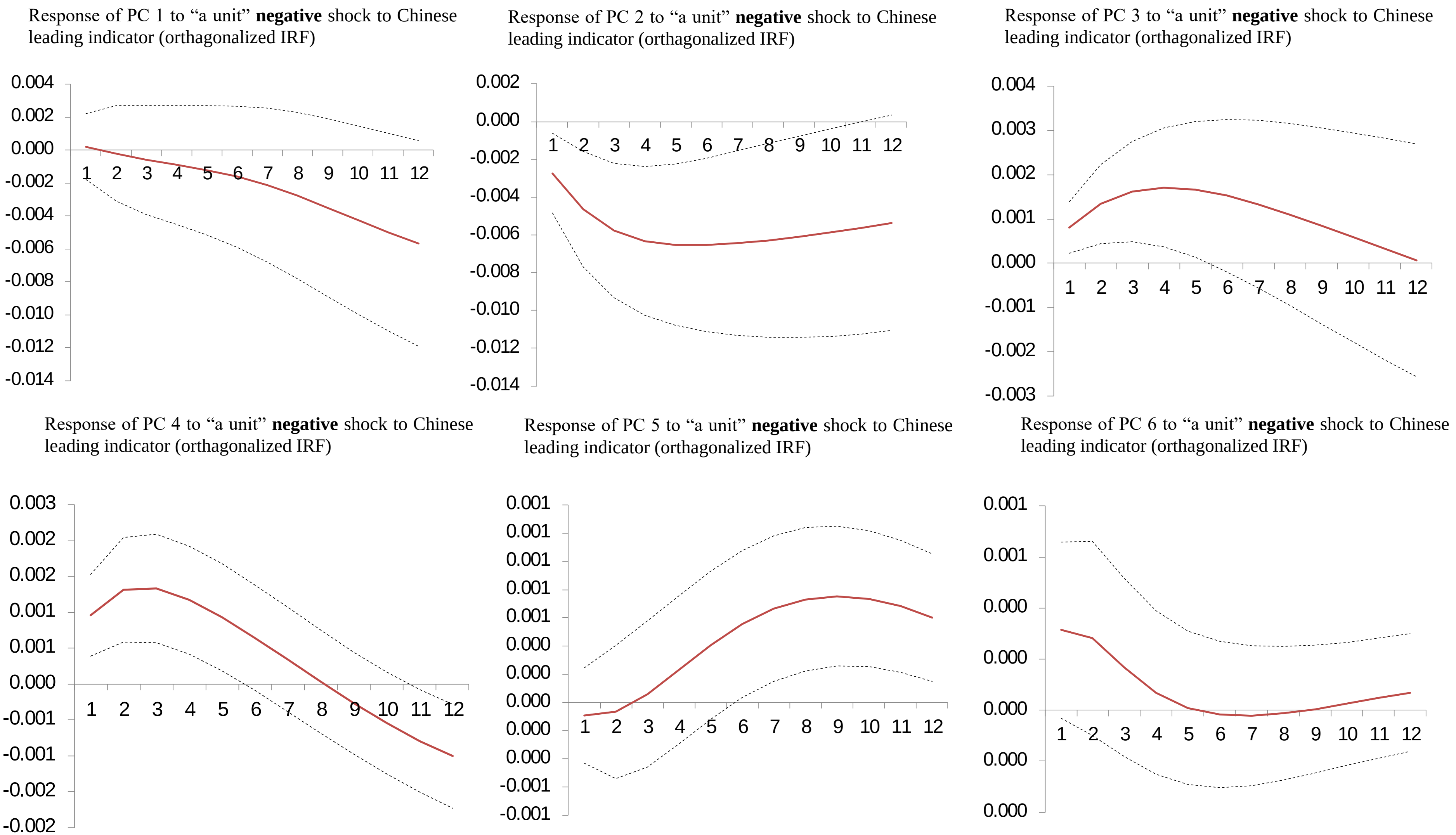

Figure 11: Orthogonalized responses of the six principal components to the negative impulse to the Chinese leading indicator (Cholesky identification scheme with lower triangular variance-covariance matrix). Sample spans from June 2009 to December 2017. Variables included in the VAR are ordered as in the second row of Table 5.

