ESTIMATING THE OIS TERM PREMIUM WITH ANALYST EXPECTATION SURVEYS

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(*) The views expressed in this paper are those of the authors and do not necessarily coincide with those of the Banco de España and the Eurosystem.

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Abstract

This paper estimates the euro area overnight index swap yield curve, which is considered to be the risk-free yield curve in the euro area, using an affine term structure model. We expand the Adrian, Crump and Moench (2013) procedure with survey data to dissect rates into short-term expectations and term premia. This approach reveals the market expectations of short-term interest rates and monetary policy, and gauges the premium demanded by risk-averse investors in uncertain interest rate environments. As compared to the simpler model, the use of survey information in our estimation yields estimates more aligned with professional expectations data. Our approach enables us to obtain daily forecasts of short-term rates for up to 10 years ahead which are aligned with professional surveys on interest rates. Our estimation of real-time information on short-term rate expectations proves valuable as it complements the survey data, which are typically available at longer intervals.

Keywords: affine term structure model, interest rates, survey expectations.

JEL classification: E43, E44, G12.

Resumen

El presente documento estima la curva de rendimiento del *overnight index swap* (OIS) del área del euro —considerada como la curva de rendimiento libre de riesgo en la eurozona— utilizando un modelo afín de la estructura temporal de los tipos de interés. Para ello, ampliamos el procedimiento de Adrian, Crump y Moench (2013) para incluir los datos de encuestas sobre la evolución de los tipos de interés. Este enfoque revela las expectativas del mercado sobre los tipos de interés a corto plazo y sobre la política monetaria, y evalúa la prima exigida por los inversores aversos al riesgo en entornos de tipos de interés inciertos. En comparación con modelos más simples, la utilización de información procedente de encuestas produce estimaciones más alineadas con los datos de expectativas profesionales. Este enfoque nos permite obtener pronósticos diarios de los tipos a corto y a largo plazo que se encuentran alineados con las encuestas profesionales sobre tipos de interés. Además, nuestra estimación en tiempo real sobre expectativas de tipos a corto plazo resulta valiosa, ya que complementa los datos de encuestas, que generalmente están disponibles a intervalos más largos.

Palabras clave: estructura temporal de los tipos de interés, modelo afín, expectativas de encuestas.

Códigos JEL: E43, E44, G12.

Índice

1 Introduction

In this paper we estimate the euro area overnight index swap (OIS) yield curve, considered to be the risk-free yield curve in the euro area. For that aim, we combine the methods proposed by Adrian, Crump and Moench (2013, ACM henceforth) and Malik and Meldrum (2016) to estimate an affine term structure model.[1] This approach allows us to decompose rates into a short term expectations component and a term premium component taking into account survey expectations. The decomposition provides valuable insights into market participants› views on short term interest rates and monetary policy, as well as the extent to which risk-averse investors demand a premium for holding these instruments in an environment of interest rate uncertainty. By incorporating survey information, we aim to enhance the accuracy and reliability of the decomposition, enabling us to better understand market expectations and risk premia.

Our findings indicate significant differences in outcomes when survey information is incorporated, corroborating the research of Kim and Orphanides (2012). We show that this is also the case for the euro area yield curve and including information of survey expectations mitigates the underestimation of the short term interest rates implied by the standard ACM model, which doesn't use survey information. For instance, during the recent rate hike cycle, our model with surveys information attributes a substantial portion of the rise in long term rates to an increase in market participant's expectations of the short term rate. In contrast, a simpler model without survey expectations attributes a higher proportion of the rise to market risk.

The integration of survey information into our model also enables us to obtain daily estimates of the expected short term rate at various horizons, up to 10 years. These estimates align with the Survey of Monetary Analysts (SMA) and the Survey of Professional Forecasters (SPF). This real-time information on short term rate expectations proves valuable, as it complements the survey data, which is only available at longer intervals.

In conclusion, our affine term structure model, enriched with survey information, provides a robust framework for estimating the euro area OIS yield curve. This approach enhances our understanding of market expectations for short term interest rates and allows for a deeper analysis of risk premia. Additionally, the integration of survey data enables us to obtain timely estimates of short term rate expectations, thereby providing valuable information for monetary policy analysis and decision-making.

