A Chinese slowdown and the nominal term structures of the US and German interest rates

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Abstract

To measure the global spillovers of a Chinese slowdown on the long-term nominal interest rates in the US/Germany, I model the US/German nominal term structure jointly in the post financial crisis (FC) sample, including the Chinese leading indicator as a new factor. I use an affine term structure model and decompose changes in the 5-year nominal interest rates into (1) changes in the expected future nominal short rate, "the signaling channel," and (2) the 5-year term premium, "the portfolio balance channel." A drop in the Chinese leading indicator results in a significant drop in the US/German growth over the first year. In the US, this leads to clear signaling effects but no portfolio balancing effects. In Germany, I find both signaling and portfolio balancing effects, but the direction of these effects is opposite to what one might expect. To deal with the different monetary regimes since the Sovereign debt crisis (SDC) I also model the German term structure independently from the US in the post SDC sample. Like in the US, I now find that in Germany, a lower Chinese leading indicator has important signaling effects in the expected direction. However, (opposite) portfolio balancing effects neutralize these signaling effects on the estimated 5-year Bund yield.

1. Introduction

The last decades have witnessed a tremendous growth of the Chinese economy. In 2017, China accounted for 18 percent of global GDP, compared to only 4 percent in the early 1990s. On a purchasing power parity (PPP) basis, it ranks first, ahead of the entire European Union (EU) and of the United States. Given its size and high growth, it is not surprising that China is also a dominant player in the commodity markets: in 2016, China accounted for about 50 percent of the global demand for aluminum, nickel, and copper, and 12 percent of global oil demand. While the growth of the Chinese economy continues to outshine that of its

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global peers, the growth of the potential output has dropped from double digits in the 1990s and 2000s to 7–8 percent after 2013.

Existing work has investigated the impact of (changes in) Chinese growth on, amongst others, commodity prices as well as global/US/EU growth and inflation dynamics, unequivocally finding the effects to be large[3]. The main contribution of this paper is to investigate the role of Chinese growth on the term structure of US and German interest rates. Despite the vast amount of papers analyzing these series, this paper is, to the best of my knowledge, the first to systematically investigate the existence of a "China factor" in the term structure of interest rates.

I hypothesize that a Chinese slowdown can affect the US/German term structure in essentially two (possibly opposing) ways.

First, changes in Chinese growth may affect the dynamics of fundamentals drivers of the US/German term structure, such as expected 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 US and euro area (EA) growth and inflation rates (mainly through the effect that a Chinese slowdown has on global commodity prices). The resulting drop in expected real short-term interest rates and inflation

[3] Gauvin and Rebillard (2015) estimate that if Chinese annual growth decreases to 3 percent over a two year transition period, metal prices decrease by 54 and oil prices by 46 percent cumulatively over 5 years. 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. Metelli and Natoli (2017) find that a negative shock to the Chinese investments which lowers the annual output growth by 2 percentage points over two consecutive years, lowers the EA output, the US, and the EA inflation by 50 basis points cumulatively over two years. The US output decreases by 20 basis points. If oil prices decrease by 10 US dollars and metals price index by 10 percent the EA inflation decreases by 140 basis points and the US inflation by 170 basis points cumulatively over two years. Cashin, Mohaddes and Raissi (2017) find that besides lowering the inflation and the short-term interest rates, the lower Chinese growth lowers the global growth. The decrease is in economic magnitude similar to the decrease due to a surge in the global financial market volatility.

leads to a drop in expectations about future nominal short rates. Following Bauer and Rudebusch (2014), I call this the "signaling channel[4]."

Second, changes in Chinese real growth may affect US and German term premia through the so-called "portfolio balance channel." The idea that events in China may affect US and German term premia is not surprising given the substantial Chinese holdings of foreign bonds; in fact, by 2018, China held nearly 10% of all US Treasury bonds. Suggestive evidence indicates also a substantial Chinese presence in the German bond market. Beltran, Kretchmer, Marquez and Thomas (2013) estimate the effect of a drop in foreign official holdings of US Treasuries (from all foreign countries, not just from China) on the 5-year Treasury term premium, and find the effect to be significantly positive[5]. Just like them, I will focus on US Treasuries and German Bunds with a maturity of up to 5 years, as foreign holdings seem to be concentrated in the short to intermediate maturity buckets[6].

Figure 1 shows the development of the 5-year Treasury and Bund yields, and of the Chinese leading indicator, in the post financial crisis sample. Actual 5-year 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 5-year Bund yield[7]. In 2013 the FED chairman Ben Bernanke signaled a decrease of the QE programmes ("the taper tantrum"). The monetary policies in the US and EA diverged. From December 2011 to December 2017

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[4] Bauer and Rudebusch (2017) investigate how changes in the nominal short rate transmit into the term structure. By decomposing the nominal short rate into the real equilibrium interest rate, driven among others, by a lower productivity and an aging population, and the trend in inflation, they find that both components of the nominal short rate are important for understanding the dynamics of the US term structure of interest rates.

[5] The effect continues being positive even after taking into account the reaction by foreign private investors to the yield changes induced by the shocks to foreign official inflows.

[6] The average maturity of the EA government bonds held by the foreign Central Banks is approximately equal to four years with a standard deviation below two months (Blattner and Joyce, 2016). In the US, in June 2017 approximately 75 percent of the Treasury and Agency debt held by the foreign Central Banks has the maturity of 5 years or less (Department of the Treasury, 2018).

[7] The Bund free-float decreased from 50 to 10 percent after 2015, when the ECB initiated the public sector purchase programme. The percentage of the US Treasuries outstanding available to the private investors did not fall below 50 percent when the FED was conducting the QE programmes. The lower Bund free-float depressed the long-term Bund yields, the long-term Bund term premia, and the volatility of Bunds (Cœuré, 2018).

the actual 5-year Bund yield decreased from 87 to −18 basis points while the actual 5-year Treasury yield increased from 87 to 217 basis points.

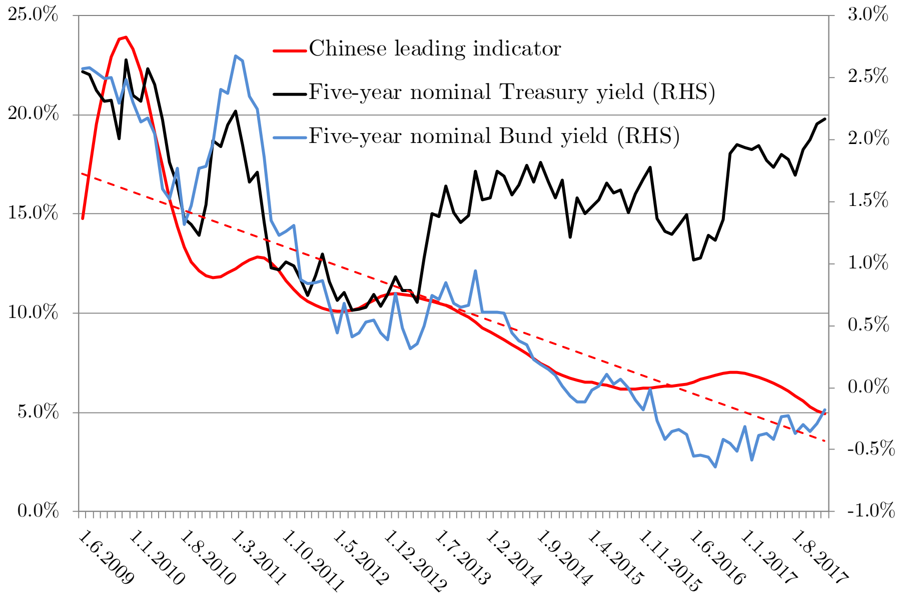

Figure 1: Chinese composite leading indicator (CLI) with trend-restored in twelve-month log differences and the actual 5-year Treasury and Bund yields. The dotted red line depicts a linear trend of the Chinese leading indicator after the crisis. Sample spans from June 2009 to December 2017. Source: BUBA,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

My main contribution is to measure the global spillovers of a Chinese slowdown on the 5-year nominal interest rates in the US and Germany. To quantify the global spillovers of a Chinese slowdown on the US/German nominal term structure through the signaling and portfolio balance channel, as well as to disentangle both channels, I proceed as follows.

First, to measure the *global* spillovers of a Chinese slowdown I estimate the *joint* affine model of the US and German nominal term structures in the post financial crisis sample. I use the principal component analysis and extract the principal components which affect the bond prices directly. The macroeconomic variables affect the bond prices merely through the principal components with a lag. In the model I include, the US and German unemployment rates, the leading indicators, and core inflations, the Chinese leading indicator and inflation, and the USD/EUR exchange rate.

Second, I use an affine term structure model to decompose changes in the 5-year nominal interest rates into (1) changes in the expected future nominal short rate, "the signaling channel," and (2) the estimated 5-year term premium, "the portfolio balance channel." The alternative name for the first component, the expected future nominal short rate, is the risk-neutral yield.

Third, to deal with the different monetary regimes since the Sovereign debt crisis (SDC) I also model the German term structure independently from the US in the post SDC sample (after 2011).

Forth, I measure the effect of the Chinese real growth on the US/German nominal term structure with the Chinese leading indicator *after* I control for Chinese CPI inflation. I focus on the Chinese OECD composite leading indicator with a trend restored. The leading indicator is composed of the broad mix of economic time series which fluctuate similarly to the business cycles, and with the trend restored, resembles the long-run output dynamics[8].

The empirical results yield essentially two key new findings.

First, estimates of the joint model in the post financial crisis sample show that a drop in the Chinese leading indicator leads to a significant drop in US/German growth over the first year: the US leading indicator decreases by 42 basis points, and German leading indicator by 45 basis points (after I control for the US/German core inflation). In the US, this leads to clear negative signaling effects but no portfolio balancing effects. A lower Chinese leading indicator (a percentage point decrease) signals a downward correction of expectations of the US future nominal short rate, on average by 5 basis points. In Germany, I find effects with the opposite sign to what I expected. The lower Chinese leading indicator signals an upward correction of expectations of the German future nominal short rate, and lowers the estimated 5-year Bund term premium.

[8] The change of Chinese demand for the US Treasuries and German Bunds is proportionate to the Chinese real growth over the long-run (Gourinchas and Jeanne, 2012, Caballero, Farhi and Gourinchas, 2015, 2016, 2017). At the same time, the Chinese foreign reserves are an instrument of the Chinese foreign exchange policy (ECB, 2017, Kroeber, 2011).

Second, in the post Sovereign debt crisis sample, a drop in the Chinese leading indicator leads to an even bigger drop in German growth over the first year: the German leading indicator decreases by almost 60 basis points (after I control for German core inflation). Like in the US, now a lower Chinese leading indicator (a percentage point decrease) signals a downward correction of expectations of the German future nominal short rate, on average by 7 basis points. However, the higher estimated 5-year Bund term premium neutralizes these negative signaling effects on the estimated 5-year Bund yield.

A Chinese slowdown affects the US/German long-term nominal interest rates mainly by signaling a downward correction of expectations of the future nominal short rates in the US and Germany. I find a weaker empirical support for "the portfolio balance channel." Given the fact that China has grown essentially into the biggest economy in the world, is an important player in commodity markets, and holds a substantial amount of the global public debt, China has become an important determinant of global nominal interest rates. The FED and the ECB should closely monitor the factors such as the Chinese growth and inflation to prevent any unnecessary negative spillovers on the US and EA growth and long-term nominal interest rates. Especially, because the FED began to tighten the monetary policy in the US, and the ECB's net asset purchases are expected to end in December 2018.

2. Review of the literature on the global spillovers of a Chinese slowdown

I start this section by surveying the literature on the relationship between the Chinese and global growth. I continue by surveying the literature on how important China is for global commodity markets. I conclude this section by stating some of the recent estimates of how big are the global spillovers of a Chinese slowdown.

Before the financial crisis, Chinese growth was mainly based on the exports. After the financial crisis, high domestic investments are supporting the Chinese growth model. The financial crisis substantially decreased the demand for the Chinese products by developed economies. After the financial crisis, the Chinese authorities committed to rebalancing the economy towards domestic private consumption. Nevertheless, investments in 2013 still account for 45 percent of GDP whereas the private consumption accounts for 35 percent (Gauvin and Rebillard, 2015).

Kose, Otrok and Prasad (2012) conclude that business cycles converged within advanced economies and EMEs but decoupled between. Gauvin and Rebillard (2015) argue that decoupling could be an end result of high and imbalanced Chinese growth which is slowing down. The decoupling could be a temporary phenomenon rather than "the new normal." 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. A Chinese slowdown has an effect on the lower real growth in the US and EA.

Chinese investment-led growth is highly commodity-intensive. 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. Chinese rising demand for commodities has been one of the main drivers of the commodity price boom before the financial crisis. Caballero, Farhi and Gourinchas (2008) argue that a super-cycle in commodity prices, global imbalances and the subprime crisis share a global environment where sound and liquid financial assets are in a scarce supply. Figure 2 depicts the price of iron ore from December 1998 to May 2017. We can see that the price of iron ore decreases from 180 US dollars per metric ton during the crisis to 60 US Dollars in 2017.

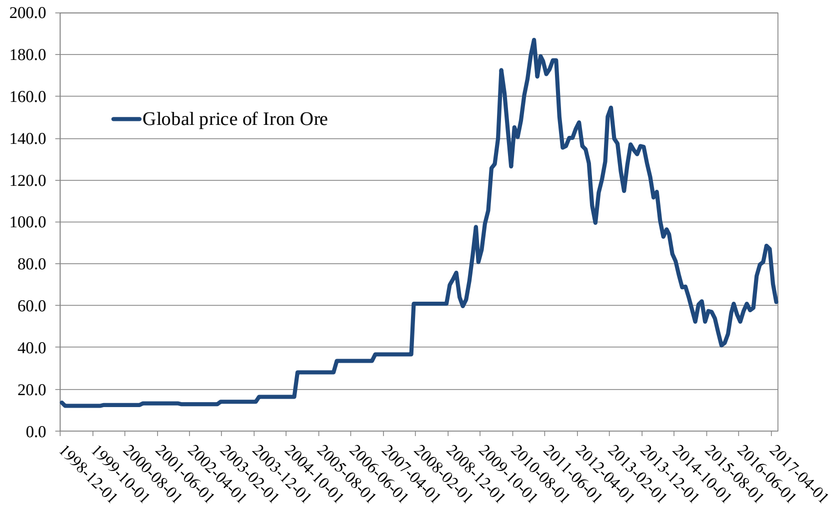

Figure 2: the Global price of Iron Ore, US Dollars per Metric Ton, Monthly, Not Seasonally Adjusted. From December 1998 to May 2017. Source: St. Louis Fed.

Kilian and Hicks (2013) show that the unexpectedly high growth in emerging Asia drove the repeated positive shocks to the demand for commodities between 2003 and 2008. Kilian and Park (2009) show that during 1975 and 2006 the demand and supply shocks driving the global crude oil market jointly account for 22 percent of the long-run variation in the real US stock returns. Marazzi and Sheets (2007) explore the sensitivity of the US import prices to changes in the exchange rate. They find that the exchange rate sensitivity of US import prices declined, from 0.5 during the 1970s and 1980s, to around 0.2 after 2000. When the exchange rate sensitivity of US import prices is equal to 0.5, a 1 percent depreciation of the US dollar is associated with an *increase* of US import prices of about 0.5 percent. When the exchange rate sensitivity is low, even a significant drop in the US dollar has only a modest effect on import prices. The *quantity* of imports is reduced by only a small amount. This limits the increase of the *real* net exports and the real US growth when the US dollar depreciates. Authors link the decline in the exchange rate sensitivity to the increased global competition arising mainly from China.

Metelli and Natoli (2017) estimate that, without taking into account the Central Bank's responses, a negative shock to Chinese investments, a reduction in annual output growth equal to 2 percentage points over two consecutive years, decreases the US and EA inflation by 10 basis points in the first, and 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 more in the second. US GDP decreases by 20 basis points in the first year and remains unchanged in the second. Independently, the authors introduce a negative shock to the commodity prices. In particular, oil price declines by 10 US dollars and the metals price index by 10 percentage points. Lower commodity prices decrease the EA inflation by 60 basis points in the first and by 80 basis points in the second year. The US inflation decreases by 70 basis points in the first and by a percentage point in the second. Gauvin and Rebillard (2015) state four reasons why a Chinese slowdown could continue and become sharper than expected: (1) rebalancing towards the domestic private consumption, (2) overinvestments, (3) unsustainable debt trends, and (4) a growing real estate bubble. Based on the reviewed literature I conclude that China is important for global growth and inflation, and it is important to measure the global spillovers of the Chinese real growth on the long-term nominal interest rates in the US and EA (Germany).

3. Affine Term Structure Model

I estimate an affine term structure model with unspanned macroeconomic variables. 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[9]

$$X_t = \mu + \Phi X_{t-1} + v_t = \begin{bmatrix} X_t^s \\ X_t^u \end{bmatrix} = \mu + \Phi \begin{bmatrix} X_{t-1}^s \\ X_{t-1}^u \end{bmatrix} + \begin{bmatrix} v_t^s \\ v_t^u \end{bmatrix} \tag{1}$$

Where

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

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

I use the principal component analysis and extract the principal components from the US and German nominal term structures of interest rates which affect the bond prices directly (X_t^s). The macroeconomic variables (X_t^u) affect the bond prices merely through the principal components with a lag. In the model I include, the US and German unemployment rates, the leading indicators, and core inflations, the Chinese leading indicator and inflation, and the USD/EUR exchange rate.

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,

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

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

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.[10] I model the German term structure independently from the US in the post Sovereign debt crisis (SDC) sample. Correspondingly, I extract the principal components solely from the German nominal term structure in the post SDC sample, and impose $\delta_0^{j,s}$ and $\delta_1^{j,s'}$ equal to zero for $j = US$.

The pricing (risk-neutral) transition matrices, $\mu^\star$ and $\Phi^\star$, can be written as

$$\mu^\star = \begin{bmatrix} \mu_s - \lambda_0^s \\ \mu_u - \lambda_0^u \end{bmatrix} = \begin{bmatrix} \mu_s - \lambda_0^s \\ \mu_u \end{bmatrix} = \begin{bmatrix} \mu_s^\star \\ \mu_u^\star \end{bmatrix}, \qquad \Phi^\star = \begin{bmatrix} \Phi_{ss} - \lambda_1^{ss} & \Phi_{su} - \lambda_1^{su} \\ \Phi_{us} - \lambda_1^{us} & \Phi_{uu} - \lambda_1^{uu} \end{bmatrix} = \begin{bmatrix} \Phi_{ss} - \lambda_1^{ss} & 0 \\ \Phi_{us} & \Phi_{uu} \end{bmatrix} = \begin{bmatrix} \Phi_{ss}^\star & 0 \\ \Phi_{us}^\star & \Phi_{uu}^\star \end{bmatrix}. \tag{4}$$

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 $\Phi_{su} = \lambda_1^{su} \in \mathcal{R}^{K_s \times K_u}$.