Table 6 presents the estimated prices of risks of the six-factor model for the German economy. The risk of the first principal component is affected significantly by itself, German unemployment, German leading indicator, and the Chinese leading indicator. Risks of the second principal component are affected significantly by the first, the second, the third, and the sixth principal component. The risks of the third principal component are not affected significantly in the German case. The risks of the fourth principal component are affected significantly by the first, the second, the fourth principal component, the US leading indicator, and the Chinese leading indicator. The risks of the fifth PC are affected significantly by the second principal component, by itself, the sixth principal component, German core inflation, and the German leading indicator. The sixth PC is affected significantly by the third, the fourth, and the sixth PC.

Table 6: Estimated prices of risk, λ_0^s and $\lambda_1^{s.}$ of the two-country affine term structure model using an estimator as outlined in Diez de Los Rios (2018). Sample spans from June 2009 to December 2017. Spanned factors: $X_t^s = [PC\,1_t \quad PC\,2_t \quad PC\,3_t \quad PC\,4_t \quad PC\,5_t \quad PC\,6_t]'$. Unspanned factors: $X_t^u = [ur_{GER,t} \quad CCPI_{GER,t} \quad CLI_{GER,t} \quad CLI_{CH,t}]'$. Bolded coefficients are significant at the 10% level. I present the remaining estimated parameters in Appendix A.1. $ur_{GER,t}$ – German unemployment rate, $CCPI_{GER,t}$ – German core inflation rate, $CLI_{GER,t}$ – German leading indicator, $CLI_{CH,t}$ – Chinese leading indicator.

Factor	$\boldsymbol{\lambda_0}$	$\boldsymbol{\lambda_{1,1}}$	$\boldsymbol{\lambda_{1,2}}$	$\boldsymbol{\lambda_{1,3}}$	$\boldsymbol{\lambda_{1,4}}$	$\boldsymbol{\lambda_{1,5}}$	$\boldsymbol{\lambda_{1,6}}$	$\boldsymbol{\lambda_{1,7}}$	$\boldsymbol{\lambda_{1,8}}$	$\boldsymbol{\lambda_{1,9}}$	$\boldsymbol{\lambda_{1,10}}$
	(constant)	(PC1)	(PC2)	(PC3)	(PC4)	(PC5)	(PC6)	(ur_{ger})	($CCPI_{ger}$)	(CLI_{ger})	(CLI_{ch})
PC 1	**-0.5327**	**-0.1591**	-0.0177	0.1200	-0.2197	-0.0184	-0.7666	**13.6070**	5.4407	**1.4448**	**-2.4243**
(t-statistic)	-3.059	-2.637	-0.430	1.041	-0.685	-0.045	-1.284	3.880	1.342	1.980	-3.452
PC 2	-0.1132	**-0.1075**	**-0.0852**	**0.2302**	0.0886	-0.0790	**-1.2165**	3.2420	0.7140	0.4637	-0.2359
(t-statistic)	-0.637	-1.745	-2.025	1.952	0.270	-0.189	-1.994	0.907	0.173	0.623	-0.329
PC 3	-0.0108	-0.0001	0.0143	-0.0209	0.1269	-0.1951	0.1786	-0.1504	-0.0249	-0.0014	-0.0387
(t-statistic)	-0.215	-0.005	1.140	-0.590	1.323	-1.573	0.966	-0.150	-0.022	-0.006	-0.193
PC 4	0.0619	**0.0336**	**-0.0263**	-0.0079	**-0.4359**	-0.1193	0.1715	-0.3215	0.3008	**0.6114**	**-0.6186**
(t-statistic)	1.330	2.064	-2.255	-0.240	-4.896	-1.033	0.993	-0.349	0.283	3.193	-3.356
PC 5	**-0.0489**	-0.0139	**0.0166**	0.0181	0.0916	**-0.2317**	**-0.2584**	0.8703	**-1.1762**	**-0.4057**	-0.0531
(t-statistic)	-1.758	-1.413	2.166	0.818	1.620	-3.079	-2.262	1.638	-1.915	-3.672	-0.499
PC 6	0.0111	0.0012	-0.0107	**0.0466**	**-0.1659**	0.0825	**-0.2270**	0.2680	-0.2612	0.1111	-0.1559
(t-statistic)	0.394	0.124	-1.572	2.421	-3.139	1.214	-2.258	0.475	-0.401	0.946	-1.380