1 Adrian, Crump and Moench (2013) and Malik and Meldrum (2016) estimate term structure models for the US and UK yield curves respectively.

2 Methodology

2.1 State variables and expected excess returns

This section sets out the key equations of a standard Gaussian Affine Term Structure Model (ATSM), following ACM. We assume that the dynamics of a Kx1 vector of pricing factors, X_t, evolve according to the following Gaussinan autoregression (VAR):

$$X_{t+1} = \mu + \Phi X_t + v_{t+1} \ , \tag{1}$$

where the shocks $v_{t+1} \sim N(0, \Sigma)$ are conditionally Gaussian, homoskedastic and independent across time. We denote $P_t^{(n)}$ the zero-coupon bond price with a maturity n at time t The assumption of no-arbitrage implies (Dybvig and Ross, 1987) the existence of a pricing kernel M_{t+1} such that

$$P_t^{(n)} = E_t\left[M_{t+1} P_{t+1}^{(n-1)}\right], \tag{2}$$

We assume that the pricing kernel M_{t+1} is exponentially affine:

$$M_{t+1} = \exp\left(-r_t - \frac{1}{2}\lambda_t'\lambda_t - \lambda_t'\Sigma^{-\frac{1}{2}}v_{t+1}\right), \tag{3}$$

where $r_t = \ln P_t^{(1)}$ denotes the continuously compounded one-period risk-free rate, which is affine in the factors:

$$r_t = \delta_0 + \delta_1' X_t + \varepsilon_t \ , \tag{4}$$

We further assume that market prices of risk are of the essentially affine form as suggested in Duffee (2002):

$$\lambda_t = \Sigma^{-\frac{1}{2}}(\lambda_0 + \lambda_1 X_t). \tag{5}$$

The log excess one-period holding return of a bond maturing in n periods is defined as:

$$P_{t+1}^{(n-1)} = \ln P_{t+1}^{(n-1)} - \ln P_t^{(n)} - r_t \ . \tag{6}$$

Using Eqs. (3) and (6) in (2), ACM show that

$$E_t\left[\exp\left(rx_{t+1}^{(n-1)} - \frac{1}{2}\lambda_t'\lambda_t - \lambda_t'\Sigma^{-\frac{1}{2}}v_{t+1}\right)\right] = 1 \ , \tag{7}$$

and under the assumption of joint normality of $\left\{rx_{t+1}^{(n-1)}, v_{t+1}\right\}$ they demonstrate that

$$E_t\left[rx_{t+1}^{(n-1)}\right] = Cov_t\left[rx_{t+1}^{(n-1)}, v_{t+1}'\Sigma^{-\frac{1}{2}}\lambda_t\right] - \frac{1}{2}Var_t\left[rx_{t+1}\right]. \tag{8}$$

By denoting $\beta^{(n-1)} = Cov_t\left[rx_{t+1}^{(n-1)}, v_{t+1}'\right]\Sigma^{-1}$ and using Eq. (5), Eq. (8) can be rewritten as

$$E_t\left[rx_{t+1}^{(n-1)}\right] = \beta^{(n-1)}\left[\lambda_0 + \lambda_1 X_t\right] - \frac{1}{2}Var_t\left[rx_{t+1}^{(n-1)}\right]. \tag{9}$$

We can use Eq. (9) to decompose the unexpected excess return into a component that is correlated with v_{t+1} and another which is conditionally orthogonal:

$$rx_{t+1}^{(n-1)} - E_t\left[rx_{t+1}^{(n-1)}\right] = \beta^{(n-1)'} v_{t+1} + e_{t+1}^{(n-1)}, \tag{10}$$

where $e_{t+1}^{(n-1)} \sim iid(0, o^2)$. The return generating process for log excess returns can be written as

$$rx_{t+1}^{(n-1)} = \underbrace{\beta^{(n-1)}(\lambda_0 + \lambda_1 X_t)}_{\text{Expected return}} - \underbrace{\frac{1}{2}(\beta^{(n-1)'}\Sigma\beta^{(n-1)} + o^2)}_{\text{Convexity adjustment}} + \underbrace{\beta^{(n-1)'}v_{t+1}}_{\substack{\text{Priced return}\\ \text{innovation}}} + \underbrace{e_{t+1}^{(n-1)}}_{\substack{\text{Priced return}\\ \text{Error}}}. \tag{11}$$

