Anchoring the Yield Curve Using Survey Expectations

Online Supplemental Appendix[1]

Carlo Altavilla[2]
European Central Bank

Raffaella Giacomini[3]
University College London
CeMMAP

Giuseppe Ragusa[4]
Luiss University, Rome

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[2] E-mail: carlo.altavilla@ecb.int

[3] University College London, Gower Street WC1E6BT London, UK. Email: r.giacomini@ucl.ac.uk

[4] Luiss University, Viale Romania, 32 - 00197 Rome, Italy. E-mail: gragusa@luiss.it

1 Online Supplemental Appendix

This Appendix contains additional empirical results that are not included in the main text.

2 Data

We describe the yields data, the macroeconomic data and the survey data that we used.

The yields data are pooled from two sources. The three-month yield is from the Fed's H-15 release. For longer maturities, we use zero-coupon yields constructed in (**?**).[1] We do not use the three-month yield from this dataset because the BC explicitly asks participants to predict this particular rate. We focus on average-of-the-month data from January 1985 to December 2011. We consider yields of the following 17 maturities (in months): 3, 6, 9, 12, 15, 18, 21, 24, 30, 36, 48, 60, 72, 84, 96, 108, 120. This choice provides us with a panel of 324 monthly observations on 17 different yields. Descriptive statistics of the sample are given in Table 1 and a plot of the data is in Figure 1.

The macroeconomic variables used in the macro augmented DNS model consist of monthly observations on 23 U.S. macroeconomic time series from 1985:1 through 2011:12. Table 2 lists the variables and the data transformationsf.

Survey data are from Blue Chip Financial Forecasts (BC). The interest rates that the BC analysts forecast are the quarterly average of constant maturity Treasury yields as defined by the Federal Reserve Statistical Release H.15.

There are two important issues to consider when comparing the accuracy of survey data to that of model-based forecasts: the alignment of information sets and the conversion of quarterly forecasts into monthly forecasts. Here we explain how we dealt with both issues.

First, in order to guarantee a fair comparison between model and survey forecasts, we made sure that the information sets on which the forecasts are based are aligned. In particular, one must pay attention to the timing of the survey in relation to the type of data used. For example, if the model is estimated using end-of-the-month data and the survey is released around the 15th of the month (which is the typical release date for the quarterly Survey of Professional Forecasters conducted by the Federal Reserve Bank of Philadelphia), the informational advantage of the survey might be simply related to

[1] This dataset is publicly available on the website of the Federal Reserve Board. The data can be obtained at the address: http://www.federalreserve.gov/pubs/feds/2006/.

Table 1. Yield data, 1985:1-2011:12. Descriptive statistics

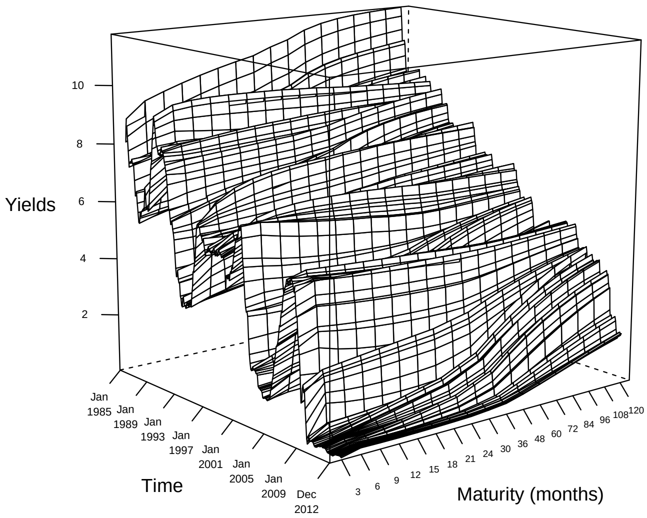
Maturity (months)	*Mean*	*SD*	*Min*	*Max*	*MAE*	*RMSE*	$\hat{\rho}(1)$	$\hat{\rho}(12)$	$\hat{\rho}(30)$
3	-0.109	0.119	-0.772	0.208	0.085	0.119	0.78	0.268	-0.038
6	0.024	0.056	-0.097	0.378	0.037	0.056	0.67	0.098	-0.031
9	0.040	0.056	-0.139	0.335	0.038	0.055	0.75	0.238	-0.069
12	0.046	0.050	-0.129	0.272	0.036	0.050	0.79	0.293	-0.063
15	0.044	0.040	-0.081	0.200	0.030	0.040	0.82	0.330	-0.025
18	0.037	0.029	-0.034	0.123	0.022	0.029	0.85	0.359	0.061
21	0.027	0.020	-0.025	0.083	0.016	0.020	0.83	0.348	0.192
24	0.014	0.017	-0.051	0.052	0.013	0.017	0.74	0.242	0.165
30	-0.013	0.028	-0.145	0.087	0.018	0.028	0.75	0.236	-0.082
36	-0.037	0.040	-0.231	0.089	0.030	0.040	0.80	0.302	-0.061
48	-0.068	0.055	-0.297	0.064	0.042	0.054	0.85	0.371	0.048
60	-0.073	0.053	-0.253	0.067	0.040	0.053	0.87	0.397	0.131
72	-0.057	0.040	-0.173	0.049	0.030	0.040	0.87	0.402	0.191
84	-0.027	0.020	-0.081	0.023	0.015	0.020	0.84	0.371	0.223
96	0.010	0.015	-0.027	0.098	0.011	0.015	0.81	0.325	-0.046
108	0.050	0.037	-0.047	0.190	0.029	0.037	0.86	0.387	0.103
120	0.089	0.063	-0.074	0.271	0.048	0.063	0.86	0.389	0.141

Notes: The data on yields used in the paper are pooled from two sources. The end-of-month three-month yield is taken from the Fed's H-15 release. For longer maturities, we use zero-coupon yields constructed in **?**.