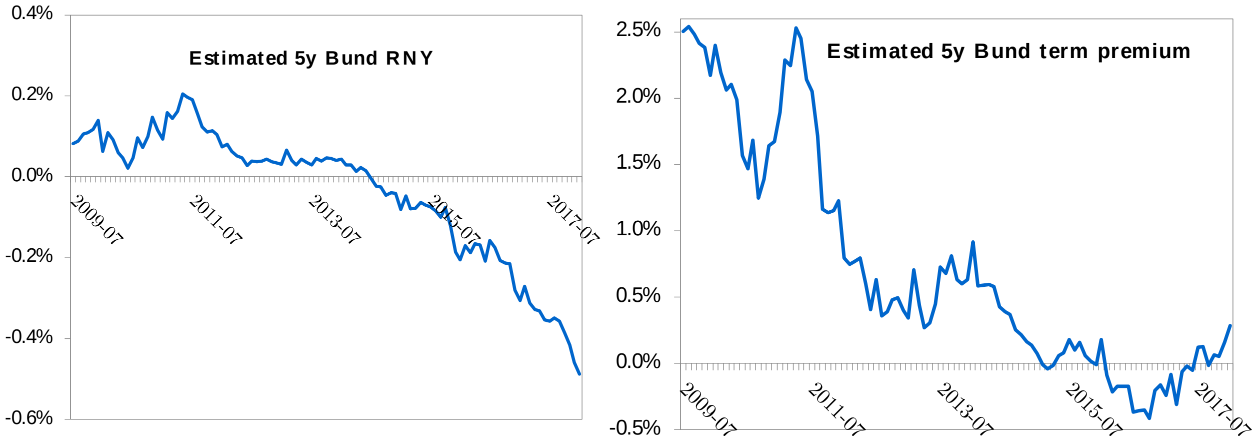

Figure 12: Model implied 5-year Bund risk-neutral yield (expected future nominal short rate) (left panel) and the 5y Bund term premium (right panel) estimated with the six-factor model (which uses PC1 to PC6) and unspanned macroeconomic variables: German unemployment, German core inflation, German leading indicator, and the Chinese leading indicator. I use an estimator as outlined in Diez de Los Rios (2018). Sample spans from June 2009 to December 2017.

The 5y Bund risk-neutral yield presented in the left panel of Figure 12 decreased from 8 basis points in June 2009 to -49 basis points by December 2017. The 5y Bund term premium, depicted in the right panel of Figure 12, decreased from 2.5 percent in June 2009 to 1 percent in August 2010. It increased back to 2.5 percent by March 2011. After the sovereign debt crisis, the 5y Bund term premium decreased to 30 basis points by March 2013. By December 2013, the 5y Bund term premium increased to 90 basis points. It decreased to -40 basis points by July 2016. The 5y Bund term premium increased to 30 basis points by December 2017.

To measure the effect of the Chinese leading indicator on the German yield curve, I perform a similar exercise as in the US case. I increase the principal components by the significant coefficients $\hat{\lambda}_{1,10}$ which are estimated in Table 6 and multiply them by -0.01. I calculate the change of the in-sample mean of the 5y Treasury yield, the 5y Treasury risk-neutral yield and the 5y Treasury term premium which are presented in Figure 12.

A *one percentage point decrease of the Chinese leading indicator increases the model implied 5y Bund yield by 3.8 basis points, the model implied 5y Bund term premium by 3.3 basis points, and the model implied 5y Bund risk-neutral by 0.5 basis points*[16]*. However, using the four-factor single country model, the model implied 5y Bund yield and its term premium decrease by 0.5 basis points in the post sovereign debt crisis sample (from December 2011 to December 2017). The 95 percent confidence interval in the post sovereign debt crisis sample includes zero effects.*

The 95 percent confidence interval (in basis points) for a percentage points decrease of the Chinese leading indicator of the model implied 5y Bund yield is (**1.7, 5.8**), the model implied 5y Bund term premium is (**1.5, 5**) and of the model implied 5y Bund risk-neutral yield is (**0.2, 0.8**). The 95 percent confidence interval (in basis points) in the post sovereign debt crisis sample using a four-factor single-country model of the model implied 5y Bund yield is (**−2.4, 1.4**), the model implied 5y Bund term premium is (**−2.43, 1.34**) and of the model implied 5y Bund risk-neutral yield is (**0.03, 0.06**).