We observe returns for t = 1, 2, ...,T and maturities $n = n_1, n_2, ..., n_N$. Stacking Eq. (11) across t and n, ACM construct the following expression:

$$rx = \beta'(\lambda_0 1_t' + \lambda_1 X) - \frac{1}{2}(B^* vec(\Sigma) + o^2 1_N') 1_T + \beta' V + E \tag{12}$$

where rx is and NxT matrix of excess returns, $\beta = [\beta^{(1)}, \beta^{(2)}, ... \beta^{(N)}]$ is a KxN matrix of factor loadings, 1_T and 1_N are a Tx1 and Nx1 vector of ones, $X = [X_0, X_1, ... X_{T-1}]$ is a KxT matrix of lagged pricing factors, $\beta^* = [vec(\beta^{(1)}, \beta^{(1)'}) ... vec(\beta^{(N)}, \beta^{(N)'})]'$ is an NxK^2 matrix, V is a KxT matrix and E is an NxT matrix.

2.2 Inclusion of interest rate survey expectation

In order to improve the identification of the persistence of yields, previous studies suggested the inclusion of survey expectations of future short-term interest rates. For that aim, we follow Malik and Meldrum (2016) who adapt ACM's approach to include the short rate and h-month ahead survey expectations in the following model:

$$\begin{bmatrix} X_{t+1} \\ r_t \\ E_t[r_{t+h}] \end{bmatrix} - \begin{bmatrix} \mu & \Phi \\ \delta_0 & \delta_1 \\ \delta_0 & \delta_1^1 \Phi^h \end{bmatrix} \begin{bmatrix} 1 \\ X_t \end{bmatrix} + v_{t+1}$$

$$v_{t+1} \sim N(0, R_\eta) \tag{13}$$

$$R_\eta = diag([\Sigma\, o_\varepsilon^2\, o_s^2])$$

Eq. (13) settles a VAR model which embedded Eqs. (1) and (4). On top of that, it includes an additional equation which stablishes the relationship between survey data and the pricing factors. Σ, o_ε^2, o_s^2 refers to the variance-covariance matrix of the first, second and third equations of the VAR model, respectively. This setup allows survey data ($E_t[r_{t+h}]$) to inform the path of expectations but without constraining the model to fit the surveys exactly.

2.3 Estimation

In this section we provide a brief outline of the estimation technique which is structured in the following three steps, which, closely follow ACM approach.

1. We estimate Eq. (13) by maximum likelihood. To fix the starting values of the optimization, we estimate Eqs. (1) and (4) as in ACM which involve OLS estimations. We impose $\mu = 0$ to ensure that the means of the pricing factors (mean-zero principal components) are equal to their sample averages. Once we have all parameter estimated (i.e, $\widehat{\Phi}, \widehat{\delta_0}, \widehat{\delta}_1, \widehat{\Sigma}, \widehat{\sigma^2_\varepsilon}, \widehat{\sigma^2_s}$) we get the innovations of Eq. (1) as follows: $\widehat{v_{t+1}} = x_{t+1} - \widehat{\Phi}X_t$. We then stack these innovations into the matrix $\widehat{V}$ and construct an estimator of the state variable variance-covariance matrix $\widehat{\Sigma} = \widehat{V}\widehat{V}/T$ As factors X_t, we use the first 3 principal components of the OIS curve.

2. We estimate a reduced-form of Eq. (12) using OLS in which we regress excess return on a constant, lagged pricing factors and contemporaneous pricing factor innovations according to

$$rx = a1_T' + \beta' \widehat{V} + cX + E. \tag{14}$$

   As result we get the estimated parameters (i.e, $\hat{a}, \hat{\beta}, \hat{c}$) as well as $0^2 = tr(EE')/NT$. We also construct $\widehat{B}^*$ from $\widehat{\beta}$.