Given the assumptions (1) – (4), (log) bond prices of maturity n in country j at time period t are exponentially affine in the spanned factors (principal components)

$$lnP_{j,t}^{(n)} = A_n^{j,s} + B_n^{j,s'} X_t^s \tag{5}$$

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

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

$$y_{j,t}^{(n)} = a_n^{j,s} + b_n^{j,s\prime} X_t^s, \tag{6}$$

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 $B_n^{j,s\prime}$ are given as $(for\ n > 1)$

$$A_n^{j,s} = A_{n-1}^{j,s} + B_{n-1}^{j,s\ \prime}(\mu_s - \lambda_0^s) + \frac{1}{2} B_{n-1}^{j,s\ \prime} \Sigma_{ss} B_{n-1}^{j,s} - \delta_0^{j,s} \tag{7}$$

$$B_n^{j,s\prime} = B_{n-1}^{j,s\ \prime}(\Phi_{ss} - \lambda_1^{ss}) - \delta_1^{j,s\prime} \tag{8}$$

$$A_0^{j,s} = 0, \quad A_1^{j,s} = -\delta_0^{j,s}, \quad B_0^{j,s\prime} = 0, \quad B_1^{j,s\prime} = -\delta_1^{j,s\prime}, \quad for\ j = US\ and\ Germany. \tag{9}$$

Again, when $\delta_0^{j,s}$ and $\delta_1^{j,s\prime}$ equal zero for $j = US\ or\ Germany$ the two-country model is reduced to a single country model. When prices of risk parameters λ_0^s and λ_1^{ss} in (7) and (8) are set to zero, the recursions generate the risk adjusted bond pricing parameters

$$A_n^{j,s,RF} = A_{n-1}^{j,s,RF} + B_{n-1}^{j,s,RF\prime} \mu_s + \frac{1}{2} B_{n-1}^{j,s,RF\prime} \Sigma_{ss} B_{n-1}^{j,s,RF} - \delta_0^{j,s} \tag{10}$$

$$B_n^{j,s,RF\prime} = B_{n-1}^{j,s,RF\prime} \Phi_{ss} - \delta_1^{j,s\prime} \tag{11}$$

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, $E_t\left(-\left(\frac{1}{n}\right) lnP_{j,t}^{(n)}\right) = -\left(\frac{1}{n}\right)\left(A_n^{j,s,RF} + B_n^{j,s,RF\prime} X_t^s\right)$. 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[11,12,13]

[11] 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.

$$RNY_{j,t}^{(n)} = -\left(\frac{1}{n}\right)\left[\left(A_n^{j,s,RF}\right) + B_n^{j,s,RF'} X_t^s\right] \tag{12}$$

$$TP_{j,t}^{(n)} = -\left(\frac{1}{n}\right)\left[\left(A_n^{j,s} - A_n^{j,s,RF}\right) + \left(B_n^{j,s} - B_n^{j,s,RF}\right)' X_t^s\right] \tag{13}$$

To investigate how unspanned macro factors (X_t^u), and Chinese leading indicator in particular, affect the spanned factors (X_t^s) and (log) bond prices ($lnP_{j,t}^{(n)}$) I focus on $\hat{\Phi}_{su}$. Predicted values of factors in period t, given the spanned and unspanned factors at $t-1$ equal

$$\hat{X}_t = \hat{\mu} + \hat{\Phi}\boldsymbol{X_{t-1}} \tag{14}$$

Predicted (model-implied) (log) bond prices and continuously compounded yields at time t given the information at $t-1$ can be written as

$$ln\hat{P}_{j,t}^{(n)} = A_n^{j,s} + B_n^{j,s'} \hat{X}_t^s = A_n^{j,s} + B_n^{j,s'}\left(\hat{\mu} + \hat{\Phi}\boldsymbol{X_{t-1}}\right) \tag{15}$$

$$\hat{y}_{j,t}^{(n)} = a_n^{j,s} + b_n^{j,s'}\left(\hat{\mu} + \hat{\Phi}X_{t-1}\right) = -\left(\frac{1}{n}\right)\left[A_n^{j,s} + B_n^{j,s'}\left(\hat{\mu} + \hat{\Phi}\boldsymbol{X_{t-1}}\right)\right] \tag{16}$$

Predicted risk neutral yield ($\widehat{RNY}$) and the term premium ($\widehat{TP}$) at time t given the information at $t-1$ can be written as

$$\widehat{RNY}_{j,t}^{(n)} = -\left(\frac{1}{n}\right)\left[A_n^{j,s,RF} + B_n^{j,s,RF'}\left(\hat{\mu} + \hat{\Phi}\boldsymbol{X_{t-1}}\right)\right] \ (signaling) \tag{17}$$

$$\widehat{TP}_{j,t}^{(n)} = -\left(\frac{1}{n}\right)\left[\left(A_n^{j,s} - A_n^{j,s,RF}\right) + \left(B_n^{j,s} - B_n^{j,s,RF}\right)'\left(\hat{\mu} + \hat{\Phi}\boldsymbol{X_{t-1}}\right)\right] \ (portfolio\ rebalance) \tag{18}$$

[12] D'Amico and King (2013), among others, emphasize the portfolio balance effects of the FED's QE programmes. Bauer and Rudebusch (2014) find that the FED's QE programmes have important signaling effects.

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

All conditional *in-sample* forecasts which I present in this paper, base case scenarios, and scenarios where I increase Chinese leading indicator by a percentage point, are based on equations (15) − (18), and information at time $t-1$.

Diez de Los Rios (2018) notices that when the state variables are linear combinations of yields (i.e., $X_t^s = P'y_t$, for some full-rank matrix P) self-consistency implies[14,15]

$$P'a(\theta) = 0, \qquad P'b(\theta) = I, \tag{19}$$

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

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

Diez de Los Rios (2015) exploits conditions in (19) and proposes an asymptotic least squares (ALS) estimator. Goliński and Spencer (2017) notice that the estimator diverges with more than three spanned factors. 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).

4. Data

According to the NBER, the financial crisis started in December 2007 and ended in June 2009. I estimate the joint model of the US and German nominal term structure of interest rates from June 2009 to December 2017. I estimate the affine term structure model of the German nominal term structure independently from the US nominal term structure from December 2011 to December 2017.

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[14] 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.

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

The parameters of the zero coupon yield curve are retrieved from Deutsche Bundesbank (BUBA) and Gürkaynak, Sack and Wright (2007). To construct zero-coupon yields with maturity n, $y_t^{(n)}$, I follow Gürkaynak, Sack and Wright (2007)

$$y_t^{(n)} = \beta_{0,t} + \beta_{1,t}\left[\frac{1 - exp\left(-\frac{n}{\tau_{1,t}}\right)}{\frac{n}{\tau_{1,t}}}\right] + \beta_{2,t}\left[\frac{1 - exp\left(-\frac{n}{\tau_{1,t}}\right)}{\frac{n}{\tau_{1,t}}} - exp\left(-\frac{n}{\tau_{1,t}}\right)\right] + \beta_{3,t}\left[\frac{1 - exp\left(-\frac{n}{\tau_{2,t}}\right)}{\frac{n}{\tau_{2,t}}} - exp\left(-\frac{n}{\tau_{2,t}}\right)\right] \quad (20)$$

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 the Eurostat. I retrieve the leading indicators of the US, German and Chinese economies, and the Chinese CPI inflation from OECD[16]. I retrieve the USD/EUR exchange rate from the ECB.

Figure 3 depicts the first six principal components of the joint US and German term structure in the post financial crisis sample. The loadings on the yields of different maturities of the first and the second principal component are approximately equal and are therefore representing the levels of the US and German term structures. Loadings of the third and fourth principal component are almost monotonically decreasing or increasing as I move from the shortest maturity bond to the longest maturity bond. They are representing the slopes of the term structures. The loadings of the third principal component on the US yields have a negative slope, whereas the slope of loadings on German yields is positive. The fourth principal component has a high loading on the short rate and a low loading on the 5-year bond in the US and Germany. When I consider the fourth principal component, loadings in the US and Germany have a negative slope. The fifth and sixth principal component are representing the curvatures of the US and German term structures. Again, loadings of the sixth principal component remain positive in the US but become negative in Germany.

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

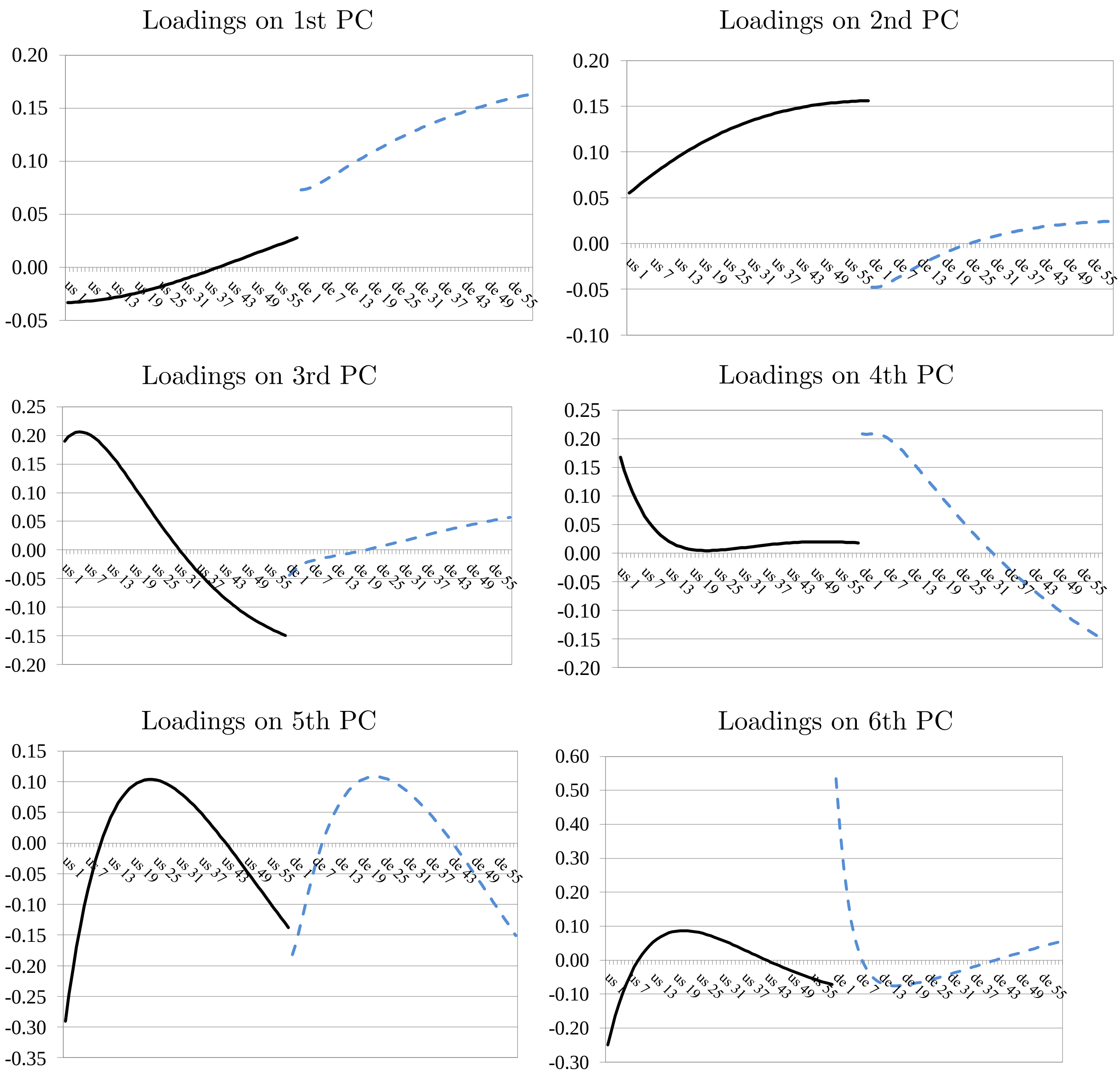

Figure 3: Loadings of US (black line) and German (dashed-blue line) monthly zero-coupon yields with maturities of one to sixty months (5 years) on the six global principal components. Sample spans from June 2009 to December 2017.

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 the variation in German nominal it explains only 11 percent of the variation in the US nominal yields (up to the maturity of 5 years).

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 shows the US, Chinese and German leading indicators in the post financial crisis sample. The growth of the Chinese leading indicator is decreasing. The Chinese leading indicator grows at an annual rate of 15 percent in 2009. The growth decreases to 5 percent in 2017. The dotted red trend line shows a linear trend after the crisis. The trend is negative and the growth of the Chinese leading indicator is converging towards the German and the US leading indicator.

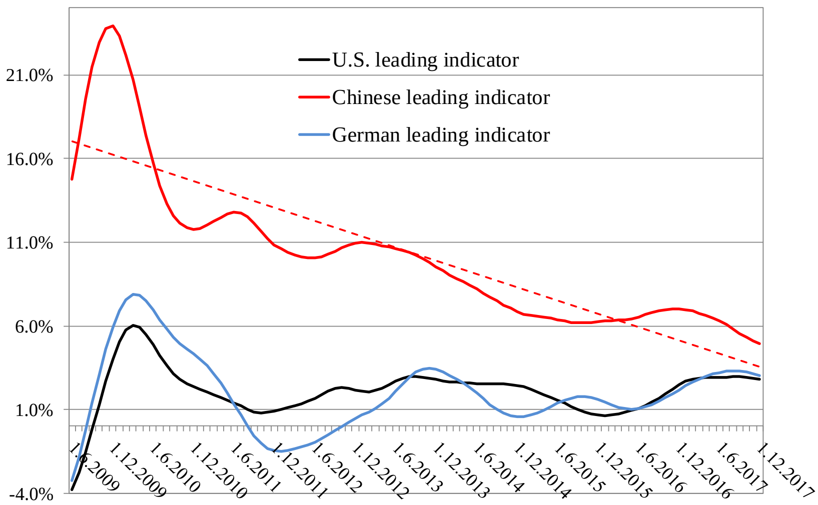

Figure 4: The US, German and Chinese composite leading indicators (CLIs) with trends-restored. Twelve-month log differences. Sample spans from June 2009 to December 2017. Source: OECD.

Figure 5 presents the US core inflation, German core inflation, and Chinese inflation. We can observe a negative inflation in China following the crisis. The inflation increases to 6 percent in 2011 and varies around 2 percent after 2012. In the post financial crisis sample, the German core inflation does not increase above the 2 percent which is the ECB's long-term goal. The US core inflation is higher than the German. In the post Sovereign debt crisis sample, it varies in a close range around the FED's 2 percent long-term goal.

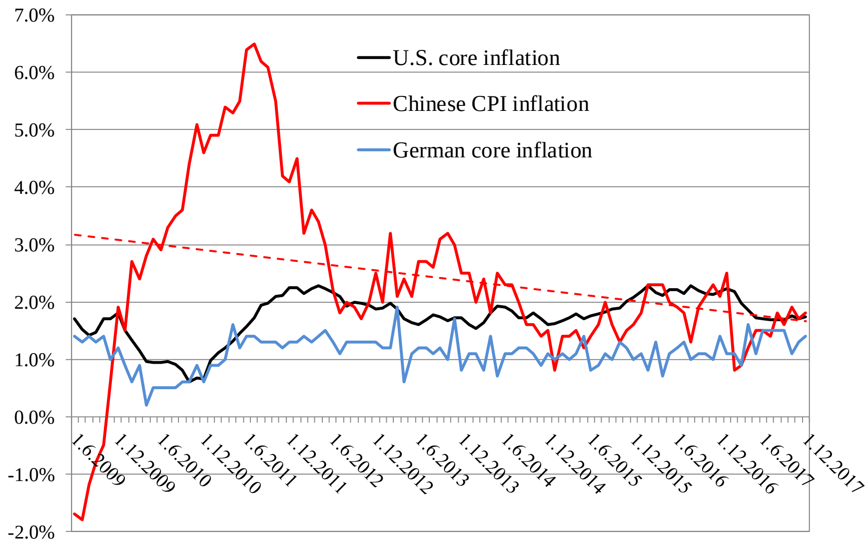

Figure 5: US core inflation, German core inflation, and Chinese inflation (yearly growth of the CPI index). Sample spans from June 2009 to December 2017. Source: St. Louis FRED, Eurostat, and OECD.

Table 2 presents the descriptive statistics. Average yearly growth rates of OECD leading indicators in the US and Germany are similar. From June 2009 to December 2017, on average, US leading indicator increases by 2.1 percent. The German leading indicator increases by 2 percent. After the crisis the average German unemployment rate, 5.3 percent, is smaller than in the US, 7 percent. Average German 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), 5-year government nominal yields, in the US and Germany, and monthly changes of US dollar against the Euro. 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
USD monthly appreciation (+) /	-0.2%		2.7%		-4.7%		3.5%	

4.1. Bund scarcity in the post financial crisis sample

I start a subsection by discussing the ECB's public sector purchase programme. I motivate, (1) why I decided to re-estimate the affine term structure model in the post Sovereign debt crisis sample, (2) why I model the German nominal term structure independently of the US, and (3) why I focus on the German Bunds. By the end of 2017 the Bund free-float, the amount of Bunds available to the private investors decreased to less than 10 percent. Cœuré (2018) argues that the lower Bund free-float depressed the long-term nominal interest rates in Germany, the term premia of longer-term Bunds, and the volatility of Bund prices.

To address the concerns of the ongoing Sovereign debt crisis, on 6th of September 2012 ECB announced free unlimited support for all Eurozone countries involved in a sovereign state bailout/precautionary programme through outright monetary transactions (OMT). In September 2014 the ECB initiated the asset purchase programme. In March 2015 it was expanded (expanded asset purchase programme, hereon APP) to include public sector securities (public sector purchase programme, hereon PSPP)[17,18].

ECB increased holdings of EA and German government bonds in particular. Together with the holdings of the foreign Central Banks, these purchases lowered the amount of government bonds available to private investors. The holdings of foreign Central Banks became relatively less important for the evolution of Bund prices than before the initiation of PSPP. The German Bunds effectively determine the risk-free curve of the Euro Area. Cœuré (2018) points out that as the result of the PSPP the outstanding amount of the Bunds available to the private investors, so-called free-float, is the lowest among all Eurozone members. Figure 6 presents the historical evolution of the PSPP.

