Estimating and discussing the term premium on German bonds

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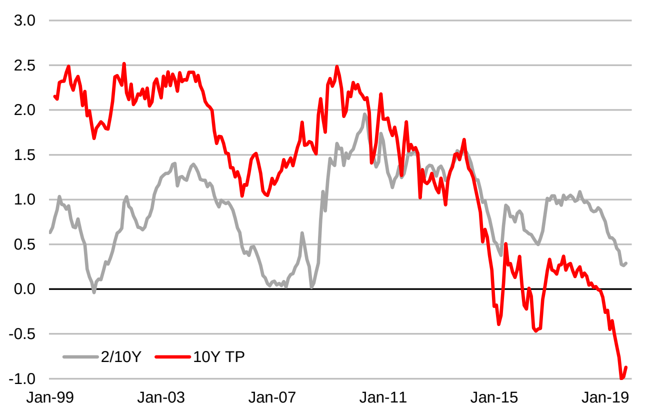
- We estimate the term premium of German bonds based on the methodology proposed by Adrian, Crump and Moench. We find that the term premium has declined sharply during 2019 and is currently negative.
- The term premium is strongly correlated with the 5Y5Y forward inflation, which explains 90% of the movement of the term premium. We also estimate, using a linear model, that the ECB monetary policy accounts for 40-70bp of the compression in the term premium.
- Term premiums at historical lows (and even negative) reduce the appeal of long term fixed income securities. This is especially the case in jurisdictions where the likelihood of a decline in rate expectations is limited, such as the eurozone.

CHART 1: 10Y GERMAN TERM PREMIUM



Source: Bloomberg, UniCredit Research

1. Estimating the term premium in the euro area

Long-maturity government bond yields have continued to decline for most of 2019 and have consolidated at negative levels in core eurozone countries.

A key question for investors is whether this decline reflects expectations of lower policy rates or a lower level of risk premium. The question is particularly relevant in light of the implementation of nonstandard policy measures in recent years as well as the ECB's decision to resume QE given the persistently weak dynamics in inflation and inflation expectations.

Rate expectations and risk premiums are not directly observable, or are available only infrequently and with very modest historical depth. Analysts have developed models to estimate risk premiums from observable variables such as yields and bond returns.

In this note we estimate and analyze the term premium for the German curve based on the methodology described by Adrian, Crump and Moench[1]. We find that there has been substantial compression in the German term premium over the last year. This trend is similar to what we observe in the US and, to some extent, in Japan.

We also investigate the main drivers of the term premium in the eurozone.

Sections 2 and 3 explain the methodology in detail, section 4 discusses the data used for the estimation, and sections 5 and 6 provide a detailed illustration of our findings.

2. The ACM model explained

The term premium, which is the variable we are interested in, is defined as the compensation that investors require to hold a long-maturity bond rather than rolling over short-maturity bonds. This definition of term premium entails some form of expectations about the future path of interest rates.

However, expectations for short-term rates over a long horizon are not observable or are available through survey data only infrequently. To overcome this problem, a model that describes the term structure is necessary. Once the relationship between yields at various maturities has been modeled, it becomes possible to estimate the term premium from observable variables such as yields and bond returns.

Affine models are quite popular in this respect. These models rely on three key assumptions: **(1)** the bond pricing function is exponentially affine in the shocks that drive the economy, **(2)** prices of risk are affine in the state variables, and **(3)** innovations to state variables and log yield observation errors are conditionally Gaussian. These assumptions give rise to yields that are affine in the state variables. The affine term structure literature has used maximum likelihood (ML) to estimate the coefficients.

An alternative approach has been proposed by Adrian, Crump and Moench (ACM). One advantage of their model is that it is computationally easy as it relies on linear regression rather than numerical optimization and, at the same time, it also delivers results that are quite stable.