3. Using $\widehat{B}^*$ constructed from $\widehat{\beta}$ and noting that $a = \beta'\lambda_0 - \frac{1}{2}(B^* vec(\Sigma) + \sigma^2 1_n)$ and $c = \beta'\lambda_1$, we estimate the price of risk parameters λ_0 and λ_1 via cross-sectional regression:

$$\lambda_0 = (\widehat{\beta}\widehat{\beta}')^{-1} \widehat{\beta} \left(\hat{a} + \frac{1}{2} (\widehat{B}^* vec(\widehat{\Sigma}) + \hat{\sigma}^2 1_N) \right), \tag{15}$$

$$\lambda_1 = (\widehat{\beta}\widehat{\beta}')^{-1} \widehat{\beta} \hat{c}. \tag{16}$$

2.4 Model implied yields and term premium

Given the assumptions made so far, it can be shown that zero-coupon bond yields are affine functions of the factors (see Piazzesi, 2003)

$$Y_t^{(n)} = -\frac{1}{2}[a_n + b_n' x_t], \tag{17}$$

where the coefficients a_n and b_n follow the recursive equations:

$$a_n = a_{n-1} + b_{n-1}'(\mu - \lambda_0) + \frac{1}{2}(b_{n-1}' \Sigma b_{n-1} + o^2) - \delta_0 \tag{18}$$

$$b_n' = b_{n-1}' (\Phi - \lambda_1) - \delta_1'. \tag{19}$$

We have, as initial conditions, $a_0 = 0$ and $b_0 = 0$.

Following the definition of Dai and Singleton (2002), an n-period bond yield can be decomposed as:

$$Y_t^{(n)} = \frac{1}{n} \sum_{i=0}^{n-1} E_t r_{t+i} + TP_t^{(n)} , \tag{20}$$

where the first-term on the right-hand side of Eq. (20) is the average expected short rate over the current and n - 1 subsequent periods. $TP_t^{(n)}$ is the term premium and can be interpreted as the additional compensation that investors require for investing in a long-term bond rather than rolling over a series of investments in short-term bonds.

2.5 Real time estimation and frequency mismatch

The main goal for this paper is to provide a tool that enables us to interpret the yield curve movements in the real time. To do this, we follow ACM and aggregate yields at weekly frequency by selecting end-of-week values and extract the principal components from these weekly yields. We continue to compute log excess holding period return at weekly frequency to obtain estimates of the parameters of the model as outlined in Section 2.3. We finally estimate daily yield factors by applying the weights from the weekly principal components to the daily yields and construct the model-implied yields and term premiums as described in Section 2.4 using the daily yield factors.

In addition, the use of survey information adds an additional layer of complexity to our analysis since the frequency of these data is much lower (see Section 3). We address this issue in the maximum likelihood estimation. First, rewrite Eq. (13) as follows

$$\underbrace{\begin{bmatrix} X_{t+1} \\ r_t \\ E_t[r_{t+h}] \end{bmatrix}}_{Yt} = \underbrace{\begin{bmatrix} \mu & \Phi \\ \delta_0 & \delta_1 \\ \delta_0 & \delta_1^1 \Phi^h \end{bmatrix}}_{\beta} \begin{bmatrix} 1 \\ X_t \end{bmatrix} + v_{t+1} ,$$

and formulate the following maximization problem:

$$\text{Max } f\,(y^T | \beta) . \tag{21}$$

The log-likelihood function is as follows:

$$f(y^T | \beta) = \sum_{t=1}^{T} \log f(y_t | x_y, \beta) = -\frac{T}{2} \log \det(2\pi R_\eta) - 0.5 \sum_{t=1}^{T} (y_t - \beta x_t) I_s' R_\eta^{-1} (y_t - \beta x_t) \tag{22}$$

where is an indicator vector that take value 1 in the last positions if survey information is available and zero otherwise. By doing that, if survey information is not available for that week, Eq. (13) transforms in a combination of Eqs. (1) and (4).

3 Data

We use the euro area overnight index swap (OIS) yields, which is considered as the risk-free yield curve in the euro area. Our sample spans from 15/08/2005 up to 20/07/2023 on daily basis and uses the EONIA as the underlying contract up to 26/09/2019 and the €STER from that date onwards.

As pricing factors we use the three principal components extracted from the end-of-week OIS yields for maturities of 9-month, 12-month, 15-month, 18-month, 21-month, 2-years, 3-years, …,10-years. These three factors are commonly used in the literature due to their direct relation with the level, slope and curvature of the yield curve.