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[17] At many occasions ECB Governor Mario Draghi stressed that monetary policies in the US and EA will stay on the diverging paths for longer period, i.e. ECB (2014) and Draghi (2015).

[18] Obstfeld (2018) questions if extremely accommodative monetary policies in the US and the EA after the financial crisis contributed to the productivity slowdown.

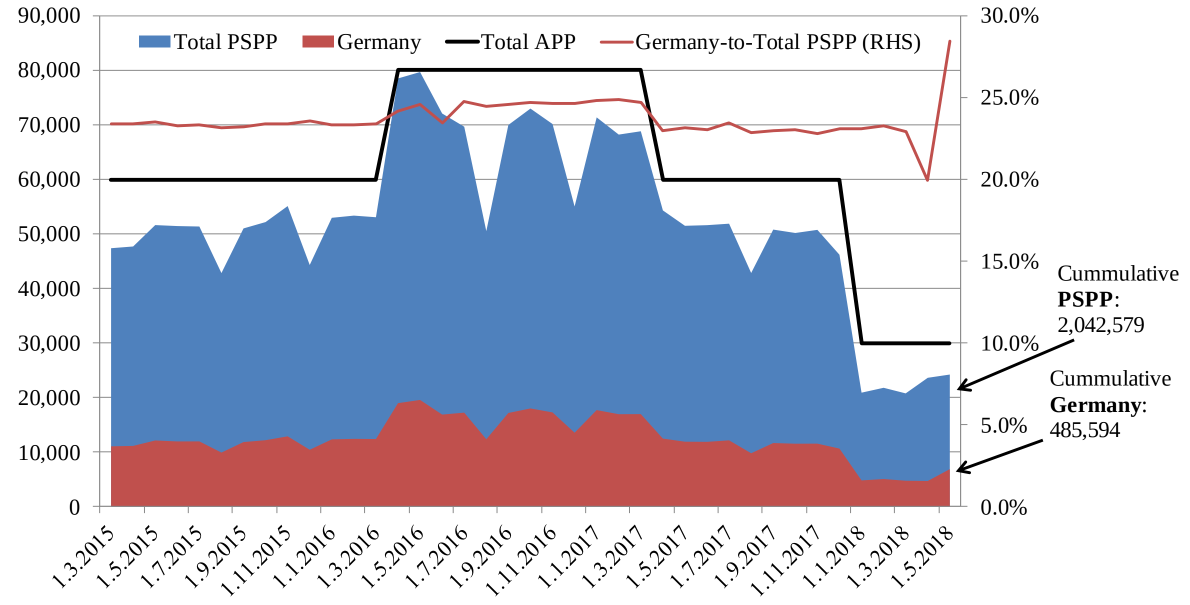

Figure 6: Amount of German bonds bought through the Public sector purchase programme (PSPP) in millions of EUR. Source: ECB.

From March 2015 to March 2016 the ECB was buying 60 billion EUR of securities each month. The pace strengthened from April 2016 to March 2017 when purchases increased to 80 billion EUR per month. From April to the end of 2017 the programme is reduced back to 60 billion EUR per month. In 2018 the ECB is buying 30 billion EUR of securities each month and the programme is expected to end in September. Blue area in Figure 6 shows that the ECB is mainly buying the public debt of Euro Area members. A major part of total PSPP represents the public debt of Germany. In particular, every month when PSPP was equal to 60 billion EUR or more the ECB bought at least 10 billion EUR of German Bunds per month. The German Bunds represent approximately 25 percent of the total PSPP. At the moment, ECB is holding more than 2 trillion EUR of the Euro Area's public debt and almost a half of a trillion EUR of German Bunds.

Figure 7 depicts evolution of 5 year German yield since the financial crisis in three sub-periods: (1) during the Sovereign debt crisis, (2) after the Sovereign debt crisis, shortly before the ECB announced full unlimited support to financial markets and initiated Outright Monetary Transactions programme, and (3) after the beginning of PSPP.

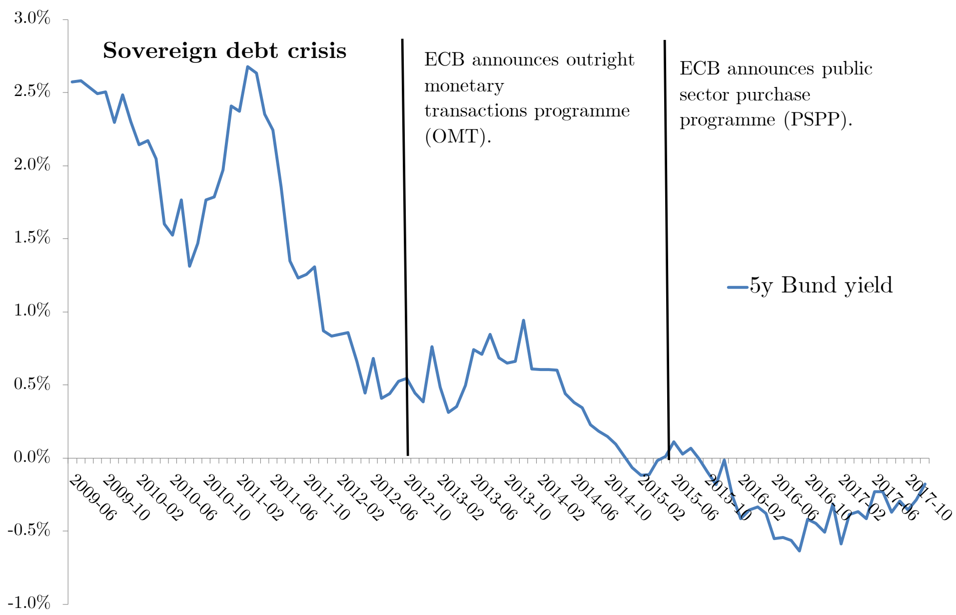

Figure 7: German 5-year yield in the post financial crisis sample (monthly data). Source: Deutsche Bundesbank (BUBA).

After the financial crisis, 5-year yield decreased from 2.5 percent to 1.5 by 2010. After 2011 we observe a decrease of 5-year Bund yield over the longer-term. Cœuré (2017) argues that a combination of regulatory requirements, and direct and indirect effects of the PSPP, lowered the Bund yields. After 2011, 5-year Bund yield did not recover from falling below one percent. In December 2017 5-year Bund yield was still negative, –18 basis points. Its mean over December 2011 to December 2017 equals 14 basis points.

Figure 8 turns to the German public debt. We observe a steady *decrease* of the public debt-to-output ratio after the sovereign debt crisis, from 80 to almost 60 percent. Figure 9 compares holdings of domestic Central Bank (Deutsche Bundesbank, hereon BUBA) with holdings of foreign investors (both variables are scaled by the total public debt). Holdings of foreign investors increased from 40 percent in 2000 to 60 percent by the end of the Sovereign debt crisis in 2012. Afterwards, they decreased to approximately 50 percent in 2017. Arslanalp and Tsuda (2014) show that at the end of 2011 out of total foreign holdings, foreign Central Banks (official sector) held a half of 50 percent or approximately 25 percent of total outstanding German government debt. The foreign Central Banks were holding 814 billion USD of Bunds at the end of 2011. Before the initiation of PSPP in 2015 the share of Bunds held by BUBA was essentially zero. Approximately half a trillion (486 billion) EUR of

Bunds which are currently held by BUBA represent approximately 15 percent of total outstanding German public debt. A sudden surge in BUBA's holdings is a result of the initiation of the PSPP. Combination of the sudden surge of BUBA's holdings and a steady decrease of holdings by foreign investors after 2014 imply that after the initiation of PSPP the *relative* importance of the foreign Central banks for the development of Bund prices decreased substantially vis-à-vis the BUBA.

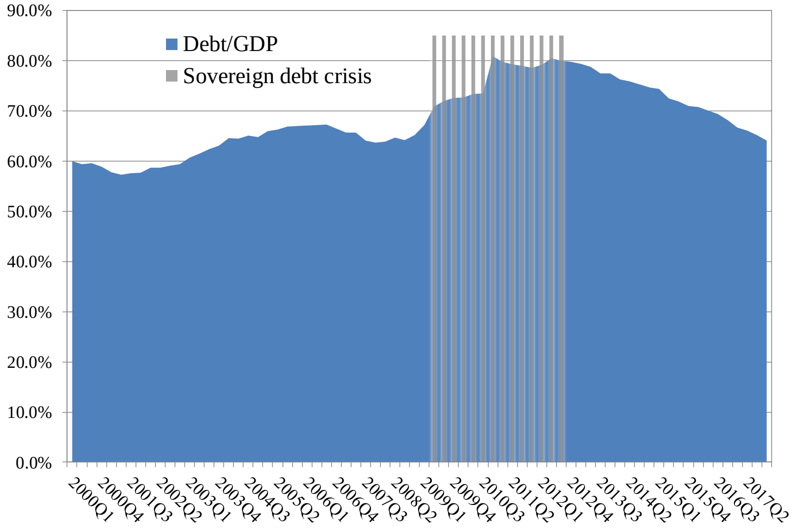

Figure 8: German's public debt-to-GDP from 2000 to 2017 (quarterly data). The European sovereign debt crisis in the shaded area. Source: Deutsche Bundesbank (BUBA).

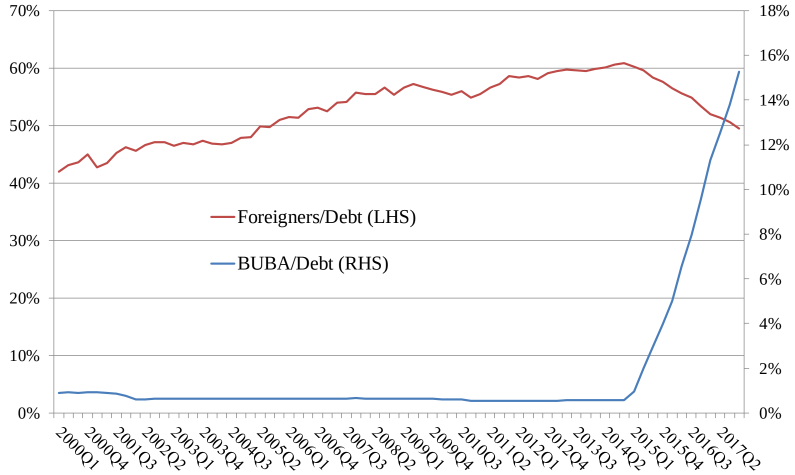

Figure 9: Holdings of German government debt by foreign investors and Deutsche Bundesbank (BUBA). Source: Deutsche Bundesbank (BUBA).

Figure 10 shows that non-EA investors increased holdings of shorter-term Bunds (with a maturity of up to two years), from 70 percent in 2013 to more than 80 percent in 2017 (left panel)[19]. However, the increase is exacerbated due to two reasons. First, on the demand side, BUBA's holdings increased from effectively 0 to 15 percent since 2015. Second, on the supply side, lower yields stimulate government to issue disproportionate amounts of longer maturity debt in order to lock in low costs of financing. While the share of bonds with maturities of two to 5 years accounted for more than 17 percent of outstanding German government debt in 2012, this share decreased to 11 percent by 2017 (Cœuré, 2017). At the end of 2017, the non-EA investors held approximately 50 percent of the outstanding German government debt with longer maturity than two years (Figure 10, right panel). The share slightly increased since the ECB announced the PSPP. Blattner and Joyce (2016) find that the average maturity of EA safe asset holdings by foreign central banks is four years with a standard deviation below two months.

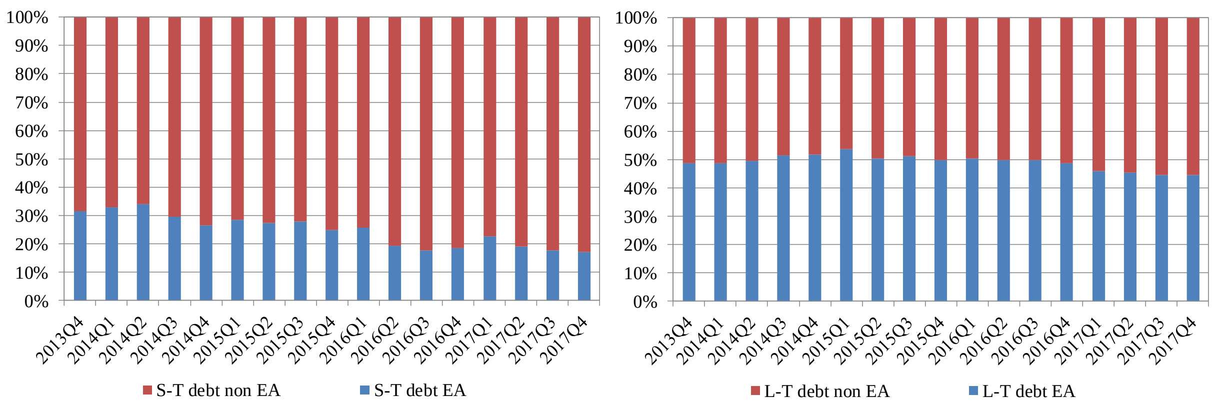

Figure 10: Holdings of German government debt with original maturity of up to two- and more than two- years by euro area (EA) and non-euro area investors (non-EA) once netted of holdings by Deutsche Bundesbank. Source: ECB's Securities holdings statistics.

The Bund bond free-float is constructed by computing the fraction of outstanding bonds that are held neither by the Eurosystem under the PSPP nor by foreign central banks as part of their foreign exchange reserves. It represents a fraction of bonds available to private investors. The Bund free-float decreased substantially after ECB initiated PSPP, from approximately 50 to 10 percent. Cœuré (2018) notices the highly non-linear relationship

[19] The outstanding debt is netted of the BUBA's holdings.

between the bond free-float and the term premium. The relationship is only mildly positive when the bond free-float is lower than 50 percent while it increases substantially and becomes highly positive as the bond free-float approaches 100 percent. When the bond free-float is low the term premium of the longer-term bonds moves closer to zero and becomes less volatile. Long-term interest rates increase only after the expected supply of bonds changes by a very large amount. Blattner and Joyce (2016) compute the bond free-float by subtracting *only* the holdings of foreign Central Banks from outstanding bonds (they do not account for the holdings of the Eurosystem). They find that a shock to bond free-float decreases the short rate, slope and the curvature of the term structure of EA interest rates[20,21].

4.2. Post Sovereign debt crisis sample

Figure 11 shows loadings of the first (solid black), second (dotted red), third (dashed green) and forth (dotted-dashed pink) principal component on the sixty monthly maturity yields when I extract principal components from the German nominal term structure independently from the US. The first principal component loads fairly equally on yields of different maturities. It is designated as the level factor. Patterns of loadings of the second principal component, "the slope," increase as I move from the left to the right. The slope is positive. The third principal component loads negatively on yields of shorter and longer maturities, whereas weights on the middle maturities are positive. It resembles the curvature of the term structure. Table 3 shows that the first four principal components on average explain almost all variation of monthly maturity yields in Germany from December 2011 to December 2017.

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[20] Germany, France, Italy and Spain.

[21] Cœuré (2017, 2018) discusses the importance of the bond free-float for bond yields. When the Central Bank is buying the government bonds it decreases the quantity of bonds available to the private investors. By removing the duration risk from the market purchases decrease the volatility and move the term premium closer to zero. Changes in the long-term nominal interest rates are to a larger extent accounted by the variation in expectations about the future nominal short rate. Krishnamurthy, Nagel, and Vissing-Jorgensen (2017), Lemke and Werner (2017), and Altavilla, Giannone, and Lenza (2014) among others investigate the impact and the channels of the asset purchase programmes on bond yields. Aggarwal, Bai, and Laeven (2017) show that Central Banks interventions play an important role in reducing the safe asset shortages in the lending markets. Pelizzon et al. (2017) investigate spotlight and scarcity effects of Central Bank intervention in Japan. Greenwood and Vayanos (2014) present a term-structure model where risk-averse arbitrageurs absorb shocks to the demand and supply for bonds of different maturities which alters the price of the duration risk.

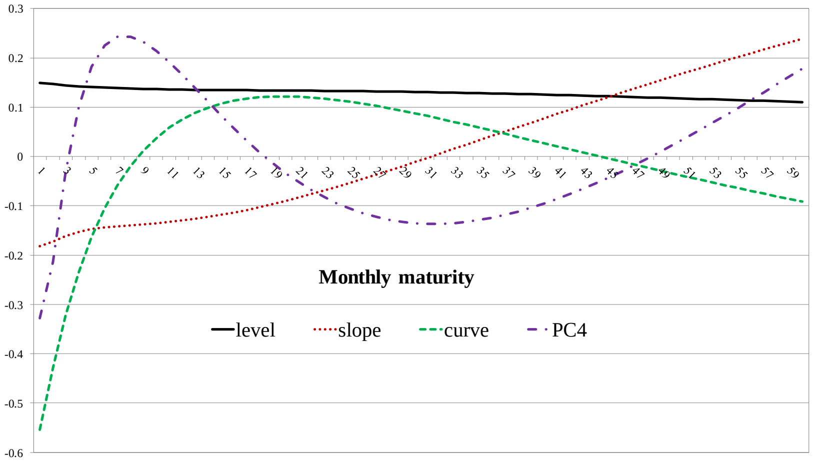

Figure 11: Loadings of principal components on 60 monthly maturity yields in Germany from December 2011 to December 2017.

Table 3: Average percentage of explained variation of 60 monthly maturity yields in Germany when I use one, two, three, or four principal components from December 2011 to December 2017.

	One Factor	Two Factors	Three Factors	Four Factors
Germany	97.6%	99.7%	100.0%	100.0%

Table 4 presents the descriptive statistics of the German economy in the post Sovereign debt crisis sample. The German economy is growing slower. The average yearly growth of the leading indicator equals 1.5 percent. Average core German inflation from December 2011 to December 2017 equals 117 basis points. Nominal yields are lower than in the post financial crisis sample. Average one-month Bund yield equals –24 basis points while the average 5-year Bund yield decreases to 14 basis points.

Table 4: Descriptive statistics. Yearly growth of OECD leading indicator, core inflation rate, unemployment rate, nominal short rate (one-month government nominal yield), and 5-year government nominal yield for the German economy. Sample spans from December 2011 to December 2017. Source: Eurostat, OECD, Deutsche Bundesbank (BUBA).