Figure 13 presents the impulse response functions of the six principal components to "a unit" shock to the Chinese leading indicator in the model which includes the German macroeconomic variables. The variables which are included in the model are the six principal components (extracted jointly from the US and German yield curve), German unemployment, German core inflation, the German leading indicator, and the Chinese leading indicator.

The response of the first principal component equals −0.0041 in the 1st month. The response of the first principal component increases in absolute terms to −0.0072 in the 5th month from where it reverts back to 0. Again, I divide the responses by 0.00168 which is equal to a response of the Chinese leading indicator on itself in period zero. Afterwards, I multiply the response by −0.01 to quantify a one percentage point decrease. In Figure 13, we can observe that the responses of the fourth and the fifth principal components are significant as well.

To measure the long-run effects of the Chinese leading indicator on the German yield curve, I increase the principal components by the significant responses in the 5th month when the responses of the 1st, the 4th, and the 5th PCs are significant and the largest in absolute terms.

[16] When I do not condition on German unemployment, German core inflation and German leading indicator, average estimated effects in Germany decrease to (in absolute terms): the model implied 5y Bund yield decreases by −0.1 basis points, the model implied 5y Bund term premium by −0.15 basis points, and the model implied 5y Bund risk-neutral increases by 0.05 basis points.

A one percentage point decrease of the Chinese leading indicator increases the in-sample average of the model implied 5y Bund yield by 5.9 basis points, the 5y Bund term premium by 4.7 basis points and the 5y Bund risk-neutral yield by 1.2 basis points in the 5th month. The 5y Bund yield and the 5y Bund term premium increase by 0.6 basis points in the 12th month.

However, using the four-factor single country model, in the 12th month, the model implied 5y Bund yield decreases by 22.5 basis points, the 5y Bund term premium by 21.9 basis points and the 5y Bund risk-neutral yield by 0.6 basis points in the post sovereign debt crisis sample (from December 2011 to December 2017).

The 95 percent confidence interval (in basis points) for a percentage points decrease of the Chinese leading indicator of the model implied 5y Bund yield in the 5th month is (**1.2, 10.6**), the model implied 5y Bund term premium is (**0.7, 8.6**) and of the model implied 5y Bund risk-neutral yield is (**0.5, 2**).

The 95 percent confidence interval (in basis points) for a percentage points decrease of the Chinese leading indicator in the 12th month in the post sovereign debt crisis sample using a single-country model of the model implied 5y Bund yield is ($\mathbf{-17.3,\ -27.7}$), the model implied 5y Bund term premium is ($\mathbf{-16.9,\ -27}$) and of the model implied 5y Bund risk-neutral yield is ($\mathbf{-0.4,\ -0.7}$). The impulse response functions of the first four principal components extracted from the German yield curve to a positive impulse to the Chinese leading indicator in the post sovereign debt crisis sample are depicted in Appendix A.2.