Similar to ACM, we use monthly excess returns for n=6, 7, …,12,15, …,24,36, …,120 months, giving a cross section of monthly excess returns for N=19 maturities. We use as risk-free rate the OIS 1-month for computing the excess returns, as defined in Eq. (6).

Finally, we employ two different data sources for survey information: Consensus Economics Forecasts (CEF) and ECB Survey of Monetary Analyst (SMA). CEF provides information on quarterly basis since 2016Q4 on the future path of the Euribor 3-month. In addition, we use the SMA, available every 6 weeks since May 2021which provides forecasts for the €STER short rate and various horionzs. For the CEF we use the 3, 12 and 24-month horizons whereas for the SMA we use the short rate expectations at the 4, 10, 16 and 22-month horizon. We pick these horizons for the SMA forecasts as these are consistently updated every six weeks whereas other horizons forecasts are more infrequent.

4 Empirical Results

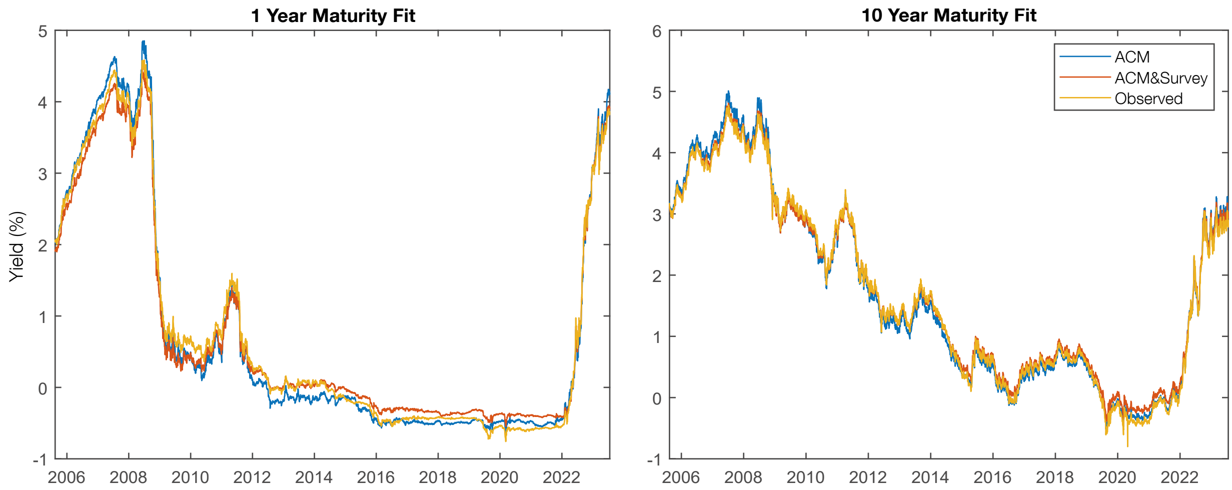
4.1 Model Fit and Term Premia Estimation

To ensure comparability, we estimate two versions of the affine term structure model: one that incorporates data from survey expectations and one that uses the ACM model without survey expectations. We analyse both models against the 10-year and 1-year yields to assess their fit.

Chart 1 shows that including survey expectations in the ACM model slightly improves the fit, particularly at longer maturities. At the 1-year maturity, both models have a similarly good fit, with the largest discrepancies occurring during the negative interest rate period. At the 10-year maturity, both models present a very good fit but again, the model with survey information performs slightly better. For example, in Figure 1, we see that while the fit for the models without survey and with survey for the 1-year rate are of 99.49% and 99.51% respectively, if we look at the low interest rate period from 2012 to end of 2021, the fit is 89.5% compared to the 96.4% of the model with surveys. However, the key difference between the two models lies in how they decompose rates into the term premium and short rate expectations component from Eq. (20). Since the term premium is given by the difference between the model rate at a given maturity and the expected return obtained from rolling over an investment in short term rates up until that given maturity, expectations of the short term rate play a key role.