	Mean	Standard deviation	Percentiles 5th	95th
OECD CLI (yearly growth)	1.5%	1.4%	-1.3%	3.3%
Core Inflation	1.2%	0.2%	0.8%	1.5%
Unemployment rate	4.7%	0.6%	3.7%	5.4%
Short rate (1m nominal yield)	-24	38	-86	16
5-year yield	14	46	-55	84

Table 5 presents the average yearly growth rate of the Chinese leading indicator before and after the Sovereign debt crisis. The yearly growth of the Chinese leading indicator equals 15.8 percent before 2011 and decreases to 8 percent after 2011. The high average yearly growth rate from June 2009 to December 2011 is artificially inflated because of the rebound of the Chinese leading indicator following the financial crisis.

Table 5: Descriptive statistics. Yearly growth of OECD leading indicator and core inflation rate of the Chinese economy in two samples: from June 2009 to December 2011 (before 2011), and from January 2012 to December 2017 (after 2011). Source: OECD.

		Before 2011		After 2011	
		OECD CLI (yearly growth)	CPI index (yearly growth)	OECD CLI (yearly growth)	CPI index (yearly growth)
Mean		15.8%	3.2%	8.0%	2.1%
Standard deviation		4.4%	2.5%	1.9%	0.7%
Percentiles	5th	11.7%	-1.5%	5.7%	1.2%
	95th	23.6%	6.3%	10.9%	3.3%

I conclude this section by presenting the average yearly growth rates of Chinese leading indicator and the Chinese inflation rate in the post financial crisis sample, and after 2013 when a Chinese slowdown intensified, in Table 6. The average yearly growth rate of Chinese leading indicator in the post financial crisis sample equals 10.3 percent, and decreases substantially, to 6.8 percent after 2013. Average Chinese inflation rate decreases from 2.4 to 1.8 percent.

Table 6: Descriptive statistics. Yearly growth of OECD leading indicator and core inflation rate of the Chinese economy in two samples: from June 2009 to December 2017 (in the post financial crisis sample), and from December 2013 to December 2017 (after 2013). Source: OECD.

		Post financial crisis sample		After 2013	
		OECD CLI (yearly growth)	CPI index (yearly growth)	OECD CLI (yearly growth)	CPI index (yearly growth)
Mean		10.3%	2.4%	6.8%	1.8%
Standard deviation		4.5%	1.6%	1.0%	0.4%
Percentiles	5th	6.1%	0.6%	5.4%	1.0%
	95th	21.4%	5.5%	9.0%	2.5%

5. Main Results[22]

The principal components of the term structure are spanned while macro variables, the US and German unemployment rates, core inflations, the US, German and Chinese leading indicators, the Chinese CPI inflation, and the USD/EUR exchange rate are unspanned by the US/German nominal term structure. I present results in the post financial crisis sample, from June 2009 to December 2017, when I model the German nominal term structure of interest rates jointly with the US. I present results from December 2011 to December 2017 when I model the German nominal term structure of interest rates independently from the US.

5.1. Two-country affine term structure model

In this subsection, I estimate the two-country affine term structure model following Diez de Los Rios (2018). Figure 12 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 variation of yields. There are two small blips which are gauging the lower percentage of explained variation in the short rates.

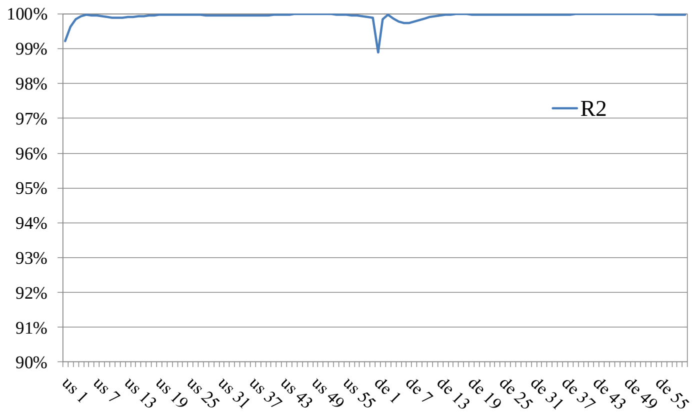

Figure 12: Percentage of explained variation of monthly yields with maturities of one to sixty months (5 years) in the US and Germany with the global six-factor model (which uses global PC1 to PC6). Sample spans from June 2009 to December 2017.

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[22] Estimated yields and term premia are based on Diez de Los Rios (2015, 2018) estimator.

5.1.1. Two-country affine term structure model – Short-run effects in the post financial crisis sample

Table 7 presents the estimated prices of risks of the global six-factor model. Higher Chinese leading indicator increases second PC, level 2, decreases the fourth PC, slope 2, and sixth PC, curve 2. Because slopes of both term structures are negative (when considering only the PC4), and the effect of Chinese leading indicator on PC4 is negative, an increase of the Chinese leading indicator increases the PC4 ("the slopes"). Figure 13 depicts the estimated average in-sample estimated 5-year Treasury and Bund yields and their estimated term premia. 5-year Treasury term premium decreases from 3.2 percent after the financial crisis to –2 percent by the end of 2017 (upper middle panel). The 5-year Bund term premium decreases from 1.7 percent in 2009 to 1.2 percent by the end of 2017. The US estimated 5-year risk-neutral yield (the expected future nominal short rate) increases from 0 after the financial crisis to 1.5 percent by the end of 2017. The German estimated 5-year risk-neutral yield (the expected future nominal short rate) decreases from 0.8 percent after the financial crisis to –1 percent by the end of 2017.

The estimated in-sample 5-year Bund term premium is lower and less volatile than the US term premium. When I take into account the dynamics of nominal term structures in the US and Germany volatility of estimated in-sample 5-year Bund yield is higher than in the US, 96 basis points compared to 47 basis points. When I increase the Chinese leading indicator by a percentage point, the in-sample average model implied Treasury 5-year yield increases by 5 basis points, from 153 to 158 basis points (Table 8, left panel). The term premium component remains intact. Average estimated 5-year Treasury term premium equals 113 basis points with a standard deviation of 130 basis points. Sensitivity analysis shows that the in-sample average estimated Treasury 5-year yield increases mainly because of the higher expected future nominal short rate. The estimated 5-year Treasury term premium remains mainly unchanged. The lower Chinese leading indicator lowers the estimated 5-year Treasury yield by lowering the expectations of the future short rate in the US through "the signaling channel."

Average in-sample estimated 5-year Bund yield after the financial crisis equals 67 basis points with a standard deviation of 96 basis points (Table 8, right panel). When I decrease the

Chinese leading indicator by a percentage point average estimated 5-year Bund yield decreases by 2 basis points. The estimated 5-year Bund term premium decreases by 5 basis points, from 71 to 76 basis points. The decrease of the estimated 5-year Bund term premium is compensated by an increase of the expected future nominal short rate by 3 basis points. The lower Chinese leading indicator decreases the estimated 5-year Bund yield by decreasing the estimated 5-year Bund term premium.

Table 7: Estimated prices of risk, λ_0^s and $\lambda_1^{s\cdot}$ of global (two-country) affine term structure model using an OLS estimator as outlined in Diez de Los Rios (2018). Sample spans from June 2009 to December 2017. Spanned factors: $X_t^s = [global\ PC\ 1_t \quad global\ PC\ 2_t \quad global\ PC\ 3_t \quad global\ PC\ 4_t \quad global\ PC\ 5_t \quad global\ PC\ 6_t]'$. Unspanned factors: $X_t^u = [ur_{U.S.,t} \quad ccpi_{U.S.,t} \quad CLI_{U.S.,t} \quad USD/EUR_t \quad ur_{de,t} \quad ccpi_{de,t} \quad CLI_{de,t} \quad CPI_{ch,t} \quad CLI_{ch,t}]'$. Bolded coefficients are significant at the 10% level. I present remaining estimated parameters in the Appendix A.1..

Factor	λ_0	$\lambda_{1,1}$	$\lambda_{1,2}$	$\lambda_{1,3}$	$\lambda_{1,4}$	$\lambda_{1,5}$	$\lambda_{1,6}$	$\lambda_{1,7}$	$\lambda_{1,8}$	$\lambda_{1,9}$	$\lambda_{1,10}$	$\lambda_{1,11}$	$\lambda_{1,12}$	$\lambda_{1,13}$	$\lambda_{1,14}$	$\lambda_{1,15}$
	(constant)	(global PC1)	(global PC2)	(global PC3)	(global PC4)	(global PC5)	(global PC6)	(ur_{us})	($CCPI_{us}$)	(CLI_{us})	(USD/EUR)	(ur_{de})	($CCPI_{de}$)	(CLI_{de})	(CPI_{ch})	(CLI_{ch})
global PC 1	-0.0048	**-0.3946**	0.0757	**-0.5090**	0.1483	0.3239	**-1.1162**	**13.7541**	**-18.5057**	**-5.2009**	0.1045	-10.9673	4.4333	2.0680	-1.4615	-0.1398
(t-statistic)	-0.093	-4.061	1.078	-2.613	0.447	0.768	-1.886	3.056	-2.861	-3.077	0.330	-1.581	1.147	1.563	-1.095	-0.122
global PC 2	**0.1087**	-0.0130	**-0.2624**	0.2913	-0.1178	-0.5400	-0.8016	-4.2809	**-16.5183**	-2.5193	-0.5063	-7.4600	-2.1194	-0.2034	-0.6525	**2.5641**
(t-statistic)	2.041	-0.129	-3.609	1.443	-0.343	-1.235	-1.306	-0.920	-2.470	-1.442	-1.547	-1.040	-0.530	-0.149	-0.473	2.166
global PC 3	**-0.0469**	**-0.0756**	**0.0870**	**-0.1548**	**0.2486**	0.0073	0.0047	**3.5066**	1.4927	-0.1058	**0.1803**	-0.8445	0.7841	0.2178	0.1236	-0.4467
(t-statistic)	-3.053	-2.709	4.209	-2.677	2.527	0.058	0.026	2.752	0.815	-0.221	2.011	-0.430	0.716	0.581	0.327	-1.378
global PC 4	-0.005	**0.070**	-0.019	0.039	**-0.416**	-0.038	0.034	1.457	2.500	0.639	-0.050	-1.400	-0.263	**0.837**	**-1.1292**	**-1.2105**
(t-statistic)	-0.325	2.651	-0.983	0.708	-4.457	-0.313	0.195	1.214	1.450	1.419	-0.592	-0.756	-0.256	2.372	-3.174	-3.964
global PC 5	**-0.022**	0.003	-0.004	**0.063**	0.038	**-0.299**	-0.157	**-2.018**	-0.073	0.313	**0.082**	**2.993**	**-1.088**	**-0.671**	**0.4107**	0.071
(t-statistic)	-2.314	0.169	-0.322	1.798	0.641	-3.777	-1.351	-2.881	-0.073	1.190	1.669	2.771	-1.808	-3.258	1.977	0.398
global PC 6	0.009	**0.035**	-0.010	**0.112**	**-0.176**	0.114	**-0.291**	0.054	**2.740**	**0.707**	-0.054	1.268	-0.481	0.212	**-0.5396**	**-0.6705**
(t-statistic)	1.018	2.223	-0.843	3.472	-3.195	1.612	-2.898	0.074	2.617	2.586	-1.048	1.129	-0.769	0.988	-2.499	-3.617

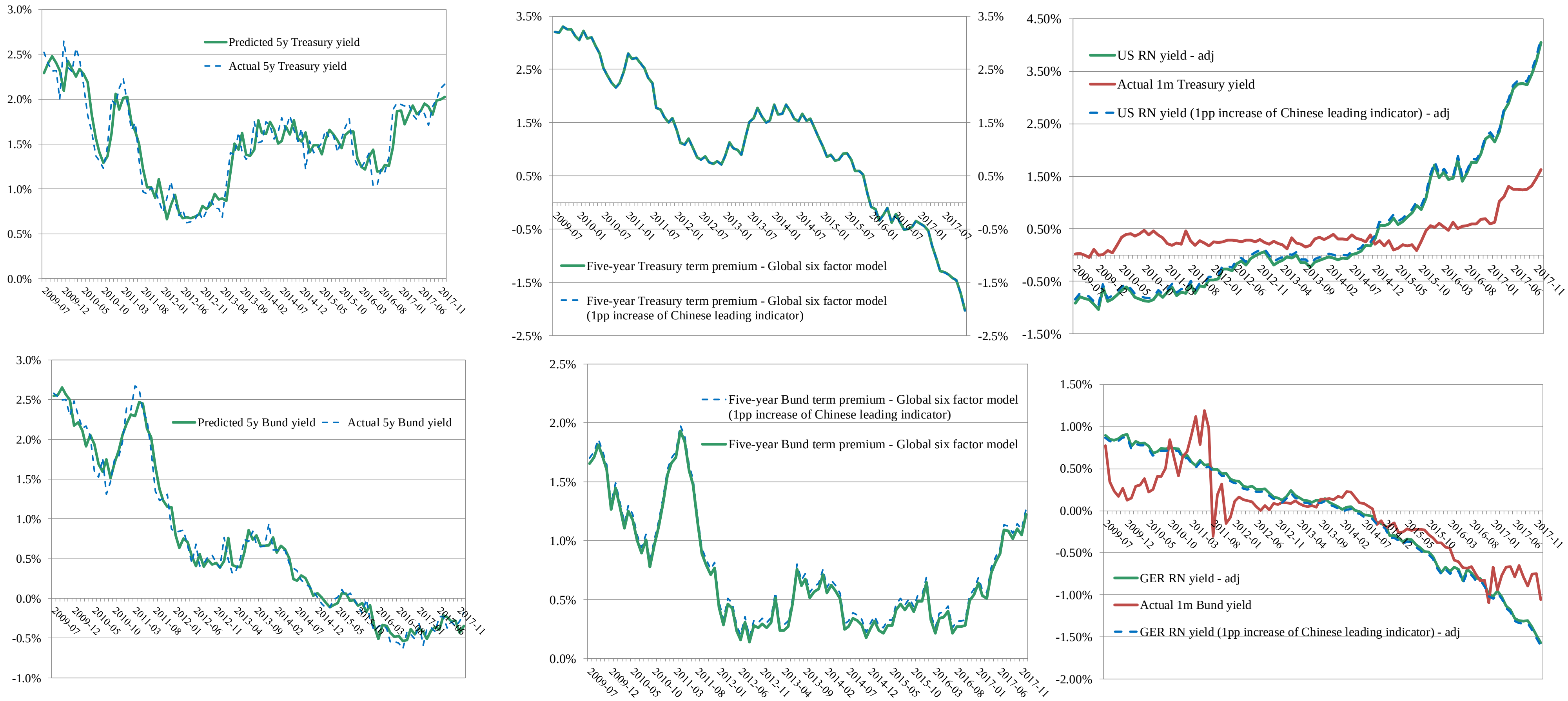


Figure 13: Model implied 5-year Treasury and Bund yield, the term premia, and the expected future nominal short rates (risk neutral yields), of a global six-factor model (which uses global PC1 to global PC6) and nine unspanned macro variables: US and German unemployment rates, core inflation rates, leading indicators (CLI), USD/EUR exchange rate, yearly change of Chinese consumer price index (CPI) and Chinese leading indicator. Using an OLS estimator as outlined in Diez de Los Rios (2018). Sample spans from June 2009 to December 2017. 5-year Treasury yield (upper left panel), Treasury term premium (upper middle panel), Treasury risk-neutral yield (upper right panel), and 5-year Bund yield (lower right panel), Bund term premium (lower middle panel), and Bund risk-neutral yield (lower left panel). Estimates are based only on the information available at $t-1$.

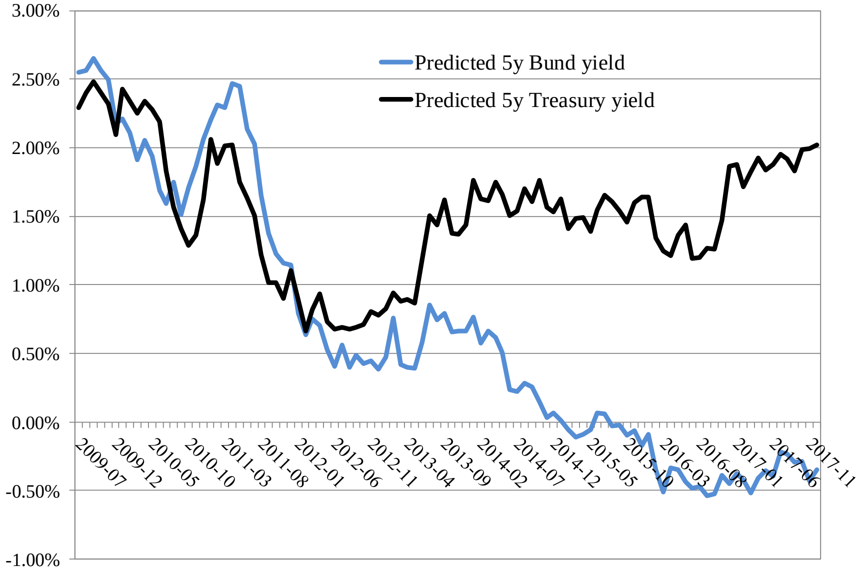


Figure 14: Model implied 5-year Treasury and Bund yield of global six-factor model (which uses global PC1 to global PC6) and nine unspanned macro variables: US and German unemployment rates, core inflation rates, leading indicators (CLI), USD/EUR exchange rate, yearly change of Chinese consumer price index (CPI) and Chinese leading indicator. Using an OLS estimator as outlined in Diez de Los Rios (2018). Sample spans from June 2009 to December 2017. Estimates are based only on the information available at $t-1$.

Table 8: Summary of the effects on the estimated 5-year Treasury yield, estimated 5-year Treasury term premium, estimated 5-year Treasury risk-neutral yield (expected future nominal short rate), the estimated 5-year Bund yield, estimated 5-year Bund term premium, estimated 5-year Bund risk-neutral yield (expected future nominal short rate), in the post financial crisis sample. The lower panel of the table presents the estimated effects of a percentage point increase of Chinese leading indicator.