[1] Adrian, T., Crump, R.K., Moench, E. (2008, revised in April 2013), *Pricing the Term Structure with Linear Regressions*, Federal Reserve Bank of New York Staff Reports, n. 340, available here:
https://www.newyorkfed.org/medialibrary/media/research/staff_reports/sr340.pdf

The key assumptions of their model are:

1) Prices of fixed income securities are all driven by a limited number of common factors, which are represented by the principal components of the yield curve. The authors assume that these factors evolve according to the following process:

$$X_t = \mu + \phi X_{t-1} + u_t \quad (1)$$

2) The shocks u_t are normally distributed with an expected value equal to 0 and a variance-covariance matrix Σ.

3) The assumption of no-arbitrage implies the existence of a unique discount factor that is assumed to be exponentially affine:

$$P_t^n = E_t\left[exp\left(-r_t - \frac{1}{2}\lambda'_t\lambda_t - \lambda'_t\Sigma^{-1/2}u_{t+1}\right)P_{t+1}^{n-1}\right] \quad (2)$$

P_t^n indicates the price at time t of a zero-coupon bond with maturity n; λ_t represents the market price of risk and is assumed to be linearly dependent on the unobservable factors:

$$\lambda_t = \Sigma^{-1/2}(\lambda_0 + \lambda_1 X_t) \quad (3)$$

and r_t denotes the risk-free rate.

It can be shown that the excess return is also a linear combination of the unobservable factors:

$$ExcessRet_{t+1} = f(\lambda_t) \quad (4)$$

The set of assumptions of the model implies that log bond prices are linear combinations of the unobservable factors:

$$lnP_t^n = A_n + B'_n X_t + e_t^n \quad (5)$$

and zero-coupon yields are equal to:

$$y_t^n = -\frac{1}{n}(A_n + B'_n X_t + e_t^n) \quad (6)$$

The general formula for the excess return obtained from holding a bond with an original maturity n from t-1 to t compared to the risk free rate is defined as:

$$ExcessRet_{t+1}^{n-1} = lnP_{t+1}^{n-1} - lnP_t^n - r_t \quad (7)$$

Which can be written using equation 5 as:

$$ExcessRet_{t+1}^n = A_{n-1} + B'_{n-1}X_{t+1} + u_{t+1}^{n-1} - A_n + B'_n X_t + u_t^n - r_t \quad (8)$$

Thus, from equation 4 and equation 8 we are able to better explore the excess returns and to analyze market price of risk. We can then extrapolate the term premium from the excess returns.

There are a number of different techniques to extract risk premiums, and a detailed review of the literature is beyond the scope of this research note. It is important to stress that the term premium estimation is significantly affected by the model specification as well as by the choice of data and the estimation sample. Hence, while estimating the term premium is highly interesting, the results should be handled with care. The qualitative picture is probably more robust and informative than the quantitative results themselves.

Note that in this specification the term premium is expressed in nominal terms, hence reflecting both a real term premium and an inflation risk premium.

3. Parameters estimation

Starting from the previous assumptions, ACM propose a three-step procedure to estimate the parameters of the model, based on linear regression.

First, the principal components (PCA) are calculated from yields. PCA represent the factors that drive the term structure. Then, we derive the parameters μ and ϕ in Equation 1 using ordinary least squares (OLS) and from these estimates we obtain an estimate for Σ ($\hat{\Sigma} = \hat{V}\hat{V}'/T$, where $\hat{V}$ is the matrix of residuals).

Secondly, we regress the bond excess returns over the lagged factors X_ and the matrix $\hat{V}$.

$$ExcessRet = a + \beta'\hat{V} + cX\_ + E \quad (9)$$

We use the residuals from this regression to compute an estimate for σ^2, the variance of returns that is not explained by either lagged factors or shocks relating to the unobservable factors ($\hat{\sigma}^2 = trace(\hat{E}\hat{E}')/NT$).

Thirdly, having obtained $\hat{\Sigma}$, $\hat{\sigma}^2, \hat{a}, \hat{\beta}'$ and $\hat{c}$ we can derive an estimate of λ_0 and λ_1.