Chart 2 demonstrates that incorporating expectations on short term rates at various horizons mainly influences the decomposition of the yield curve. Differences between the

Chart 1
MODEL FIT AGAINST OBSERVED YIELDS

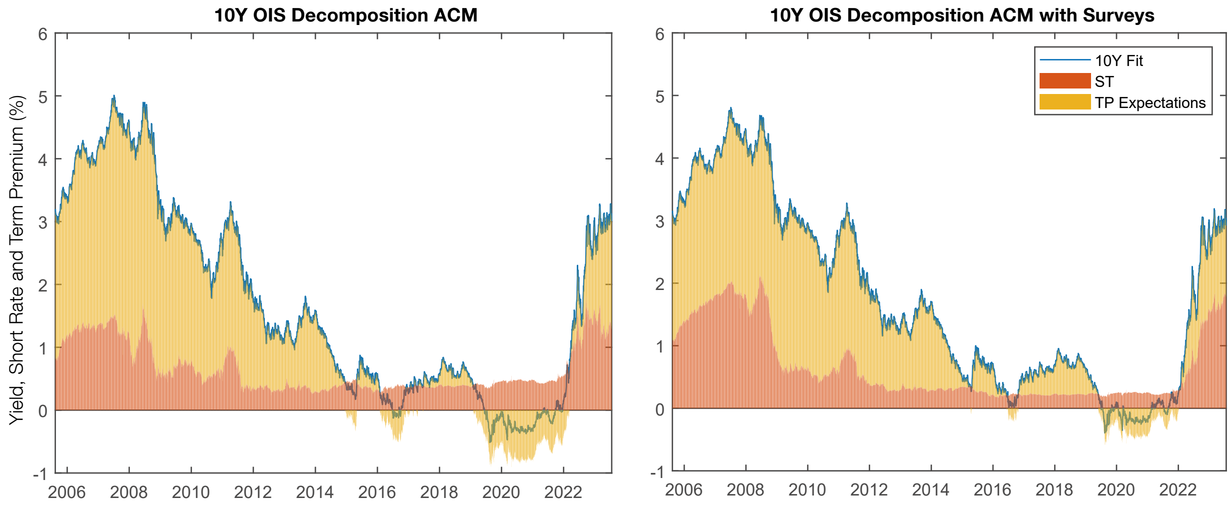


(a) 10 year maturity model fit
R2 ACM without survey: 99.49%
R2 ACM with survey: 99.51%

(b) 10 year maturity model fit
R2 ACM without survey: 99.59%
R2 ACM with survey: 99.82%

SOURCE: Banco de España.

Chart 2
10 YEAR YIELD DECOMPOSITIONS INTO TERM PREMIUM AND SHORT TERM RATES



(a) ACM model without surveys

(b) ACM model with surveys

SOURCE: Banco de España.

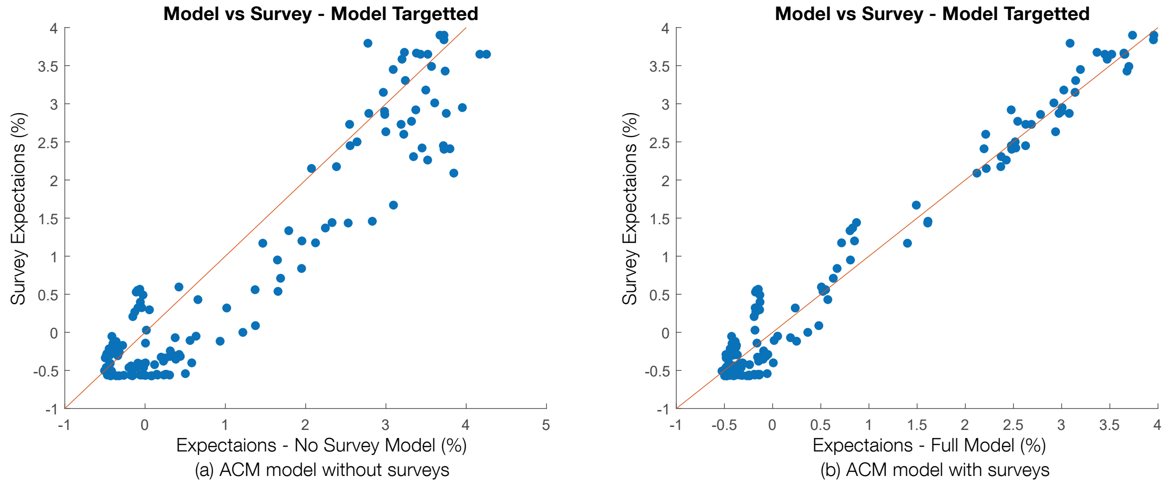
two models vary over time, with more pronounced disparities during periods of significant interest rate increases (e.g., 2005-2008 and 2022-2023). Before the global financial crisis, large differences emerge between the alternative models, being the short term expectations of the ACM model with survey information on average 0.45 percentage points higher. During the sovereign debt crisis, both models converge and there are minimal discrepancies between decompositions. From 2016 to 2021, a period characterized by negative interest rates, the gap between the two models widens again, with the size of the short term expectations of the ACM model with survey information 0.2 percentage points smaller. Since the recent ECB rate hikes, the short term expectations of the ACM model with survey information exhibit a steeper slope. Specifically, during 2023, the short rate expectations of the ACM model with survey information are, on average, 0.3 percentage points larger. The observed differences between the two models, particularly during periods of significant interest rate hikes, may be attributed to the well-known limitations of systems like Eq. (1) (Kim and Orphanides, 2012) when additional information is not provided to the model. More precisely, the ACM model displays a quicker convergence of the short-rate path to the asymptotic value, resulting in an underestimation of the short-term interest rate implied by the model and an overestimation of the term premium.