US			
Base case			
	5y yield	5y TP	5y RNY
average	1.53%	1.13%	0.40%
s.d.	0.47%	1.30%	1.26%
+ 1pp increase of Chinese CLI			
average	1.58%	1.13%	0.46%
s.d.	0.47%	1.30%	1.26%

Germany			
Base case			
	5y yield	5y TP	5y RNY
average	0.67%	0.71%	-0.04%
s.d.	0.96%	0.48%	0.66%
+ 1pp increase of Chinese CLI			
average	0.69%	0.76%	-0.07%
s.d.	0.96%	0.48%	0.66%

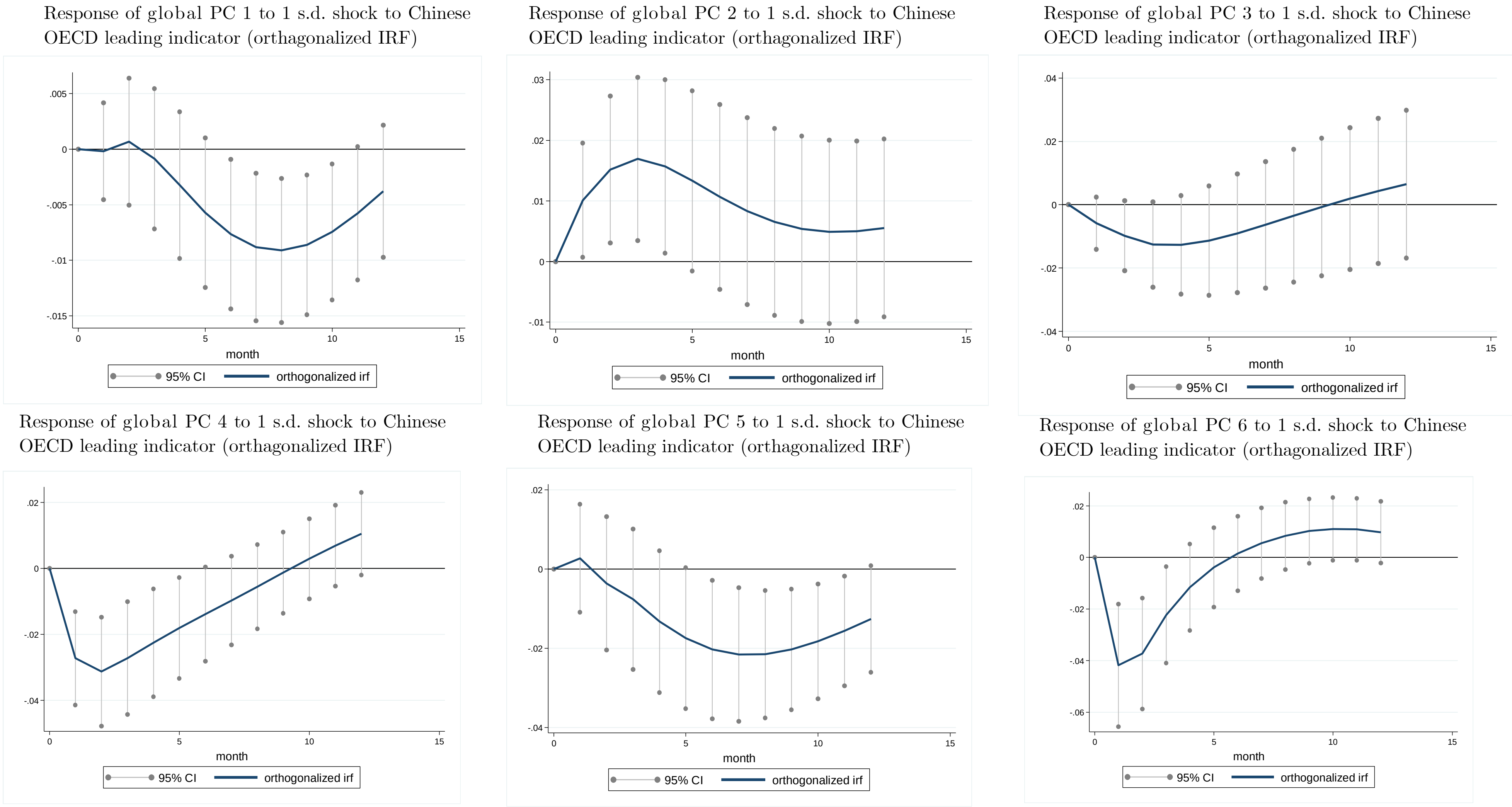
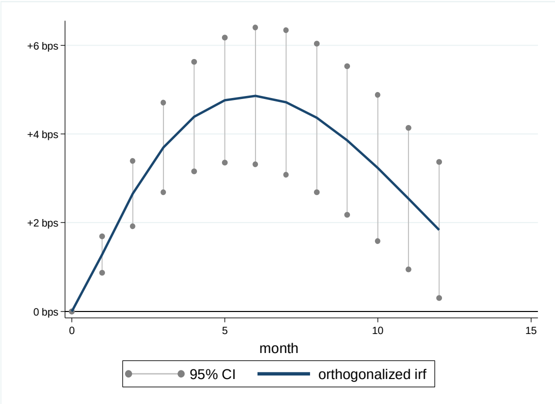


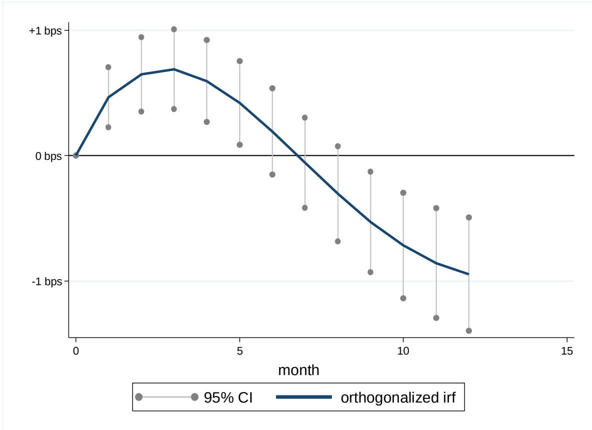
Figure 15: Orthogonalized impulse response functions of the first six principal components on the Chinese OECD leading indicator in structural vector auto-regression with Cholesky identification scheme from June 2009 to December 2017. Variables are ordered as in the second row of Table 7.

Responses of fundamental variables

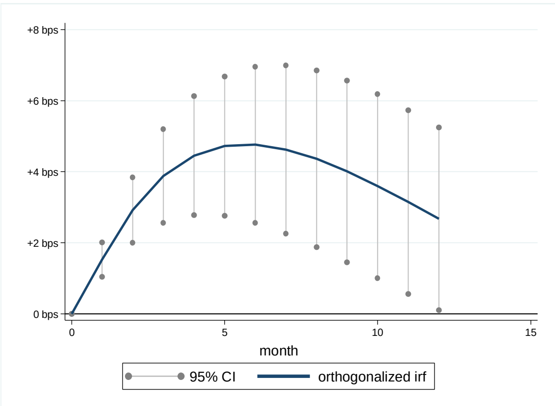
Response of US leading indicator to 1 s.d. shock to Chinese OECD leading indicator (orthagonalized IRF)



Response of US core inflation to 1 s.d. shock to Chinese OECD leading indicator (orthagonalized IRF)



Response of German leading indicator to 1 s.d. shock to Chinese OECD leading indicator (orthagonalized IRF)



Response of German core inflation to 1 s.d. shock to Chinese OECD leading indicator (orthagonalized IRF)

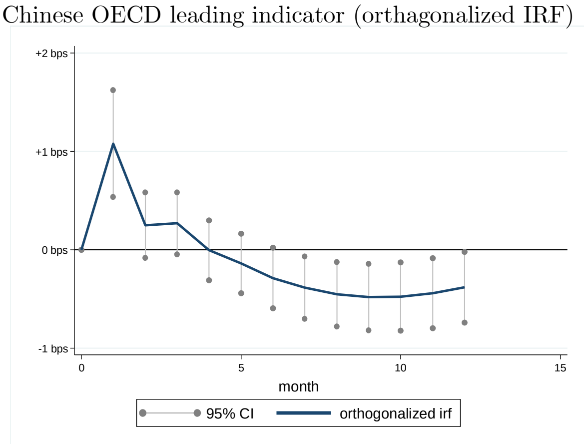


Figure 16: Orthogonalized impulse response functions of US leading indicator, US core inflation, German leading indicator, and German core inflation on Chinese OECD leading indicator in structural vector auto-regression with Cholesky identification scheme. Sample spans from June 2009 to December 2017. Variables are ordered as in the second row of Table 7.

5.1.2. Two-country affine term structure model – Long-run effects in the post financial crisis sample

Figure 15 depicts long-run responses (impulse response functions) of first six principal components derived out of the US and German nominal term structures, and macro variables (Figure 16), to a one standard deviation shock to the Chinese leading indicator. Chinese leading indicator affects first, second, fourth, fifth and sixth PC significantly over the long-run. First principal component, level 1, is affected negatively over the long term (upper left panel of Figure 15). A positive shock to the Chinese leading indicator decreases the level 1 by

0.006 standard deviation after six months and stays significant until the tenth month. The second PC, level 2, is affected positively (upper middle panel of Figure 15). Figure 15 (lower left panel) depicts the effect of the higher Chinese leading indicator on the fourth principal component PC4, "the slopes," of the US and German nominal term structures over the long-run. The slopes decrease by 0.03 standard deviation until the second month. Decrease remains significant until the fifth month.

Figure 16 depicts the responses of the U.S and German leading indicators, and core inflation rates, to a standard deviation shock to the Chinese leading indicator. US leading indicator increases by 6 basis points after six months from where it gradually decreases, to 2 basis points after twelve months (upper left panel of Figure 16). When I sum all significant monthly responses (at 95% level) of the US leading indicator over the first year, it increases by 42 basis points after the first year (12 months). US core inflation increases by 0.5 basis points after the first three months from where it decreases to zero after six months. It becomes negative afterwards (upper right panel of Figure 16).

The German leading indicator increases by 5 basis points in the first six months and reverts to 2 basis points (lower left panel of Figure 16). After summing all significant responses over the first 12 months, the German leading indicator increases cumulatively by 42 basis points over the first year. The response of German inflation is positive in the first month and equals one basis point. Afterwards, the German core inflation decreases and becomes negative in the fifth month (lower right panel of Figure 16).

5.1.3. Two-country affine term structure model – Key findings

The two-country affine term structure model reveals that the lower Chinese leading indicator lowers the level of the US and German interest rates, the leading indicators, and core inflations. Slopes of the US and German nominal term structures are negative (when considering only the PC4). In the US, the lower Chinese leading indicator lowers the long-term nominal interest rates by lowering the expected future nominal short rate. Using the sensitivity analysis I show that a percentage point decrease of the Chinese leading indicator decreases average in-sample estimated 5 year Treasury yield by 5 basis points by lowering the expected future nominal short rate. The estimated 5-year Treasury term premium remains mainly unchanged. A percentage point decrease of the Chinese leading indicator decreases the average estimated 5-year Bund yield by 2 basis points. The 5-year Bund term premium decreases by 4 basis points. The decrease of the estimated term premium is compensated by a corresponding increase of the expected future nominal short rate by 2 basis points. Average in-sample estimated 5 year Treasury term premium is higher than the Bund term premium and twice more volatile.

5.2. The German economy – Post Sovereign debt crisis sample

I estimated the affine term structure model of the German economy in the post Sovereign debt crisis (SDC) sample because: (1) the average actual 5-year Bund yield between June 2009 and December 2011 equaled 2 percent and decreased to 14 basis points after 2011. (2) The average estimated 5-year Bund term premium between July 2009 and December 2011 equaled 1.67 percent and decreased to 29 basis points after 2011. To account for the different monetary regimes in the US and EA after the Sovereign debt crisis I model the German term structure independently from the US.

5.2.1. The German economy – Short-run effects in the post Sovereign debt crisis sample

A percentage point increase of the Chinese leading indicator decreases the slope by 0.0095 units. The standard deviation of Chinese leading indicator in this period equals 1.7 percent. Hence, a one standard deviation increase of Chinese leading indicator lowers the slope by 0.017 units (Table 9). The slope in this sample is positive (Figure 11, right panel). Figure 17 depicts the estimated 5-year Bund yield and the estimated 5-year Bund term premium. Blue dotted line depicts the estimated 5-year Bund term premium when I increase the Chinese leading indicator by a percentage point. The estimated 5-year Bund term premium increases by 7 basis points when I decrease the Chinese leading indicator by a percentage point. Average in-sample 5-year Bund yield does not change. The increase of the estimated 5-year Bund term premium is compensated by the corresponding decrease of the future expected nominal short-term rate. In the post Sovereign debt crisis sample, when I model the German nominal term structure independently of the US, my empirical findings support the signaling and portfolio balance channels. The lower Chinese leading indicator signals a downward correction of the expectations of the German future nominal short rate, and at the same time increases the estimated 5-year Bund term premium.

Table 9: Estimated prices of risk, λ_0^s and λ_1^s, of an affine term structure model using an estimator proposed by Diez de Los Rios (2015, 2018) from December 2011 to December 2017. Spanned factors, $X_t^s = [level_t \quad slope_t \quad curve_t \quad PC4_t]'$, and unspanned factors are $X_t^u = [ur_t \quad ccpi_t \quad CLI_{de,t} \quad CPI_{ch,t} \quad CLI_{ch,t}]'$. Bolded coefficients and test statistics are significant at the 10% level. I present the results of the model with the minimal value of the ALS criterion function. The minimized value of the ALS criterion is 101 (p-value 1). I present remaining estimated parameters in the Appendix A.2..

Factor	λ_0	$\lambda_{1,1}$	$\lambda_{1,2}$	$\lambda_{1,3}$	$\lambda_{1,4}$	$\lambda_{1,5}$	$\lambda_{1,6}$	$\lambda_{1,7}$	$\lambda_{1,8}$	$\lambda_{1,9}$
	(constant)	(level)	(slope)	(curve)	(PC4)	(ur_{de})	($CCPI_{de}$)	(CLI_{de})	(CPI_{ch})	(CLI_{ch})
PC 1 ("level")	**-0.1129**	**-0.5728**	-0.3571	-0.8778	0.7888	**28.5158**	3.4853	**2.7577**	1.2093	-1.3101
(t-statistic)	-2.281	-3.868	-0.971	-1.515	0.439	3.081	1.183	3.046	0.944	-1.083
PC 2 ("slope")	**-0.0406**	-0.0036	**-0.4856**	-0.0484	0.2553	4.5610	-1.4669	0.0137	-0.4566	**-0.9513**
(t-statistic)	-2.516	-0.076	-4.057	-0.256	0.436	1.517	-1.533	0.047	-1.098	-2.420
PC 3 ("curve")	0.0013	-0.0198	**0.1686**	**-0.5472**	-0.2373	-0.0981	0.2117	0.0322	**0.5020**	0.0231
(t-statistic)	0.137	-0.692	2.373	-4.856	-0.680	-0.055	0.374	0.185	2.036	0.099
PC 4	0.005	0.001	-0.022	-0.026	**-0.644**	-0.117	-0.006	0.002	0.066	0.018
(t-statistic)	1.484	0.154	-0.896	-0.685	-5.409	-0.196	-0.031	0.029	0.798	0.225

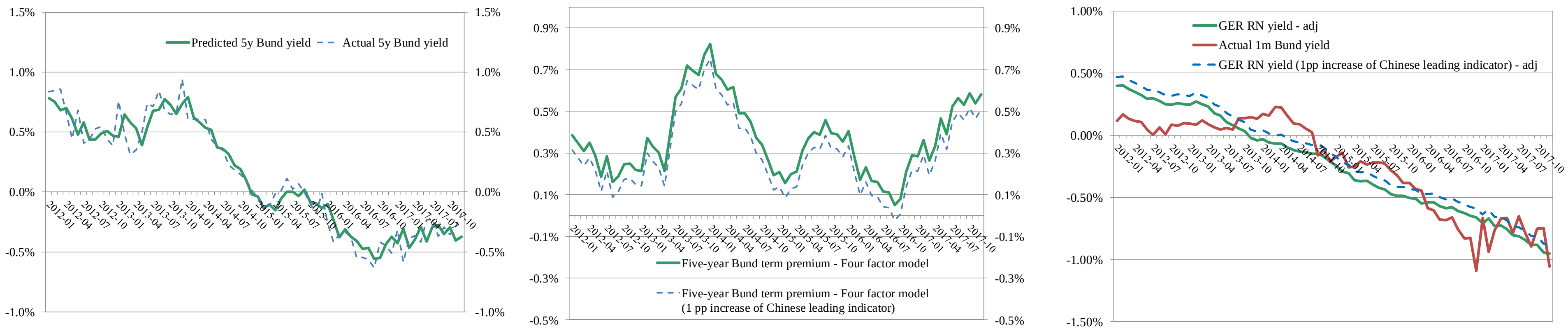
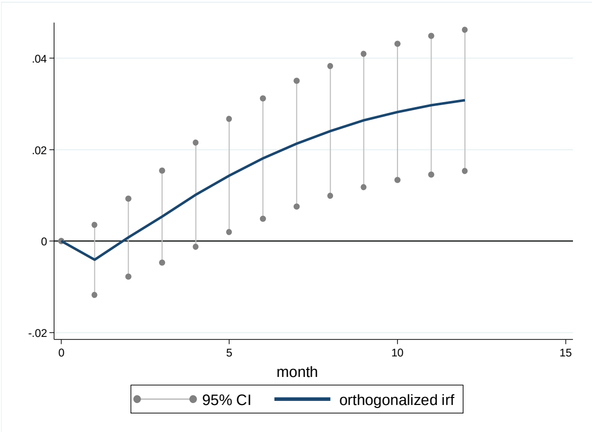


Figure 17: Actual and model-implied a 5-year Bund yield (green and dotted blue lines, left panel). Estimated 5-year Bund term premium (middle panel) and expected future nominal short rate (estimated 5-year risk neutral yield, right panel) (green line). Blue line depicts the estimated 5-year Bund term premium and the estimated 5-year risk neutral yield when the Chinese leading indicator increases by one percentage point. Red line in right panel depicts actual 1 month Bund yield. Sample spans from December 2011 to December 2017. Estimates are based only on the information available at $t-1$.

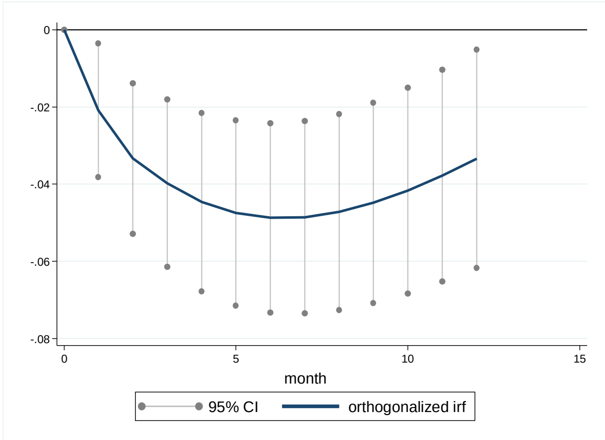
5.2.2. The German economy – Long-run effects in the post Sovereign debt crisis sample

In the post Sovereign debt crisis sample, a positive shock to the Chinese leading indicator increases the first principal component (level) by approximately 0.03 standard deviation and persists for more than 12 months (Figure 18, upper left panel). A one standard deviation shock to the Chinese leading indicator decreases the second principal component (slope) by approximately 0.05 standard deviation. The effect is significant over the first twelve months (Figure 18, upper right panel). The third principal component (curve) decreases by approximately 0.03 standard deviation. The effect becomes significant in the seventh month (Figure 18, lower left panel). The Chinese leading indicator affects all three principal components of the term structure significantly over the long-run. In the post Sovereign debt crisis sample, only the effect on the slope is significant over the short-run (Table 9). Although the short-run effects of the Chinese leading indicator on the first and third principal component (level and curve) are insignificant, they do become significant after 5 and 7 months (Figure 18, upper and lower left panels).