In the ACM specification, the risk-free rate, which we introduced in equations 2, 7 and 8, is the yield earned on a bond which has maturity of 1 period (1 month in our analysis). We can express it as a linear function of the underlying factors:

$$r_t = \delta_0 + \delta'_1 X_{t-1} + \epsilon_t \quad (10)$$

Equation (10) is a specific case of equation (6). δ_0 and δ_1 can be estimated through OLS. Once we have obtained μ, ϕ, σ^2, λ_0, λ_1, δ_0 and δ_1, we compute the model yields as indicated in equation (6), by using the following recursive system of equations:

$$A_0 = 0,\ B'_0 = 0, A_1 = -\delta_0,\ B'_1 = -\delta'_1 \quad (11)$$

$$A_n = A_{n-1} + B'_{n-1}(\mu - \lambda_0) + \frac{1}{2}(B'_{n-1}\Sigma B_{n-1} + \sigma^2) - \delta_0 \quad (12)$$

$$B'_n = B'_{n-1}(\Phi - \lambda_1) - \delta'_1 \quad (13)$$

Setting $\lambda_0 = 0$ and $\lambda_1 = 0$ and calculating (12) and (13) we obtain risk-neutral yields. Under the assumption of risk neutrality, log prices are expected to grow only by the risk-free rate, meaning that exposure to the factors does not provide extra compensation to investors. Subtracting risk-neutral yields from model-implied yields gives the estimate of the term premium.

4. Data

Our analysis focuses on the German curve and is based on daily data from 1 February 1999 to 30 October 2019. As suggested by ACM, we use zero-coupon yields fitted using the Nelson-Siegel-Svensson model. The model parameters are calculated by the Deutsche Bundesbank[2].

We use these parameters to calculate zero-coupon rates for maturities from 3-120 months, from which we extract the principal components. The first three principal components already account for 99% of the sample variance, hence providing an accurate description of the yield curve.

We use the 1M OIS as a proxy for the risk-free return from which excess returns are calculated. We use the 1M OIS because the Nelson-Siegel-Svensson model is very difficult to apply to very short tenors. Indeed, the 1M rate obtained from the NSS interpolation has quite a few spikes that do not correspond to any episode of market tension.

We estimate the relevant regressions as well as the term premium with monthly frequency.

It is important to note that the choice of dataset affects the final result that we obtain. For example, using observed zero-coupon yields without smoothing them using the NSS model, provides a somewhat higher estimate for the term premium in the most recent years. Please see the Appendix for a more detailed discussion on this topic.

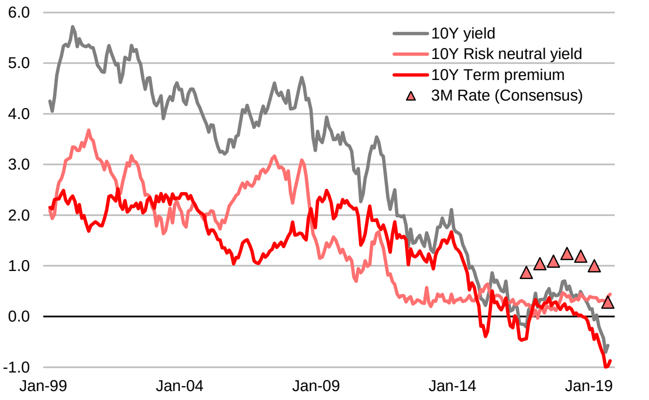
5. Surprise! The term premium has declined in recent months

The estimation result shows that the 10Y term premium remained in the 100-250bp range from the introduction of the euro until early 2014, after which it dropped sharply to almost zero, where it remained until the end of 2018, since when it has declined further and entered negative territory. This movement in the term premium since 2014 is in line with the idea that ECB's expansionary monetary policy has worked mainly through compression of the term premium.

Chart 2 shows the decomposition of the 10Y German yield into a risk neutral yield and a term premium, and highlights that the episodes of decline in nominal yields in 2014 and in 2019 were caused by a compression in the term premium.