4.2 Comparing model short term interest rate expectations

Next, we compare how the estimated short term interest rate expectations align with survey expectations. In Chart 3 we plot expectations for the short term rate produced by both models against those coming from the surveys. That is, for every date for which we have a survey expectation, we produce model estimates from the same period to match the horizon of that survey estimate. Given that the model with survey expectations is targeted to

Chart 3

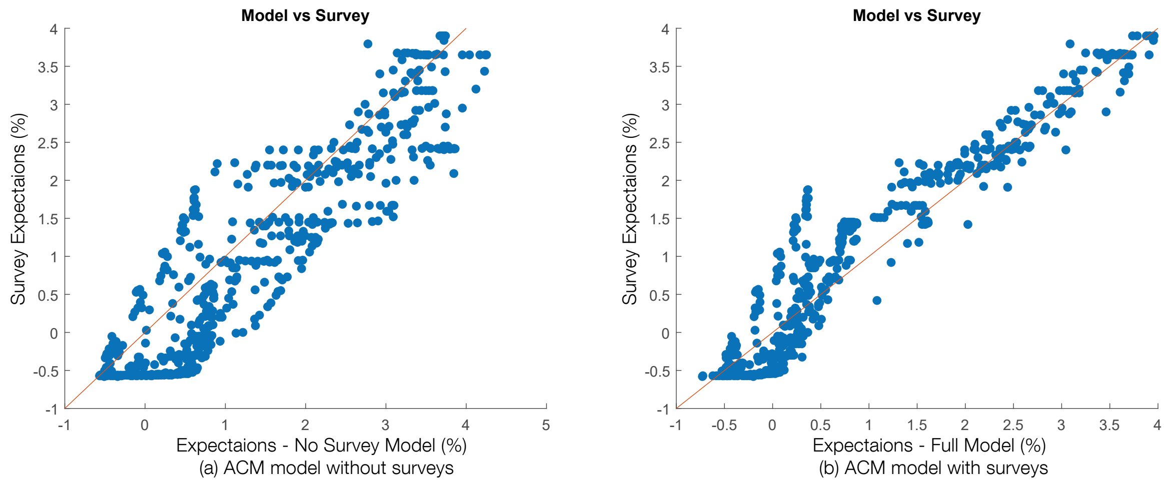
PLOTS OF MODEL EXPECTED SHORT TERM RATES AGAINST TARGETED SURVEY EXPECTATIONS



SOURCE: Banco de España.

Chart 4

PLOTS OF MODEL EXPECTED SHORT TERM RATES AGAINST ALL CEF AND SMA SURVEY EXPECTATIONS



SOURCE: Banco de España.

minimize differences with respect to the surveys, we should expect that our model at least is aligned with the targeted horizons.