Response of PC 1 (level) to 1 s.d. shock to Chinese OECD leading indicator (orthagonalized IRF)



Response of PC 2 (slope) to 1 s.d. shock to Chinese OECD leading indicator (orthagonalized IRF)



Response of PC 3 (curve) to 1 s.d. shock to Chinese OECD leading indicator (orthagonalized IRF)

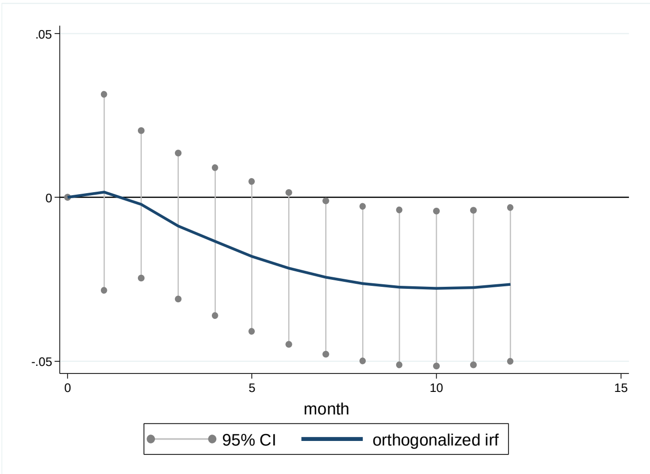


Figure 18: Orthogonalized impulse response functions of first, second and third principal component on the Chinese OECD leading indicator in structural vector auto-regression with Cholesky identification scheme from December 2011 to December 2017. Variables are ordered as in the second row of Table 9.

Figure 19 depicts the impulse responses of German leading indicator and core inflation to a standard deviation shock to the Chinese leading indicator. A positive one standard deviation shock to the Chinese leading indicator increases the German leading indicator by 6 basis points. A shock persists over twelve months. When I sum all significant monthly responses (at 95% level) of German leading indicator over the first year, it increases by 58.5 basis points.

The core German inflation increases by 0.7 basis points over the first month, decreases by 0.4 basis points in the second (and becomes insignificant), slightly increases, to 0.5 basis points in the third (and becomes significant again), and fades out through approximately seven months (Figure 19, right panel). Core German inflation increases and remains higher over the first twelve months.

Response of German leading indicator to 1 s.d. shock to Chinese OECD leading indicator (orthagonalized IRF)

Response of German core inflation to 1 s.d. shock to Chinese OECD leading indicator (orthagonalized IRF)

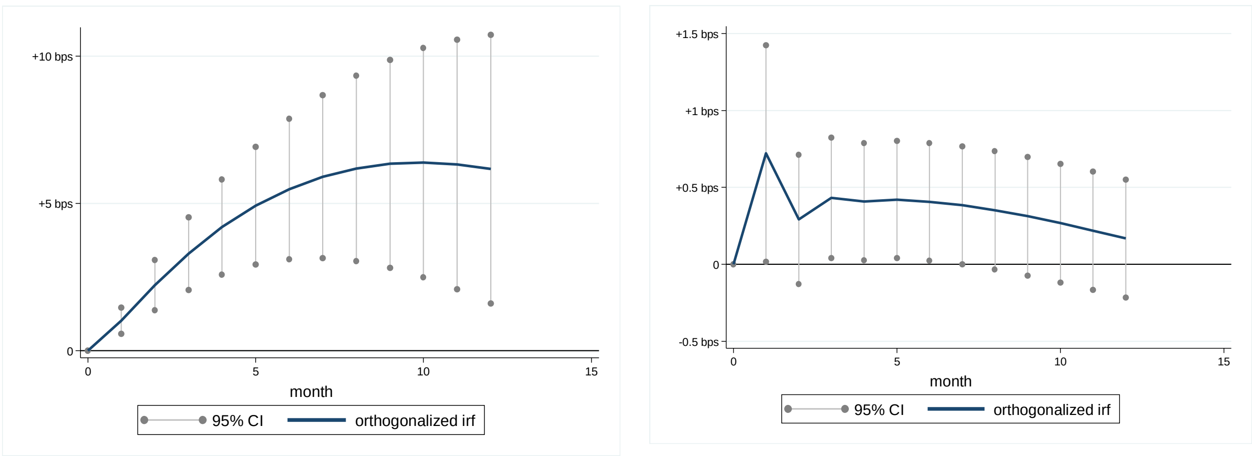


Figure 19: Orthogonalized impulse response functions of German leading indicator and core German inflation on the Chinese OECD leading indicator in structural vector auto-regression with Cholesky identification scheme from December 2011 to December 2017. Variables are ordered as in the second row of Table 9.

5.2.3. The German economy – Key findings in the post Sovereign debt crisis sample

Table 10 summarizes the main findings when I model the German nominal term structure independently from the US in the post Sovereign debt crisis sample. The average estimated 5-year Bund term premium moves closer to zero in the post Sovereign debt crisis sample, it decreases from 71 basis points to 37 basis points. The standard deviation of the estimated 5-year Bund term premium decreases from 48 to 18 basis points. Average estimated 5-year Bund yield decreases from 67 to 13 basis points. In Table 10 (right panel) I show that in the post Sovereign debt crisis sample, a percentage point decrease of the Chinese leading indicator does not change the average estimated 5-year Bund yield. The average estimated 5-year Bund term premium increases. An increase is compensated by a decrease of the expected German future nominal short rate.

By combining (1) impulse response of the level factor in Figure 18 (upper left panel) with (2) impulse responses of German leading indicator and inflation in Figure 19, and (3) the estimated effect of Chinese leading indicator on the average estimated 5-year Bund yield and the average estimated 5-year Bund term premium in Table 10, I conclude that in the post Sovereign debt crisis sample the lower Chinese leading indicator: (1) over the long-run lowers the German growth and inflation, and the level of the German interest rates, (2) *increases* the 5-year Bund term premium by 7 basis points (Table 10, right panel), (3) *decreases* the expected future nominal short rate by 7 basis points, and (5) leaves the estimated average estimated 5-year Bund yield mainly unchanged. The lower Chinese leading indicator lowers the expected future nominal short rate and the German growth and inflation over the long-run. The lower expected future nominal short rate and unchanged estimated 5-year Bund yield increase the slope of the German term structure in the post Sovereign debt crisis sample. The lower Chinese leading indicator signals a downward correction of the expectations of the German future nominal short rate.

Table 10: Summary of the effects on the estimated 5 year Bund yield and its term premium in the post Sovereign debt crisis sample when I model the German nominal term structure independently from the US. Lower parts of the table present the estimated 5-year Bund yield and its term premium when I increase the Chinese leading indicator by one percentage point.

Post Sovereign debt crisis			
Base case			
	5y yield	5y TP	5y RNY
average	0.13%	0.37%	-0.24%
s.d.	0.44%	0.18%	0.40%
+ 1pp increase of Chinese CLI			
average	0.13%	0.30%	-0.17%
s.d.	0.44%	0.18%	0.40%

6. Chinese leading indicator and the foreign exchange reserves

I start this section by describing the currency allocated EMEs foreign reserves and argue that the main part of the global currency allocated foreign reserves nowadays can be sourced to EMEs. Next, I estimate that from 1999 to 2014 the lower yearly *growth* of the Chinese leading indicator predicts the lower yearly *growth* of the currency allocated EMEs foreign reserves. I am able to confirm the robustness of results in the post financial crisis sample. The lower yearly growth of the Chinese leading indicator predicts the lower yearly growth of the Chinese foreign reserves after I control for the US/German short rate, the one-month Treasury/Bund yield, and the macro variables which I include in the joint model of the US and German nominal term structures: the US/German unemployment rates, the leading indicators, core inflations, and the USD/EUR exchange rate. By lowering the Chinese foreign exchange reserves, mainly in the form of the US Treasuries and German Bunds with an average maturity of approximately four years, the lower Chinese leading indicator should increase the estimated 5-year Treasury/Bund term premium and the estimated 5-year Treasury/Bund yield. In the data, however, I find a stronger support for "the signaling channel." A lower Chinese leading indicator signals a downward correction of expectations of the US/German nominal short rate.

Figure 20 depicts a currency composition of allocated global foreign reserves. The major part is allocated to the US dollars. At the end of 2017 more than 60 percent of the total allocated reserves were denominated in US dollars, and more than 20 percent were denominated in Euros. From 1998 to the beginning of the sovereign debt crisis share of reserves denominated in Euros increased from 15 to almost 30 percent. Afterwards, it decreased to 20 percent.

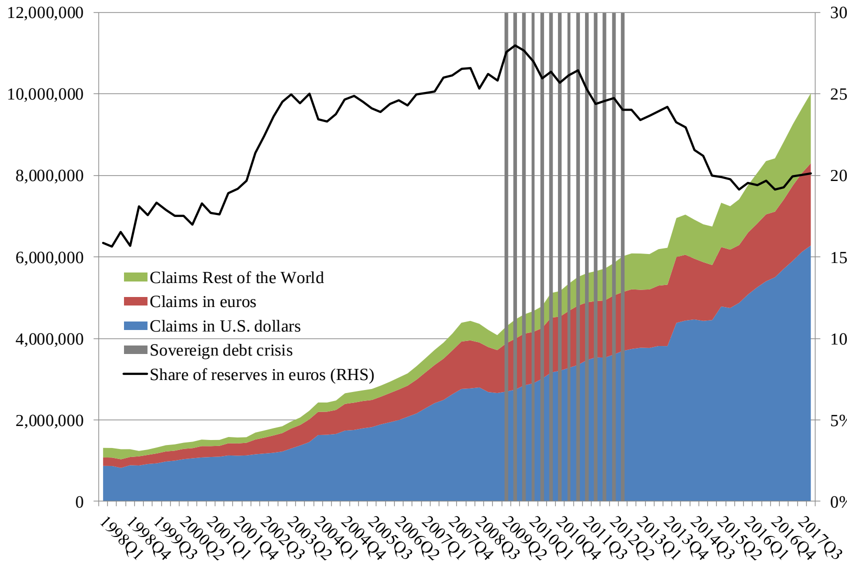


Figure 20: Total global allocated foreign exchange reserves in millions of US dollars: share of reserves in US dollars (blue), in Euros (red), and in currencies other than the US dollars or Euros (Rest of the World, green). Black line depicts the proportion of reserves denominated in Euros as a percentage share of total global allocated reserves. European sovereign debt crisis in the shaded area. Source: IMF Currency Composition of Foreign Exchange Reserves (COFER) database.

The proportion of EMEs foreign reserves in the global reserves should increase if the foreign exchange reserves are proportionate to the nominal growth. After 1998 EMEs are growing faster than advanced economies in nominal and real terms. Figure 21 shows an increase in the relative share of currency allocated foreign reserves of EMEs. While dynamics of EMEs' foreign reserves denominated in Euros and US dollars are similar to the dynamics of advanced economies, the relative importance of EMEs increased substantially (black line in Figure 20 and Figure 21). In 1998 global allocated foreign reserves equaled 1.5 trillion from where they increased to 10 trillion of the US dollars in 2017. EMEs' foreign allocated reserves increased from half of the trillion to more than 3 trillion US dollars in 2014. The share of EMEs foreign reserves increased from 30 to 50 percent from 1998 to 2014 (pink line in Figure 21). Unfortunately, IMF's COFER database does not present advanced and emerging economies foreign reserves separately since 2015 after China began to report the currency composition of its reserves.

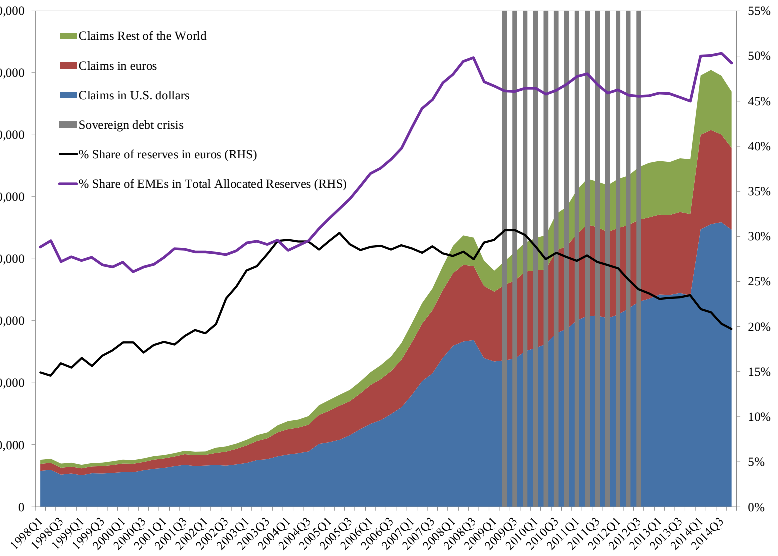


Figure 21: Allocated foreign exchange reserves of Emerging market economies (EMEs) in millions of US dollars: share of reserves in US dollars (blue), in Euros (red), and in currencies other than the US dollars or Euros (Rest of the World, green). Black line depicts the proportion of reserves denominated in Euros as a percentage share of total global allocated reserves. Pink line depicts percentage share of allocated foreign exchange reserves of EMEs in total global allocated reserves (depicted in Figure 20). European sovereign debt crisis in the shaded area. Source: IMF Currency Composition of Foreign Exchange Reserves (COFER) database.

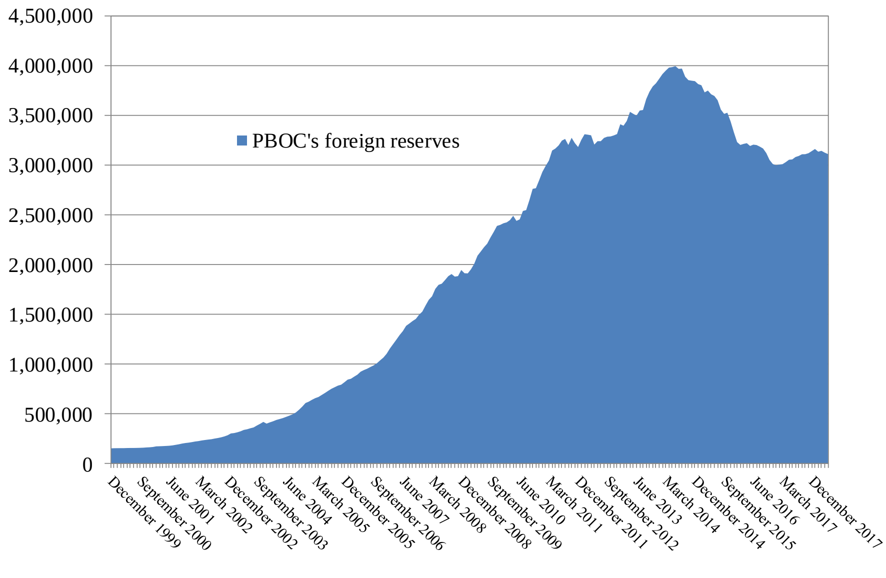


Figure 22: Total foreign exchange reserves of People's Bank of China (PBOC) in millions of US dollars. Currency decomposition is a state secret. Source: Chinese State Administration of Foreign Exchange (SAFE).

Figure 22 shows the Chinese foreign exchange reserves. I present the Chinese foreign exchange reserves without the currency breakdown because the currency composition is a state secret. The Chinese foreign reserves are higher than the total currency allocated foreign reserves of the rest of the EMEs. China is the biggest single holder of the foreign exchange reserves in the world and did not report to the COFER before Q2 2015. PBOC held 3.11 trillion US dollars of foreign reserves by May 2018. This is approximately a quarter of total global foreign reserves (COFER database). Large foreign reserves reflect a Chinese current account surplus and the Chinese foreign exchange policy. In 2015 almost 70 percent of the global foreign reserves (currency allocated and unallocated) can be sourced to the EMEs.

Figure 23 compares yearly growth rates of currency allocated EMEs foreign reserves and of Chinese leading indicator (with trend-restored). The Chinese foreign reserves are *not* a part of this aggregate (since they are reported only without the currency breakdown). The yearly growth of the Chinese leading indicator is approximately twice lower than yearly changes of foreign reserves, and much smoother. The average yearly growth of the Chinese leading indicator is 12.2 percent with a standard deviation of 3.3 percent. Low in-sample volatility results in an in-sample coefficient of variation 0.27 and is three times smaller than the coefficient of variation of yearly growth of the EMEs foreign reserves (0.83). The coefficient of variation is defined as the standard deviation divided by the mean of a variable and is sometimes denoted as a *relative* standard deviation.

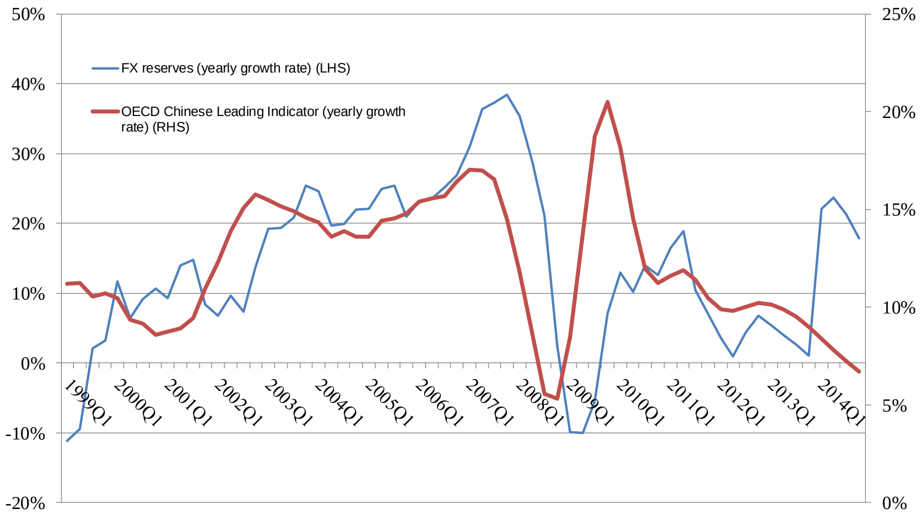


Figure 23: The yearly *growth* rate of foreign reserves (blue line) and the yearly *growth* of the Chinese OECD leading indicator (red line) from Q1 1999 to Q4 2014 (quarterly data). Source: IMF Currency Composition of Foreign Exchange Reserves (COFER) database and OECD.