[2] https://www.bundesbank.de/resource/blob/622394/f917db9f2fe9168243f272b535d67858/mL/1997-10-01-dkp-04-data.pdf

CHART 2: 10Y YIELD DECOMPOSED INTO TERM PREMIUM AND RISK-NEUTRAL YIELD



Dots indicate the expected 3M German rate over the coming ten years as reflected in the survey by Consensus Economics.

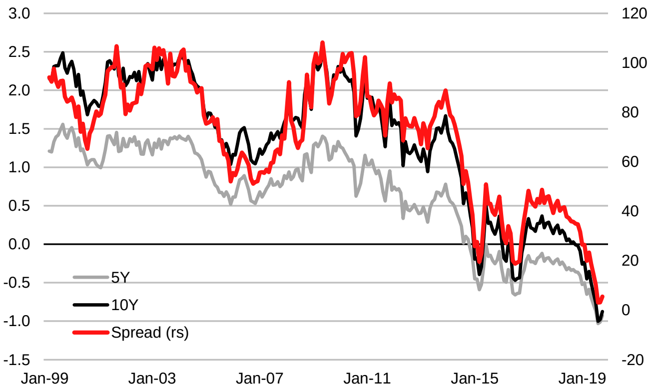
Source: Bloomberg, Consensus Economics, UniCredit Research

Risk-neutral yields dropped in early 2012 and have remained remarkably stable since then. Except for a very brief period soon after the UK Brexit referendum, risk-neutral yields have remained in positive territory. This indicates that investors regard negative policy rates as temporary.

Chart 2 also shows the expectation of short-term rates for the coming ten years as reflected by Consensus Economics (the survey is carried out with reference to the 3M Euribor, we adjusted the results to take into account the spread to German short-term rates). We observe that survey-based expectations have been substantially higher than the model-implied risk-neutral yields until very recently, as respondents to the survey have adjusted their expectations only very gradually. As a consequence, estimates of the term premium that take the survey data into account would have been lower until very recently.

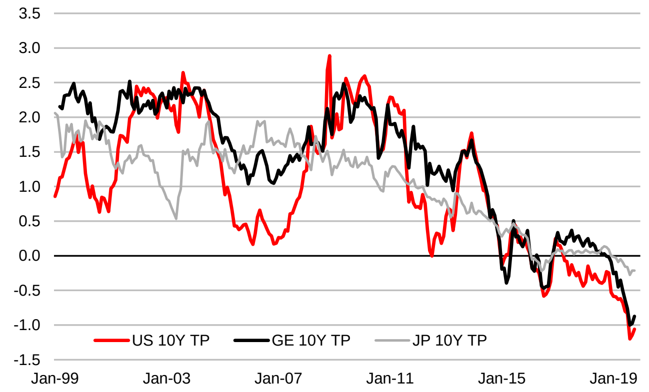
Are investors rewarded in terms of a higher term premium for holding longer bonds? Chart 3 shows that the 10Y term premium was around 60-100bp higher than the 5Y until mid-2014. This difference has narrowed considerably since the start of QE, reaching almost zero in September 2019. Historically, the term premium reward offered by the 10Y tenor relative to the 5Y has been bigger on the German curve than in the US.

**CHART 3:
10Y VERSUS 5Y TERM PREMIUM**



Source: Bloomberg, UniCredit Research

**CHART 4:
TERM PREMIUM HAS DECLINED IN VARIOUS COUNTRIES**



Source: Bloomberg, UniCredit Research

An interesting question is how the term premium dynamics of German bonds relate to other jurisdictions. Chart 4 shows the 10Y term premium estimated with the ACM model for Germany, the US and Japan. There is a clear downward trend in the term premium that began soon after the financial crisis. The decline has been slower in Japan, in part because the starting point was lower.

Estimates for the term premium are currently negative in all three jurisdictions. However, the decline has been considerably sharper in the US and Germany.