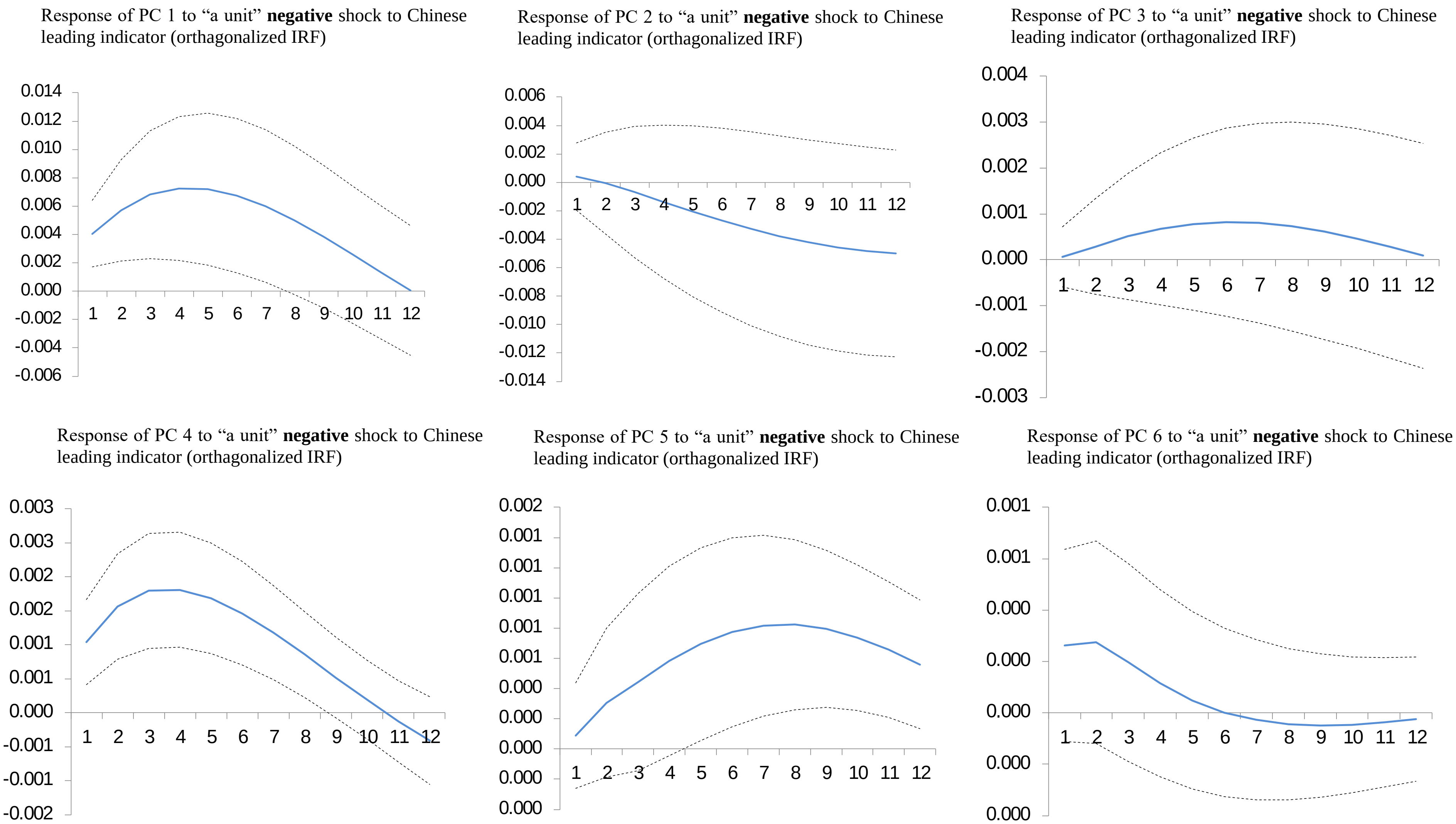

Figure 13: Orthogonalized responses of the six principal components to the negative impulse to the Chinese leading indicator (Cholesky identification scheme with lower triangular variance-covariance matrix). Sample spans from June 2009 to December 2017. Variables included in the VAR are ordered as in the second row of Table 6.

5. Conclusions

I estimate the joint affine term structure model of the US and German yield curves with the unspanned macroeconomic variables which include the Chinese leading indicator. I decompose the 5y nominal interest rates in the US and Germany in the 5y risk-neutral yields and the 5y term premia. I investigate how important is a Chinese slowdown we are observing after the financial crisis for the 5y nominal interest rates in the US and Germany, the 5y risk-neutral yields, and the 5y term premia.

I measure a Chinese slowdown as a growth differential between China and the US/Germany, which I empirically represent with the changes in the leading indicators. For each economy, in the model, I include the six principal components extracted jointly from the US and German yield curves, the domestic unemployment rate, the domestic core inflation rate, the domestic leading indicator, and the Chinese leading indicator.

A one percentage point lower Chinese leading indicator lowers the 5y Treasury yield and the 5y Treasury term premium by 4.1 basis points over the short run. In the 5^{th} month, the 5y Treasury yield decreases by 10.2 basis points, the 5y Treasury term premium by 9.2 basis points, and the 5y Treasury risk-neutral yield by 1 basis point. The 5y Bund yield *increases* by 3.8 basis points, the 5y Bund term premium by 3.3 basis points, and the 5y Bund risk-neutral yield by 0.5 basis points over the short run. In the 5^{th} month, the responses strengthen to 5.9 basis points, 4.7 basis points, and 1.2 basis points. However, the higher 5y Bund term premium could be driven by the ongoing sovereign debt crisis in the euro area.