Next, I estimate a VAR model to measure the short- and long-run effects between the yearly growth rates of the Chinese leading indicator and the yearly growth rates of the currency allocated foreign reserves of EMEs. I run a quarterly two-variable VAR model from 1999 to 2014:

$$\begin{bmatrix} \Delta reserves_t \\ \Delta CLI_t \end{bmatrix} = \mu + \Phi \begin{bmatrix} \Delta reserves_{t-1} \\ \Delta CLI_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{res,t} \\ \varepsilon_{CLI,t} \end{bmatrix} \tag{21}$$

Table 11 shows that a percentage point increase of the Chinese leading indicator on average increases the EMEs currency allocated foreign reserves by 89 basis points over the first quarter, ceteris paribus. On the other hand, the feedback effect of foreign reserves is much smaller. A one percentage point increase of foreign reserves on average decreases Chinese leading indicator by less than 6 basis points, ceteris paribus. In Appendix A.3. I show that in the post financial crisis sample, and using a monthly data, after I control for the US and German unemployment rates, the leading indicators, core inflations, the one-month Treasury and Bund yields, and the USD/EUR exchange rate, the yearly growth of the Chinese leading indicator predicts a lower yearly growth of the Chinese foreign reserves. The estimated coefficient decreases to 0.47.

Table 11: VAR model of the yearly growth rate of the Chinese leading indicator and of the yearly growth rate of the currency allocated EMEs foreign reserves. Sample spans from Q1 1999 to Q4 2014.

Variable	μ	$\Phi_{1,1}$	$\Phi_{1,2}$
	(constant)	(foreign reserves)	(CLI_{ch})
foreign reserves	**-0.0717**	**0.7682**	**0.8859**
(t-statistic)	-3.190	14.750	4.740
CLI_{ch}	0.0093	**-0.0576**	**0.9835**
(t-statistic)	1.440	-3.820	18.150

To investigate the long-run dynamics I impose Cholesky identification on the covariance matrix of the error terms in (21). I order the EMEs currency allocated foreign reserves first and the leading indicator last. Figure 24 shows that a positive one standard deviation shock to the Chinese leading indicator increases the foreign reserves by approximately 3 percent over the first 5 quarters and fades out only gradually, through nine quarters. Shock to the

Chinese leading indicator increases EMEs foreign reserves over several quarters and is important to understand the long-run dynamics. A one standard deviation shock to EMEs foreign reserves decreases Chinese leading indicator by approximately 50 basis points over the first 5 quarters. Over the next three quarters, it reverts back.

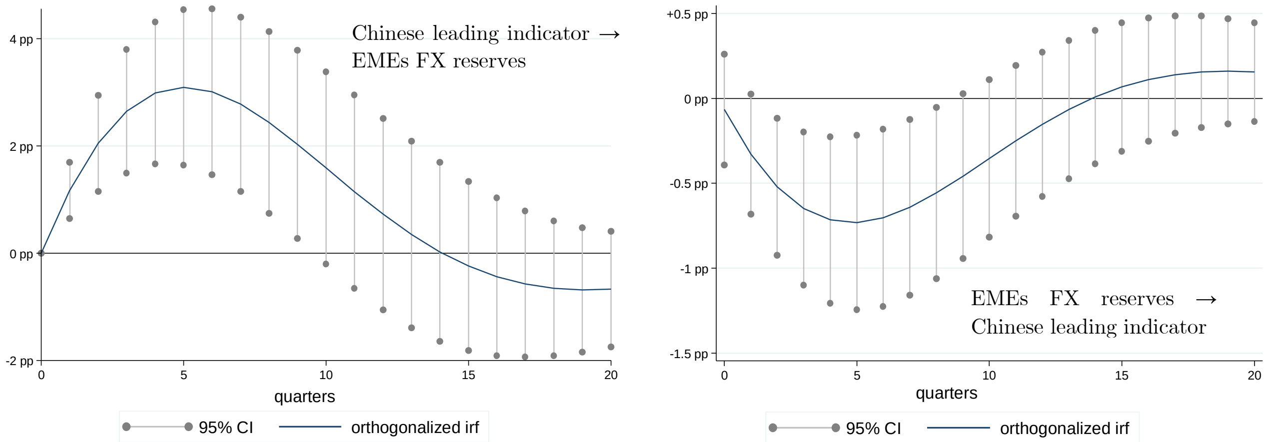


Figure 24: Orthogonalized impulse response functions of EMEs foreign exchange (FX) reserves on the Chinese OECD leading indicator (left panel) and Chinese OECD leading indicator on the EMEs foreign exchange (FX) reserves (right panel) in structural vector auto-regression with Cholesky identification scheme from Q1 1999 to Q4 2014. I order the EMEs foreign exchange (FX) reserves first and the Chinese OECD leading indicator last.

7. Conclusions

I investigated how important is a Chinese slowdown for the unusually low long-term nominal interest rates we are observing in the US and Germany after the financial crisis. I modeled the US and German nominal term structures jointly and included the Chinese leading indicator as a new factor. I used the affine term structure model to decompose changes in the 5-year nominal interest rates into (1) changes in the expected future nominal short rate, “the signaling channel,” and (2) the estimated 5-year term premium, “the portfolio balance channel.”

The lower Chinese leading indicator (a negative one standard deviation shock) lowers the US/German growth, measured with the leading indicators, over the first year. The US leading indicator decreases by 42 basis points and German leading indicator by 45 basis points (after I control for US/German core inflation). In the US, this leads to clear signaling effects but no portfolio balancing effects. A percentage point decrease of the Chinese leading indicator signals a downward correction of expectations of the US future nominal short rate, on average by 5 basis points. The estimated 5-year Treasury term premium does not change. In Germany, I find both signaling and portfolio balancing effects, but the direction of these effects is opposite to what I expected. The lower Chinese leading indicator signals an upward correction of expectations of the German future nominal short rate, on average by 2 basis points. The estimated 5-year Bund term premium decreases, on average by 4 basis points.

To deal with the different monetary regimes since the Sovereign debt crisis (SDC) I also modeled the German term structure independently from the US in the post SDC sample. Now, a negative one standard deviation shock to the Chinese leading indicator leads to an even bigger drop in German growth over the first year: German leading indicator decreases by almost 60 basis points (after I control for German core inflation). Like in the US, now in Germany the lower Chinese leading indicator has important signaling effects in the expected direction. A percentage point decrease of the Chinese leading indicator signals a downward correction of expectations of the German future nominal short rate, on average by 7 basis points. However, the estimated 5-year Bund term premium increases, on average by 7 basis points, and neutralizes these negative signaling effects on the estimated 5-year Bund yield.

Chinese dominant role in the global growth and the global spillovers of a Chinese slowdown after the financial crisis contribute in an important way to understand the unusually low long-term nominal interest rates we are observing in the US and Germany. Lower Chinese growth is an important signal of lower growth in the US and Germany and transmits into the long-term nominal interest rates mainly through the downward correction of expectations of the future expected nominal short rates. Table 12 summarizes the key findings.

Table 12: Key findings. The numbers in brackets correspond to changes in model implied 5-year yield, the term premium, and the risk-neutral yield, RNY (denoted also as the expected future short rate, EFSR), when Chinese leading indicator *decreases* by a percentage point.

Two-country model

	After the financial crisis		Germany		
			5y yield	5y TP	RNY (EFSR)
Effect of the lower Chinese CLI	S-T	L-T	67 bps	71 bps	–4 bps
Level 1 (PC1)	No effect	Positive	(–2 bps)	(–4 bps)	(+2 bps)
Level 2 (PC2)	Negative	Negative		US	
Slope 1 (PC3)	No effect	No effect	153 bps	113 bps	40 bps
Slope 2 (PC4) (negative slope)	Positive	Positive	(–5 bps)	(0 bps)	(–5 bps)

Germany (single country model)

	After the Sovereign debt crisis		5y yield	5y TP	RNY (EFSR)
Effect of the *lower* Chinese CLI	S-T	L-T			
Level (PC1)	No effect	Negative	13 bps	37 bps	–24 bps
Slope (PC2) (positive slope)	Positive	Positive	(0 bps)	(+7 bps)	(–7 bps)

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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**
0.0009	0.0009
(standard error)	(standard error)

Factor	$\delta_1^{US,s}$	$\delta_1^{GER,s}$
global PC 1	**-0.0333**	**0.0729**
(standard error)	0.0004	0.0004
global PC 2	**0.0549**	**-0.0478**
(standard error)	0.0008	0.0008
global PC 3	**0.1900**	**-0.0444**
(standard error)	0.0027	0.0027
global PC 4	**0.1676**	**0.2083**
(standard error)	0.0048	0.0048
global PC 5	**-0.2907**	**-0.1817**
(standard error)	0.0082	0.0082
global PC 6	**-0.2495**	**0.5342**
(standard error)	0.0133	0.0133

Factor	$\mu_s^\star$
	(constant)
global PC 1	**0.0016**
(standard error)	0.0003
global PC 2	**0.0033**
(standard error)	0.0005
global PC 3	**0.0032**
(standard error)	0.0009
global PC 4	**0.0034**
(standard error)	0.0010
global PC 5	**-0.0049**
(standard error)	0.0015
global PC 6	**-0.0012**
(standard error)	0.0003

Factor	$\Phi_{ss,1,1}^\star$	$\Phi_{ss,1,2}^\star$	$\Phi_{ss,1,3}^\star$	$\Phi_{ss,1,4}^\star$	$\Phi_{ss,1,5}^\star$	$\Phi_{ss,1,6}^\star$
	(global PC1)	(global PC2)	(global PC3)	(global PC4)	(global PC5)	(global PC6)
global PC 1	**1.0239**	**0.0168**	**0.0270**	**-0.0697**	**0.0156**	**-0.2475**
(standard error)	0.0002	0.0003	0.0010	0.0017	0.0029	0.0046
global PC 2	**0.0132**	**1.0274**	**-0.0804**	**-0.0588**	**0.0619**	**0.1536**
(standard error)	0.0002	0.0004	0.0014	0.0024	0.0041	0.0063
global PC 3	0.0003	**0.0194**	**1.0031**	**-0.0856**	**0.1813**	**0.2084**
(standard error)	0.0004	0.0009	0.0029	0.0050	0.0084	0.0163
global PC 4	**0.0127**	**0.0227**	**-0.0083**	**0.9695**	**0.2218**	**-0.2932**
(standard error)	0.0005	0.0009	0.0031	0.0054	0.0091	0.0176
global PC 5	**0.0021**	0.0010	**-0.0108**	0.0015	**0.9408**	0.0397
(standard error)	0.0007	0.0015	0.0049	0.0083	0.0140	0.0250
global PC 6	**0.0030**	**0.0041**	**-0.0397**	**0.0580**	**0.0114**	**0.6562**
(standard error)	0.0001	0.0003	0.0009	0.0015	0.0026	0.0054

Factor	$\boldsymbol{\mu}$
global PC 1	-0.0032
(t-statistic)	-0.06
global PC 2	0.1120
(t-statistic)	**2.12**
global PC 3	-0.0436
(t-statistic)	**-3.02**
global PC 4	-0.0014
(t-statistic)	-0.10
global PC 5	-0.0268
(t-statistic)	**-3.38**
global PC 6	0.0075
(t-statistic)	0.91
ur_{us}	0.0017
(t-statistic)	1.93
$CCPI_{us}$	-0.0003
(t-statistic)	-0.53
CLI_{us}	-0.0016
(t-statistic)	-1.67
USD/EUR	-0.0062
(t-statistic)	-0.38
ur_{de}	-0.0006
(t-statistic)	-1.41
$CCPI_{de}$	-0.0027
(t-statistic)	**-2.19**
CLI_{de}	0.0017
(t-statistic)	1.59
CPI_{ch}	0.0047
(t-statistic)	1.82
CLI_{ch}	-0.0025
(t-statistic)	-1.94

Factor	$\boldsymbol{\Phi_{1,1}}$	$\boldsymbol{\Phi_{1,2}}$	$\boldsymbol{\Phi_{1,3}}$	$\boldsymbol{\Phi_{1,4}}$	$\boldsymbol{\Phi_{1,5}}$	$\boldsymbol{\Phi_{1,6}}$	$\boldsymbol{\Phi_{1,7}}$	$\boldsymbol{\Phi_{1,8}}$	$\boldsymbol{\Phi_{1,9}}$	$\boldsymbol{\Phi_{1,10}}$	$\boldsymbol{\Phi_{1,11}}$	$\boldsymbol{\Phi_{1,12}}$	$\boldsymbol{\Phi_{1,13}}$	$\boldsymbol{\Phi_{1,14}}$	$\boldsymbol{\Phi_{1,15}}$
	(global PC1)	(global PC2)	(global PC3)	(global PC4)	(global PC5)	(global PC6)	(ur_{us})	($CCPI_{us}$)	(CLI_{us})	(USD/EUR)	(ur_{de})	($CCPI_{de}$)	(CLI_{de})	(CPI_{ch})	(CLI_{ch})
global PC 1	**0.6294**	0.0924	**-0.4820**	0.0786	0.3395	**-1.3638**	**13.7541**	**-18.5057**	**-5.2009**	0.1045	-10.9673	4.4333	2.0680	-1.4615	-0.1398
(t-statistic)	6.49	1.32	-2.49	0.24	0.81	-2.32	3.06	-2.86	-3.08	0.33	-1.58	1.15	1.56	-1.10	-0.12
global PC 2	0.0002	**0.7650**	0.2109	-0.1766	-0.4781	-0.6480	-4.2809	-16.5183	-2.5193	-0.5063	-7.4600	-2.1194	-0.2034	-0.6525	**2.5641**
(t-statistic)	0.00	10.59	1.05	-0.52	-1.10	-1.07	-0.92	-2.47	-1.44	-1.55	-1.04	-0.53	-0.15	-0.47	2.17
global PC 3	**-0.0754**	**0.1064**	**0.8483**	0.1630	0.1887	0.2130	**3.5066**	1.4927	-0.1058	**0.1803**	-0.8445	0.7841	0.2178	0.1236	-0.4467
(t-statistic)	-2.74	5.38	15.46	1.75	1.59	1.28	2.75	0.82	-0.22	2.01	-0.43	0.72	0.58	0.33	-1.38
global PC 4	**0.0825**	0.0035	0.0305	**0.5534**	0.1839	-0.2592	1.4567	2.5003	0.6394	-0.0500	-1.3996	-0.2635	**0.8369**	**-1.1292**	**-1.2105**
(t-statistic)	3.19	0.19	0.59	6.29	1.65	-1.66	1.21	1.45	1.42	-0.59	-0.76	-0.26	2.37	-3.17	-3.96
global PC 5	0.0048	-0.0030	0.0523	0.0398	**0.6416**	-0.1177	**-2.0184**	-0.0734	0.3130	0.0822	**2.9927**	-1.0876	**-0.6709**	**0.4107**	0.0710
(t-statistic)	0.32	-0.28	1.73	0.78	9.84	-1.29	-2.88	-0.07	1.19	1.67	2.77	-1.81	-3.26	1.98	0.40
global PC 6	**0.0382**	-0.0056	**0.0723**	**-0.1175**	0.1250	**0.3652**	0.0539	**2.7401**	**0.7075**	-0.0537	1.2685	-0.4814	0.2116	**-0.5396**	**-0.6705**
(t-statistic)	2.43	-0.50	2.30	-2.20	1.84	3.84	0.07	2.62	2.59	-1.05	1.13	-0.77	0.99	-2.50	-3.62
ur_{us}	0.0020	-0.0021	**0.0112**	0.0003	-0.0008	0.0058	**0.7250**	0.1152	0.0580	0.0090	**0.4210**	0.0677	-0.0245	0.0352	-0.0030
(t-statistic)	1.15	-1.70	3.27	0.06	-0.11	0.56	9.12	1.01	1.94	1.60	3.44	0.99	-1.05	1.49	-0.15
$CCPI_{us}$	0.0006	-0.0010	**-0.0044**	-0.0029	-0.0051	-0.0009	-0.0100	0.6406	**-0.0630**	-0.0010	**-0.2611**	-0.0300	-0.0227	0.0239	**0.0479**
(t-statistic)	0.63	-1.42	-2.19	-0.85	-1.16	-0.14	-0.21	9.51	-3.58	-0.30	-3.61	-0.75	-1.65	1.72	4.02
CLI_{us}	-0.0020	0.0013	-0.0047	0.0069	-0.0060	**-0.0389**	0.0772	-0.0763	**0.8318**	-0.0005	**-0.3957**	0.0600	-0.0175	**-0.1090**	**0.1342**
(t-statistic)	-1.08	0.99	-1.29	1.12	-0.76	-3.53	0.91	-0.63	26.23	-0.08	-3.04	0.83	-0.70	-4.35	6.25
USD/EUR	-0.0163	0.0050	0.0065	0.0086	-0.0833	0.0373	**3.0266**	-1.1815	**-1.6166**	**-0.2284**	-4.1759	0.9294	**1.1399**	**-0.9021**	-0.2059
(t-statistic)	-0.52	0.22	0.10	0.08	-0.62	0.20	2.10	-0.57	-2.98	-2.25	-1.88	0.75	2.69	-2.11	-0.56
ur_{de}	-0.0004	0.0002	-0.0012	0.0039	-0.0055	-0.0010	0.0496	0.0438	-0.0096	0.0029	**0.9340**	-0.0208	0.0002	-0.0205	0.0007
(t-statistic)	-0.53	0.27	-0.75	1.44	-1.60	-0.21	1.34	0.82	-0.69	1.12	16.40	-0.65	0.02	-1.88	0.07
$CCPI_{de}$	**0.0066**	-0.0007	0.0087	0.0018	**-0.0289**	0.0064	-0.0755	**-0.3022**	-0.0211	-0.0070	**-0.6430**	**-0.3169**	**-0.1478**	-0.0348	**0.1113**
(t-statistic)	2.89	-0.40	1.89	0.23	-2.92	0.46	-0.71	-1.98	-0.53	-0.93	-3.92	-3.47	-4.72	-1.10	4.11
CLI_{de}	-0.0014	-0.0017	-0.0074	**-0.0207**	0.0106	0.0053	0.0806	**-0.5659**	**-0.1492**	0.0067	**-0.6168**	0.0886	**0.9496**	**-0.1895**	**0.1590**
(t-statistic)	-0.70	-1.16	-1.82	-2.97	1.20	0.43	0.85	-4.15	-4.19	1.01	-4.22	1.09	34.08	-6.74	6.60
CPI_{ch}	0.0082	-0.0050	0.0098	0.0142	0.0372	**-0.0817**	**0.4477**	-0.0218	-0.1115	-0.0158	**-0.8472**	-0.1437	**0.2021**	**0.6087**	-0.0350
(t-statistic)	1.66	-1.40	1.00	0.85	1.75	-2.74	1.96	-0.07	-1.30	-0.98	-2.41	-0.73	3.01	8.99	-0.60
CLI_{ch}	0.0024	0.0021	-0.0059	0.0144	-0.0002	**-0.0323**	**0.4129**	**-0.4807**	**-0.4072**	0.0040	**-0.8643**	0.0733	0.0194	**-0.2765**	**1.0280**
(t-statistic)	0.98	1.20	-1.21	1.75	-0.02	-2.20	3.66	-2.97	-9.62	0.51	-4.97	0.76	0.58	-8.28	35.84