In addition, the 10Y term premiums in the US and Germany appear to have been extremely closely correlated since the start of the financial crisis in 2008, while Japan has followed a more independent pattern.

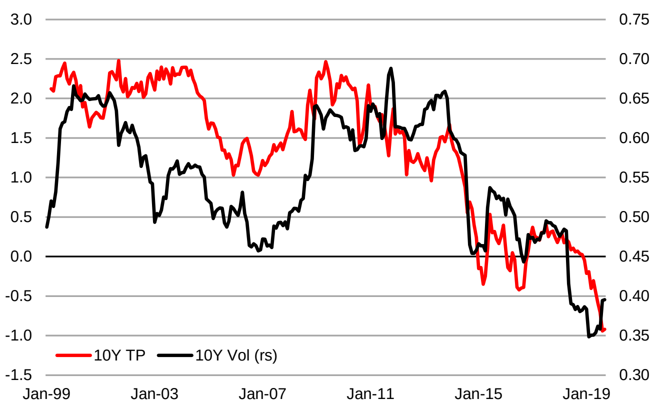
It should be noted that term premiums at historical lows (and even negative) limit the possible price performance of fixed income securities. This is especially the case in jurisdictions where the likelihood of a decline in rate expectations is also limited, such as the eurozone.

6. The main drivers of the term premium in the eurozone

In this section we analyze how the ACM term premium estimates relate to macroeconomic variables in the euro area. Although German government bonds are frequently regarded as the reference risk-free security for the euro area, it is important to stress that these bonds are also driven by idiosyncratic issues, such as supply/demand dynamics and scarcity due to the ECB's asset-purchase program (APP).

We expect the term premium to be higher when yields are more volatile, because investors will want to be compensated for the risk. We measure yield volatility as the annualized standard deviation of monthly changes in 10Y yields, calculated over a three year window. Empirical analysis confirms that the relationship between these two variables is positive.

CHART 5: TERM PREMIUM REFLECTS YIELD VOLATILITY

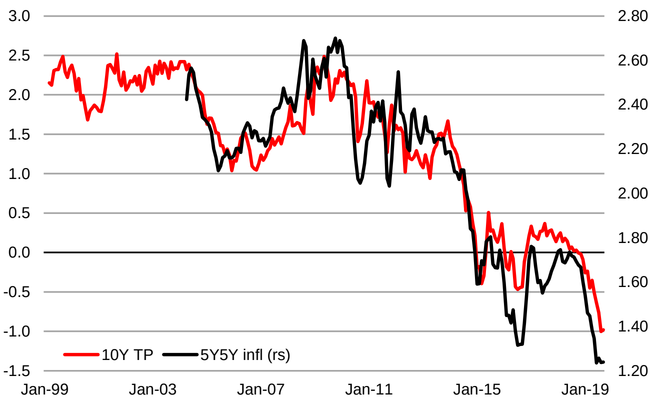


10Y yield volatility is calculated as three-year annualized standard deviation of monthly yield changes

Source: Bloomberg, UniCredit Research

According to economic theory, the relationship between the term premium and inflation and inflation volatility should be positive. We find that the correlation is indeed positive but rather weak. Empirically, it is the deterioration in inflation expectations rather than realized inflation that has contributed to the decline in the term premium. Indeed, the 5Y5Y forward inflation accounts for 90% of the movement in the German 10Y term premium. This is considerably more than what we observe in the US, where 5Y5Y forward inflation explains around 60% of changes in the term premium.