I re-estimate the four-factor single country affine term structure model in the post sovereign debt crisis sample for the German economy. In the 12^{th} month, the model implied 5y Bund yield decreases by 22.5 basis points, the 5y Bund term premium by 21.9 basis points and the 5y Bund risk-neutral yield by 0.6 basis points.

My empirical findings suggest that the lower Chinese leading indicator helped to decrease the 5y Treasury yield and its term premium after the financial crisis, and the 5y Bund yield and its term premium after the sovereign debt crisis. Long-term bonds provide a hedge against the risks of lower growth and inflation when the monetary policy is constrained by the effective lower bound. Bondholders are willing to accept lower compensation for bearing the duration risk, the 5y term premium. In such an environment, investors became particularly sensitive towards the signals about the future growth and inflation risks such as deteriorating outlook of the Chinese economy.

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A.1. Estimated parameters of the joint affine model of the US and German nominal term structures in the post financial crisis sample

$\delta_0^{US,s}$	$\delta_0^{GER,s}$
(constant)	(constant)
-0.0062	**-0.0035**
0.0011	0.0019
(standard error)	(standard error)

Factor	$\delta_1^{US,s}$	$\delta_1^{GER,s}$
PC 1	**-0.0333**	**0.0729**
(standard error)	0.0005	0.0009
PC 2	**0.0549**	**-0.0478**
(standard error)	0.0010	0.0018
PC 3	**0.1900**	**-0.0444**
(standard error)	0.0033	0.0057
PC 4	**0.1676**	**0.2083**
(standard error)	0.0059	0.0101
PC 5	**-0.2907**	**-0.1817**
(standard error)	0.0100	0.0172
PC 6	**-0.2495**	**0.5342**
(standard error)	0.0163	0.0280

Factor	$\mu_s^\star$
	(constant)
PC 1	**0.0016**
(standard error)	0.0003
PC 2	**0.0033**
(standard error)	0.0004
PC 3	**0.0032**
(standard error)	0.0009
PC 4	**0.0034**
(standard error)	0.0009
PC 5	**-0.0049**
(standard error)	0.0015
PC 6	**-0.0012**
(standard error)	0.0003

Factor	$\Phi^\star_{ss,1,1}$	$\Phi^\star_{ss,1,2}$	$\Phi^\star_{ss,1,3}$	$\Phi^\star_{ss,1,4}$	$\Phi^\star_{ss,1,5}$	$\Phi^\star_{ss,1,6}$
	(PC1)	(PC2)	(PC3)	(PC4)	(PC5)	(PC6)
PC 1	**1.0239**	**0.0168**	**0.0270**	**-0.0697**	**0.0156**	**-0.2475**
(standard error)	0.0001	0.0003	0.0009	0.0016	0.0028	0.0044
PC 2	**0.0132**	**1.0274**	**-0.0804**	**-0.0588**	**0.0619**	**0.1536**
(standard error)	0.0002	0.0004	0.0014	0.0023	0.0039	0.0061
PC 3	0.0003	**0.0194**	**1.0031**	**-0.0856**	**0.1813**	**0.2084**
(standard error)	0.0004	0.0008	0.0028	0.0048	0.0080	0.0157
PC 4	**0.0127**	**0.0227**	**-0.0083**	**0.9695**	**0.2218**	**-0.2932**
(standard error)	0.0005	0.0009	0.0030	0.0052	0.0087	0.0169
PC 5	**0.0021**	0.0010	**-0.0108**	0.0015	**0.9408**	0.0397
(standard error)	0.0007	0.0014	0.0047	0.0080	0.0135	0.0241
PC 6	**0.0030**	**0.0041**	**-0.0397**	**0.0580**	**0.0114**	**0.6562**
(standard error)	0.0001	0.0003	0.0009	0.0015	0.0025	0.0052