Factor	$\Sigma^{Chol}_{1,1}$	$\Sigma^{Chol}_{1,2}$	$\Sigma^{Chol}_{1,3}$	$\Sigma^{Chol}_{1,4}$	$\Sigma^{Chol}_{1,5}$	$\Sigma^{Chol}_{1,6}$	$\Sigma^{Chol}_{1,7}$	$\Sigma^{Chol}_{1,8}$	$\Sigma^{Chol}_{1,9}$	$\Sigma^{Chol}_{1,10}$	$\Sigma^{Chol}_{1,11}$	$\Sigma^{Chol}_{1,12}$	$\Sigma^{Chol}_{1,13}$	$\Sigma^{Chol}_{1,14}$	$\Sigma^{Chol}_{1,15}$
	(global PC1)	(global PC2)	(global PC3)	(global PC4)	(global PC5)	(global PC6)	(ur_{us})	($CCPI_{us}$)	(CLI_{us})	(USD/EUR)	(ur_{de})	($CCPI_{de}$)	(CLI_{de})	(CPI_{ch})	(CLI_{ch})
global PC 1	**0.0758**														
(standard error)	0.0058														
global PC 2	**0.0280**	**0.0732**													
(standard error)	0.0087	0.0043													
global PC 3	0.0016	**-0.0118**	**0.0179**												
(standard error)	0.0020	0.0019	0.0016												
global PC 4	**0.0064**	-0.0030	**0.0060**	**0.0179**											
(standard error)	0.0020	0.0019	0.0023	0.0012											
global PC 5	**0.0035**	-0.0008	0.0013	0.0001	**0.0111**										
(standard error)	0.0012	0.0011	0.0013	0.0012	0.0008										
global PC 6	0.0002	**0.0032**	0.0005	**0.0045**	-0.0005	**0.0109**									
(standard error)	0.0012	0.0011	0.0013	0.0012	0.0012	0.0008									
ur_{us}	0.0003	-0.0003	-0.0001	0.0000	0.0002	0.0002	**0.0012**								
(standard error)	0.0002	0.0002	0.0003	0.0002	0.0002	0.0002	0.0003								
$CCPI_{us}$	-0.0001	0.0000	0.0001	0.0000	0.0002	-0.0001	-0.0001	0.0007							
(standard error)	0.0002	0.0002	0.0003	0.0002	0.0002	0.0002	0.0006	0.0005							
CLI_{us}	0.0001	0.0004	-0.0002	0.0000	-0.0001	-0.0005	-0.0002	-0.0002	**0.0012**						
(standard error)	0.0003	0.0002	0.0003	0.0003	0.0003	0.0003	0.0007	0.0014	0.0006						
USD/EUR	**0.0126**	**-0.0077**	-0.0024	0.0009	0.0001	-0.0027	-0.0016	-0.0018	-0.0019	**0.0187**					
(standard error)	0.0021	0.0022	0.0027	0.0023	0.0023	0.0023	0.0048	0.0076	0.0051	0.0013					
ur_{de}	0.0001	0.0000	-0.0001	0.0000	0.0000	0.0002	0.0002	-0.0001	-0.0002	-0.0001	**0.0005**				
(standard error)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0004	0.0003	0.0001	0.0002				
$CCPI_{de}$	0.0003	-0.0001	0.0000	0.0003	0.0000	0.0001	-0.0001	-0.0001	0.0003	-0.0002	0.0003	**0.0017**			
(standard error)	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0004	0.0007	0.0005	0.0002	0.0005	0.0001			
CLI_{de}	0.0001	**0.0003**	**-0.0003**	-0.0003	0.0000	-0.0001	-0.0002	-0.0004	**0.0011**	0.0002	0.0000	0.0003	**0.0009**		
(standard error)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0005	0.0003	0.0002	0.0005	0.0002	0.0002		
CPI_{ch}	-0.0002	-0.0002	**0.0010**	0.0006	0.0000	0.0002	0.0005	0.0008	-0.0003	0.0002	-0.0006	**-0.0011**	0.0002	**0.0033**	
(standard error)	0.0004	0.0003	0.0004	0.0003	0.0004	0.0004	0.0007	0.0013	0.0014	0.0004	0.0009	0.0004	0.0008	0.0002	
CLI_{ch}	**0.0007**	0.0000	**-0.0006**	0.0001	0.0002	**-0.0003**	0.0005	-0.0003	0.0002	-0.0001	0.0004	0.0003	0.0004	**-0.0004**	**0.0013**
(standard error)	0.0001	0.0001	0.0002	0.0002	0.0002	0.0002	0.0003	0.0005	0.0004	0.0001	0.0004	0.0002	0.0003	0.0001	0.0001

A.2. Estimated parameters of the affine model of German nominal term structure in the post Sovereign debt crisis sample

δ_0^s
(constant)
0.0011
0.0000
(standard error)

Factor	δ_1^s
PC 1	**0.1245**
(standard error)	0.0000
PC 2	**0.2084**
(standard error)	0.0002
PC 3	**-0.4687**
(standard error)	0.0009
PC 4	**-0.4115**
(standard error)	0.0028

Factor	$\mu_s^\star$
	(constant)
PC 1	**-0.0004**
(standard error)	0.0000
PC 2	**-0.0013**
(standard error)	0.0000
PC 3	**0.0012**
(standard error)	0.0000
PC 4	**0.0012**
(standard error)	0.0000

Factor	$\Phi_{ss,1,1}^\star$	$\Phi_{ss,1,2}^\star$	$\Phi_{ss,1,3}^\star$	$\Phi_{ss,1,4}^\star$
	(PC1)	(PC2)	(PC3)	(PC4)
PC 1	**1.0027**	**-0.1042**	**0.2274**	**0.3097**
(standard error)	0.0000	0.0001	0.0006	0.0018
PC 2	**-0.0102**	**1.0001**	**0.3018**	**0.2725**
(standard error)	0.0000	0.0003	0.0009	0.0029
PC 3	**0.0075**	**-0.0055**	**0.8107**	**-0.4772**
(standard error)	0.0000	0.0003	0.0013	0.0038
PC 4	**-0.0001**	**0.0086**	-0.0012	**0.8872**
(standard error)	0.0000	0.0002	0.0010	0.0030

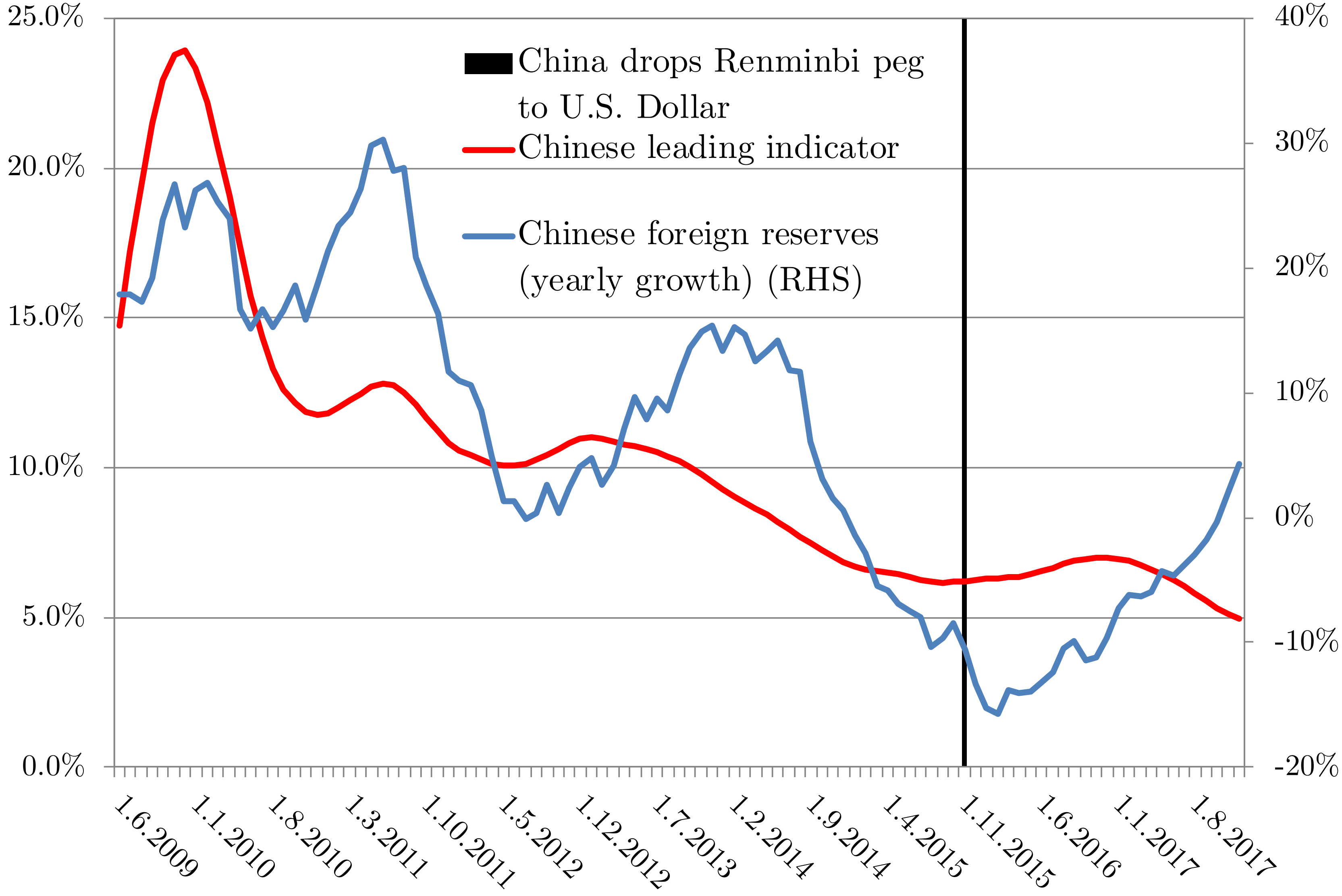
Factor	$\boldsymbol{\mu}$
PC 1	**-0.1134**
(t-statistic)	-2.29
PC 2	**-0.0419**
(t-statistic)	-2.60
PC 3	0.0025
(t-statistic)	0.27
PC 4	0.0060
(t-statistic)	1.88
ur_{de}	0.0007
(t-statistic)	1.57
$CCPI_{de}$	0.0005
(t-statistic)	0.27
CLI_{de}	0.0009
(t-statistic)	0.76
CPI_{ch}	0.0034
(t-statistic)	1.01
CLI_{ch}	0.0011
(t-statistic)	0.95

Factor	$\boldsymbol{\Phi}_{1,1}$	$\boldsymbol{\Phi}_{1,2}$	$\boldsymbol{\Phi}_{1,3}$	$\boldsymbol{\Phi}_{1,4}$	$\boldsymbol{\Phi}_{1,5}$	$\boldsymbol{\Phi}_{1,6}$	$\boldsymbol{\Phi}_{1,7}$	$\boldsymbol{\Phi}_{1,8}$	$\boldsymbol{\Phi}_{1,9}$
	(PC1)	(PC2)	(PC3)	(PC4)	(ur_{de})	($CCPI_{de}$)	(CLI_{de})	(CPI_{ch})	(CLI_{ch})
PC 1	**0.4299**	-0.4613	-0.6505	1.0984	**28.5158**	3.4853	**2.7577**	1.2093	-1.3101
(t-statistic)	2.90	-1.25	-1.12	0.61	3.08	1.18	3.05	0.94	-1.08
PC 2	-0.0139	**0.5144**	0.2535	0.5278	4.5610	-1.4669	0.0137	-0.4566	**-0.9513**
(t-statistic)	-0.29	4.31	1.35	0.91	1.52	-1.53	0.05	-1.10	-2.42
PC 3	-0.0123	**0.1632**	**0.2635**	**-0.7144**	-0.0981	0.2117	0.0322	**0.5020**	0.0231
(t-statistic)	-0.43	2.31	2.37	-2.07	-0.06	0.37	0.18	2.04	0.10
PC 4	0.0014	-0.0129	-0.0275	**0.2435**	-0.1172	-0.0059	0.0017	0.0661	0.0176
(t-statistic)	0.14	-0.54	-0.74	2.10	-0.20	-0.03	0.03	0.80	0.23
ur_{de}	**0.0041**	0.0055	-0.0050	-0.0032	**0.7410**	-0.0361	**-0.0212**	-0.0121	**0.0295**
(t-statistic)	2.98	1.60	-0.92	-0.19	8.53	-1.31	-2.49	-1.01	2.60
$CCPI_{de}$	0.0080	-0.0030	-0.0283	-0.0751	**-0.7028**	**-0.2569**	**-0.0839**	0.0344	**0.0923**
(t-statistic)	1.46	-0.22	-1.32	-1.13	-2.05	-2.35	-2.50	0.72	2.06
CLI_{de}	**-0.0117**	-0.0086	**0.0474**	**-0.1483**	0.1952	-0.0003	**1.0028**	**-0.0833**	**0.1320**
(t-statistic)	-3.16	-0.93	3.28	-3.32	0.85	0.00	44.43	-2.61	4.38
CPI_{ch}	0.0041	-0.0185	**0.0864**	**-0.2570**	-0.2408	0.1407	0.0070	**0.5209**	0.1312
(t-statistic)	0.40	-0.73	2.16	-2.08	-0.38	0.69	0.11	5.90	1.57
CLI_{ch}	-0.0037	0.0090	0.0016	-0.0547	-0.0709	-0.0514	**-0.0533**	-0.0468	**1.0606**
(t-statistic)	-1.10	1.08	0.13	-1.35	-0.34	-0.77	-2.61	-1.62	38.85

Factor	$\Sigma_{1,1}^{Chol}$	$\Sigma_{1,2}^{Chol}$	$\Sigma_{1,3}^{Chol}$	$\Sigma_{1,4}^{Chol}$	$\Sigma_{1,5}^{Chol}$	$\Sigma_{1,6}^{Chol}$	$\Sigma_{1,7}^{Chol}$	$\Sigma_{1,8}^{Chol}$	$\Sigma_{1,9}^{Chol}$
	(PC1)	(PC2)	(PC3)	(PC4)	(ur_{de})	($CCPI_{de}$)	(CLI_{de})	(CPI_{ch})	(CLI_{ch})
PC 1	**0.0533**								
(standard error)	0.0045								
PC 2	**-0.0121**	**0.0123**							
(standard error)	0.0017	0.0016							
PC 3	**0.0055**	-0.0021	**0.0083**						
(standard error)	0.0011	0.0015	0.0008						
PC 4	**-0.0010**	0.0004	**0.0016**	**0.0028**					
(standard error)	0.0003	0.0004	0.0004	0.0003					
ur_{de}	0.0001	0.0001	0.0000	0.0000	**0.0005**				
(standard error)	0.0001	0.0001	0.0001	0.0001	0.0001				
$CCPI_{de}$	0.0001	0.0002	-0.0002	0.0004	0.0000	**0.0019**			
(standard error)	0.0003	0.0003	0.0003	0.0003	0.0005	0.0002			
CLI_{de}	0.0000	**-0.0005**	0.0000	-0.0003	-0.0003	0.0002	**0.0011**		
(standard error)	0.0002	0.0002	0.0002	0.0002	0.0003	0.0002	0.0001		
CPI_{ch}	0.0004	0.0009	-0.0002	0.0001	-0.0002	**-0.0013**	-0.0007	**0.0032**	
(standard error)	0.0004	0.0005	0.0004	0.0005	0.0007	0.0006	0.0005	0.0002	
CLI_{ch}	0.0000	0.0000	-0.0001	0.0000	0.0004	-0.0001	-0.0001	0.0000	**0.0011**
(standard error)	0.0001	0.0002	0.0001	0.0002	0.0003	0.0001	0.0001	0.0001	0.0001

A.3. Estimated coefficients of the OLS regression of yearly growth of Chinese foreign reserves on its lag, the lag of the one-month Treasury and Bund yields, the US and German unemployment rates, the leading indicators, core inflations, and the USD/EUR exchange rate. Sample spans from June 2009 to December 2017 (monthly data)

change in foreign reserves (FR)	Coef.	Std. Err.	Std. Err. (Newey-West)	t	t (Newey-West)
unmp US L1.	0.5588	0.4047	0.4335	1.38	1.29
ccpi US L1.	-2.6630	1.4392	1.5384	-1.85	-1.73
Leading US L1.	-0.7102	0.2967	0.3835	-2.39	-1.85
USD/EUR L1.	0.0185	0.0714	0.0378	0.26	0.49
unmp GER L1.	-2.5182	1.2251	1.0633	-2.06	-2.37
ccpi GER L1.	2.3988	0.9226	1.2533	2.6	1.91
Leading GER L1.	0.4481	0.2675	0.3673	1.68	1.22
1m US L1.	0.5269	1.0918	1.1662	0.48	0.45
1m GER L1.	1.6323	1.1277	1.5735	1.45	1.04
Leading CH L1.	**0.4708**	**0.2347**	**0.2484**	**2.01**	**1.90**
change FR L1.	0.8649	0.0364	0.0587	23.77	14.74
constant	0.0770	0.0694	0.0569	1.11	1.35


China drops Renminbi peg to U.S. Dollar
Chinese leading indicator
Chinese foreign reserves (yearly growth) (RHS)
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
40%
30%
20%
10%
0%
-10%
-20%
1.6.2009
1.1.2010
1.8.2010
1.3.2011
1.10.2011
1.5.2012
1.12.2012
1.7.2013
1.2.2014
1.9.2014
1.4.2015
1.11.2015
1.6.2016
1.1.2017
1.8.2017