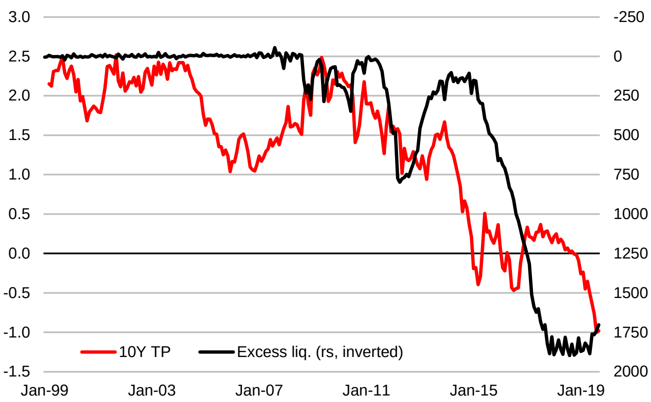
CHART 6: DETERIORATING INFLATION EXPECTATIONS HAVE DRIVEN THE TERM PREMIUM SOUTH



Source: Bloomberg, UniCredit Research

Finally, we compare the term premium with the ECB balance sheet. The interpretation of this relationship is not an easy task. For example, the term premium has tightened substantially in 2019 despite the ECB balance sheet remaining stable in this period due to the end of QE. At the same time, during the initial phase of QE no measurable compression in the term premium was observed. This suggests that the effect of the APP is non-linear and possibly works with a long lag.

CHART 7: TERM PREMIUM AND THE ECB BALANCE SHEET



Source: Bloomberg, UniCredit Research

To conclude this section, we present a linear model to explain how the 10Y term premium relates to key macroeconomic and financial variables. The variables used to explain the term premium are inflation, inflation volatility, risk aversion and the ECB's balance sheet policy (captured through the excess liquidity). Table 1 shows four model specifications, along with the R^2.

TABLE 1: THE TERM PREMIUM EXPLAINED WITH MACROECONOMIC VARIABLES

	Model 1	Model 2	Model 3	Model 4
C	**-2.50**	-0.01	**1.22**	**-1.64**
Core infl	**0.30**	0.03	-0.12	
Core infl Vol	**0.57**	**1.34**	**1.85**	
Headl. infl				0.05
Headl. infl Vol				**0.72**
10Y yld realized vol	**6.75**			**5.72**
10Y yld impl. vol		**0.29**		
EA systemic stress indicator			**2.37**	
Log(excess liquidity)	**-0.06**	**-0.09**	**-0.09**	**-0.10**
R^2	81%	64%	61%	82%
Estimated total impact of APP (bp)	-0.44	-0.68	-0.69	-0.71

Coefficient estimates in bold are statistically significant at the 95% level. The estimated impact of APP is calculated by multiplying the model coefficient by the change in ECB excess liquidity from February 2015 to September 2019.

Source: Bloomberg, UniCredit Research

All the estimated coefficients have the sign expected and are mostly statistically significant. Core inflation appears to be a more stable driver for the term premium than headline inflation. Similarly, realized yield volatility outperforms other measures of risk aversion.

As the last line of the table highlights, estimates of the impact of the ECB's balance sheet expansion vary considerably from one specification to another, ranging from 40bp to 70bp. Note that we have used the log of excess liquidity, which implies expansion has a marginally decreasing effect. A linear specification would result in a stronger impact of the ECB action. For reference, the ECB has calculated the impact of its APP on the term premium to be 95bp (see "Tracing the impact of the ECB's asset purchase programme on the yield curve"[3]). Based on our forecasts on inflation and the fact that excess liquidity should start to increase again in 2020 due to the resumption of QE, we see little case for the term premium to move back towards zero.

[3] Eser, F., Lemke W., Nyholm, K., Radde, S. Vladu A. L. (2019), *Tracing the impact of the ECB's asset purchase programme on the yield curve*. ECB Working Paper Series No 2293 / July 2019, available here: https://www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp2293~41f7613883.en.pdf?314ad453c9e18ea3ef566eb439cf1a31

7. Conclusions

We have estimated the term premium for German bonds, following the methodology presented by Adrian, Moench and Crump. The 10Y term premium estimate was between 100bp and 250bp from the introduction of the euro until mid-2014, since when it has declined markedly. The term premium has declined markedly in 2019, entering negative territory in recent months.

The choice of what data to use to feed the model affects the results, although not from a qualitative point of view.