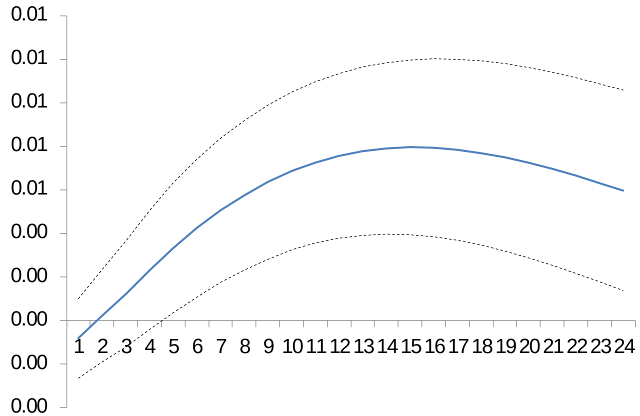
	$Eigenvalues$
λ_1	0.7491 + 0.0000i
λ_2	0.9417 + 0.0409i
λ_3	0.9417 - 0.0409i
λ_4	1.0009 + 0.0249i
λ_5	1.0009 - 0.0249i
λ_6	0.9865 + 0.0000i

Factor	$\Sigma^{Chol}_{1,1}$	$\Sigma^{Chol}_{1,2}$	$\Sigma^{Chol}_{1,3}$	$\Sigma^{Chol}_{1,4}$	$\Sigma^{Chol}_{1,5}$	$\Sigma^{Chol}_{1,6}$	$\Sigma^{Chol}_{1,7}$	$\Sigma^{Chol}_{1,8}$	$\Sigma^{Chol}_{1,9}$	$\Sigma^{Chol}_{1,10}$
	(PC1)	(PC2)	(PC3)	(PC4)	(PC5)	(PC6)	(ur_{us})	($CCPI_{us}$)	(CLI_{us})	(CLI_{ch})
PC 1	**0.0781**									
(standard error)	0.0058									
PC 2	**0.0272**	**0.0749**								
(standard error)	0.0087	0.0044								
PC 3	0.0023	**-0.0124**	**0.0181**							
(standard error)	0.0020	0.0019	0.0015							
PC 4	**0.0069**	-0.0031	**0.0054**	**0.0192**						
(standard error)	0.0021	0.0020	0.0024	0.0013						
PC 5	**0.0023**	-0.0007	0.0011	-0.0002	**0.0126**					
(standard error)	0.0013	0.0012	0.0014	0.0013	0.0009					
PC 6	-0.0001	**0.0031**	0.0000	**0.0057**	0.0001	**0.0114**				
(standard error)	0.0012	0.0011	0.0013	0.0013	0.0012	0.0008				
ur_{us}	0.0002	**-0.0004**	-0.0001	0.0000	**0.0003**	**0.0003**	**0.0013**			
(standard error)	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001			
$CCPI_{us}$	-0.0001	0.0000	0.0001	-0.0001	0.0001	**-0.0002**	-0.0001	**0.0008**		
(standard error)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		
CLI_{us}	0.0002	**0.0004**	-0.0002	0.0001	-0.0002	**-0.0004**	-0.0002	-0.0002	**0.0015**	
(standard error)	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	
CLI_{ch}	**0.0009**	0.0000	**-0.0006**	0.0004	0.0000	-0.0002	0.0003	-0.0003	**0.0013**	**0.0021**
(standard error)	0.0002	0.0002	0.0003	0.0002	0.0002	0.0002	0.0003	0.0003	0.0003	0.0001