In the model that incorporates survey expectations, we estimate the model to fit the CEF expectations for short rates at the 3, 12 and 24-month horizons, as well as the SMA short rate expectations at the 4, 10, 16 and 22-month horizons. Unsurprisingly, the model with survey expectations (Figure 3b) exhibits a much better fit, with an R2 of 97% while the standard ACM model has an R2 of 91% with respect to the 45-degree line.

However, it is also of interest to check whether our model estimates are also aligned with survey expectations that are not specifically targeted by our model. In Chart 4, we do a similar exercise as in Figure 3, but with all available survey horizons from the CEF and SMA, that is, including survey expectations not directly targeted by our model. We observe the same pattern when comparing the model-generated expectations with all available survey expectations from the CEF and SMA forecasts, spanning 50 horizons from 1 week to 5 years. As shown in Chart 4, the model with survey expectations still manages to fit the survey expectations that does not explicitly target during the estimation process. While the standard ACM model has an R2 of 78%, the model with survey expectations achieves a fit of 85% with respect to the 45-degree line. It is worth noting that although surveys cover horizons up to 10 years, the survey expectations for 5 to 10 years are very stable. This is an important result as trying to fit a model to too many horizons would result in unreliable estimates, this way we can show that a more parsimonious model is still able to match survey expectations well.

We emphasize that this result is valuable if the objective is not only to extract term premia but also to obtain real-time estimates of expected future short term rates that align with survey expectations, as these surveys are released either every 6 weeks (SMA) or quarterly (CEF).

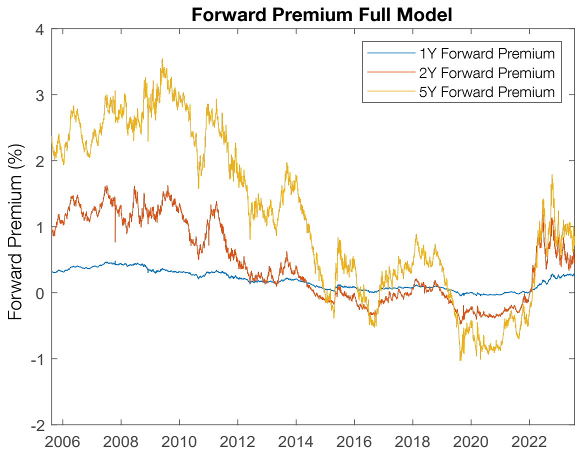
5 Additional applications

In addition to the primary application of decomposing rates into term premia and short term components and obtaining real-time expectations of the short rate, this model can also be used to produce forward curves and compare them to short term rate expectations. While instantaneous forward rates are commonly used by market observers as a proxy for the expected short rate at multiple horizons, several empirical studies reject the expectations hypothesis which implies this equality (see for instance Cochrane and Piazessi, 2005). Instead, forward rates carry a risk premium that can be positive or negative, and this risk premium would be the difference between the forward rate and the expected rate.

Below we plot the forward premium at the 1, 2 and 5 year horizons, that is the difference in the instantaneous forward rate and the expected short rate generated by our model with survey expectations at these horizons. These estimates are consistent with what we would expect given recent monetary policy developments.

From 2008 to 2016, we see a decrease in forward premia consistent with loosening monetary policy and we even observe negative premia between 2016 until the beginning of 2022. We can especially observe a significant drop in the 5 year forward premium around the time the ECB conducted its bond buying programs. Since 2022, due to increasing inflation rates and the tightening of monetary policy, we observe a recent rise in these forward premia, especially at the longer horizons. This can be partly driven by an increase in uncertainty around the evolution of future interest rates.

Chart 5
MODEL GENERATED FORWARD PREMIA FOR 1, 2 AND 5 YEAR HORIZONS



SOURCE: Banco de España.

6 Conclusion

This paper presents an estimation of an affine term structure model for the overnight index swap yield curve that incorporates survey expectations in the short rate from the CEF and SMA surveys. We follow the approach of Malik and Meldrum (2016) by incorporating survey expectations into the Adrian et al. (2013) affine term structure model. We find that adding survey expectations to the estimation reduces the underestimation of the short term expectations during periods of significant increases of interest rates, which is in line with Kim and Orphanides (2012).

We view this model as a valuable tool with several policy applications, including providing real time estimates of expected short term rates that are anchored by survey expectations, as well as estimates for risk premia along the yield curve.

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