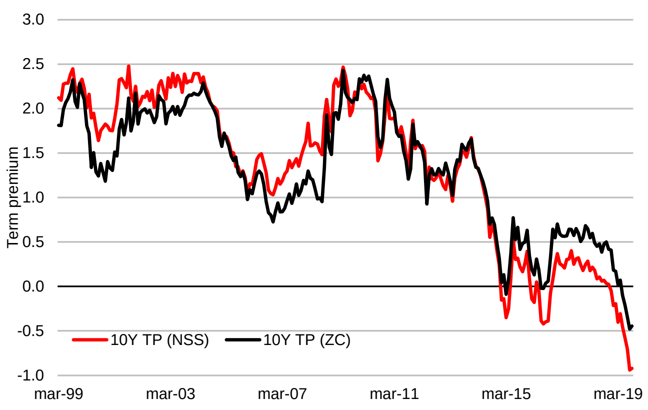
Our empirical analysis suggests that the term premium offered by 10Y German bonds is currently only a handful of basis points higher than that offered by 5Y bonds.

We showed how the term premium estimate relates to eurozone macroeconomic variables. Market based inflation expectations (5Y5Y forward) is the single most important one and accounts for 90% of the movements in the term premium. Such a high correlation likely reflects that ECB's decisions have been highly influenced by inflation expectations in recent years. Estimating the impact of the ECB APP is more difficult, not least because of the difficulty in disentangling the decisions of the central bank from the dynamics of inflation expectations. A linear model suggests that ECB monetary policy accounts for 40-70bp of compression in the term premium.

Appendix

It is important to stress that the choice of the dataset affects the final result that we obtain. For example, using observed zero-coupon yields rather than the ones interpolated with the Nelson-Siegel-Svensson model produces a somewhat lower estimate for the term premium in the most recent months. The two estimates deliver a very similar picture but in the final part of the sample differ by about 50bp. Hence, it is important to avoid reading too much into the exact level of the premium.

CHART 8: GERMAN TERM PREMIUM ESTIMATED WITH INTERPOLATED YIELDS AND WITH ZERO COUPONS

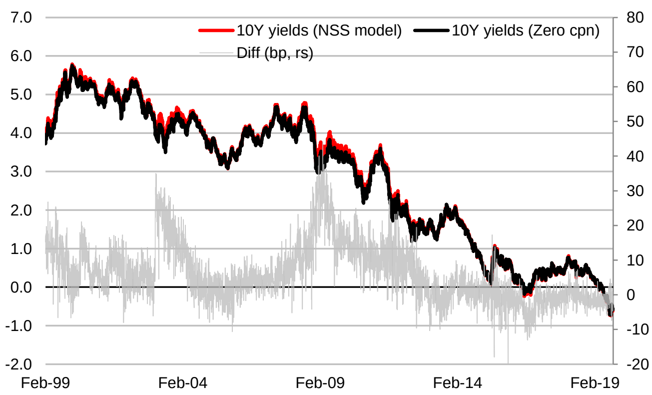


The chart shows the 10Y TP estimated using Nelson-Siegel-Svensson interpolated yields and using zero-coupon German yields.

Source: Bloomberg, UniCredit Research

The following chart illustrates the difference in the 10Y yield between the NSS interpolation and the 10Y zero-coupon yield calculated by Bloomberg.

CHART 9: DATA MAKE A DIFFERENCE



Source: Bloomberg, UniCredit Research

The two measures are quite close in general but there are divergences in some periods of up to 40bp. The following table shows a comparison across the entire maturity spectrum:

TABLE 2: DIFFERENCES BETWEEN NSS AND ZC YIELDS

	6M	12M	2Y	3Y	5Y	7Y	10Y
Top 95%	0.10	0.07	0.12	0.13	0.14	0.13	0.24
Low 5%	-0.10	-0.08	-0.07	-0.06	-0.07	-0.08	-0.06
RMSE	0.08	0.05	0.06	0.06	0.07	0.07	0.11

Source: Bloomberg, UniCredit Research

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