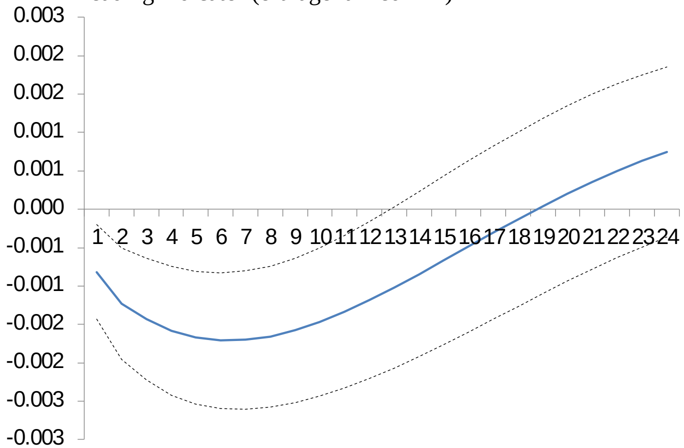
Factor	$\Sigma^{Chol}_{1,1}$	$\Sigma^{Chol}_{1,2}$	$\Sigma^{Chol}_{1,3}$	$\Sigma^{Chol}_{1,4}$	$\Sigma^{Chol}_{1,5}$	$\Sigma^{Chol}_{1,6}$	$\Sigma^{Chol}_{1,7}$	$\Sigma^{Chol}_{1,8}$	$\Sigma^{Chol}_{1,9}$	$\Sigma^{Chol}_{1,10}$
	(PC1)	(PC2)	(PC3)	(PC4)	(PC5)	(PC6)	(ur_{ger})	($CCPI_{ger}$)	(CLI_{ger})	(CLI_{ch})
PC 1	**0.0823**									
(standard error)	0.0061									
PC 2	**0.0292**	**0.0786**								
(standard error)	0.0092	0.0046								
PC 3	0.0026	**-0.0143**	**0.0184**							
(standard error)	0.0020	0.0019	0.0016							
PC 4	**0.0057**	-0.0031	**0.0052**	**0.0199**						
(standard error)	0.0022	0.0021	0.0025	0.0013						
PC 5	0.0024	-0.0001	0.0007	0.0002	**0.0122**					
(standard error)	0.0013	0.0012	0.0014	0.0013	0.0009					
PC 6	-0.0008	**0.0027**	0.0005	**0.0060**	-0.0009	**0.0114**				
(standard error)	0.0012	0.0011	0.0013	0.0013	0.0012	0.0008				
ur_{us}	0.0001	0.0000	-0.0001	0.0000	0.0000	0.0002	**0.0006**			
(standard error)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001			
$CCPI_{us}$	0.0003	0.0001	-0.0002	**0.0004**	0.0001	0.0000	0.0001	**0.0018**		
(standard error)	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0004	0.0001		
CLI_{us}	0.0004	**0.0007**	-0.0005	0.0000	0.0001	-0.0002	-0.0002	**0.0008**	**0.0022**	
(standard error)	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0008	0.0004	0.0002	
CLI_{ch}	**0.0011**	**0.0006**	**-0.0009**	0.0002	0.0002	**-0.0006**	**0.0009**	**0.0007**	**0.0020**	**0.0019**
(standard error)	0.0002	0.0002	0.0003	0.0002	0.0002	0.0002	0.0005	0.0002	0.0002	0.0002

A.2. Orthogonalized responses of the four principal components extracted from the German yield curve to the **positive** impulse to the Chinese leading indicator (Cholesky identification scheme with lower triangular variance-covariance matrix). Sample spans from December 2011 to December 2017. Variables included in the VAR (1) model: the four principal components extracted from the German yield curve, German unemployment rate, German core inflation rate, the German leading indicator, and the Chinese leading indicator.

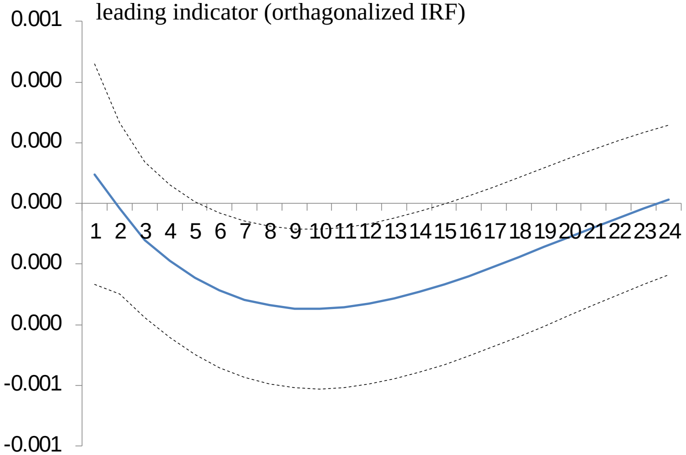
Response of PC 1 to “a unit” **positive** shock to Chinese leading indicator (orthagonalized IRF)



Response of PC 2 to “a unit” **positive** shock to Chinese leading indicator (orthagonalized IRF)



Response of PC 3 to “a unit” **positive** shock to Chinese leading indicator (orthagonalized IRF)



Response of PC 4 to “a unit” **positive** shock to Chinese leading indicator (orthagonalized IRF)