Table 2. Macroeconomic variables

	Variable	Acronym	Tran
1	Personal Income	PI	$\Delta\ln$
2	University of Michigan Inflation Expectation	UMIE	Δlv
3	Producer Price Index: All Commodities	PPI	$\Delta 2\ln$
4	Consumer Price Index for All Urban Consumers: All Items	CPI	$\Delta 2\ln$
5	Personal Consumption Expenditures: Chain-type Price Index	PCE	$\Delta 2\ln$
6	All Employees: Total non-farm	Emp	$\Delta\ln$
7	4-Week Moving Average of Initial Claims	IC	$\Delta\ln$
8	Moody's Seasoned Aaa Corporate Bond Yield	AAA	Δlv
9	Moody's Seasoned Baa Corporate Bond Yield	BAA	Δlv
10	Industrial Production Index	IP	$\Delta\ln$
11	Capacity Utilization: Total Industry	CU	Δlv
12	Civilian Labor Force	LF	$\Delta\ln$
13	Civilian Unemployment Rate	UR	Δlv
14	Average Weekly Hours of Production and Nonsupervisory Employees: Manufacturing	AWH	lv
15	Housing Starts: Total: New Privately Owned Housing Units Started	HS	$\ln$
16	ISM Manufacturing: PMI Composite Index	PMI	lv
17	M1 Money Stock	M1	$\Delta 2\ln$
18	M2 Money Stock	M2	$\Delta 2\ln$
19	Total Consumer Credit Owned and Securitized, Outstanding	CC	$\Delta 2\ln$
20	S&P 500 Stock Price Index	SP500	$\Delta\ln$
21	Average Hourly Earnings of Production and Nonsupervisory Employees: Total Private	AHE	$\Delta 2\ln$
22	Excess Reserves of Depository Institutions	RDI	$\Delta 2\ln$
23	ISM Manufacturing: Employment Index	EI	lv

Figure 1. Bond yields data in three dimensions.



Notes: The figure plots average-of-the-month U.S. Treasury bill and bond yields at maturities ranging from 6 months to 10 years. The three-month yield is taken from the Fed's H-15 release. For longer maturities, we use zero-coupon yields constructed in **?**. The sample period is January 1985 through December 2012.

the fact that when panelists submit their forecasts they have access to more information than the model. This is however less of a concern when using BC survey data, because the survey is published on the 1st day of each month, and one can thus make the assumption that the survey forecasts have access to the same information set than a model estimated using end-of-the-month data (or possibly a smaller information set if the survey participants communicate their forecasts a few days before the BC releases them).

The second issue is related to the discrepancy between the frequency of the survey (monthly) and the frequency of the target variables' predictions (quarterly). In fact, this discrepancy introduces a time-variation in the information set that has to be taken into account when analyzing the accuracy of the survey predictions at a monthly frequency. Table 3 describes how we extracted monthly forecasts from the quarterly BC survey

Table 3. Extraction of monthly forecasts from quarterly BC forecasts

Time of forecast release	Forecast horizon (h = months)			
	$h = 3$	$h = 6$	$h = 9$	$h = 12$
January 1^{st}	BC^{Now}_{Jan}	BC^{1Q}_{Jan}	BC^{2Q}_{Jan}	BC^{3Q}_{Jan}
February 1^{st}	BC^{1Q}_{Feb}	BC^{2Q}_{Feb}	BC^{3Q}_{Feb}	BC^{4Q}_{Feb}
March 1^{st}	BC^{1Q}_{Mar}	BC^{2Q}_{Mar}	BC^{3Q}_{Mar}	BC^{4Q}_{Mar}
April 1^{st}	BC^{Now}_{Apr}	BC^{1Q}_{Apr}	BC^{2Q}_{Apr}	BC^{3Q}_{Apr}

expectations. Recall that the BC analysts are asked to predict the average value of a target variable over the current and the following quarters. For this reason, we use average-of-the-month data (although using end-of-the-month data does not significantly alter our results). In practice, we use the expectation made for the current quarter as the 3-months-ahead prediction. This means that for the survey released on the 1st of January the implied 3-month-ahead forecast is given by the expected value for the current quarter, i.e. the nowcast, contained in the survey (BCNow, Jan in the table). Similarly, the 6- 9- and 12-month-ahead forecasts made on the 1st of January are retrieved from the 1-, 2-, and 3-quarter-ahead forecasts contained in the survey (BCJan,1Q, BCJan,2Q BCJan,3Q in the table).

3 Conditional forecasting

To obtain the conditional forecasts of Table 4 we follow **?** which in turn adopt the strategy for forecasting with ragged edge data sets using a Kalman filter methodology. Here the ragged edges arise as the survey forecasts are used as future observations. The methodology relies on drawing the states conditionally on the observations and the survey forecasts using the simulation smoother of **?**. More precisely, given the parameter estimates, the simulation smoother draws

$$(\beta_{t|T}, \theta_{t|T}) \sim p(\cdot|y_t, x_t, bc_{T|T+h}, \bar{\Psi}, t = 1, \dots, T), \tag{1}$$

where bc_{T+h} denotes the Blue Chip forecast at horizon h given the information set at time T, and $\bar{\Psi}$ denote the estimated parameters adjusted to take into account the ragged edges that result from introducing the survey forecasts in the state-space. The conditional forecast for the yield can then be produced by evaluating the measurement equation at different simulations of $(\beta_{t|T}, \theta_{t|T})$, and then approximating the expected value of the yield by averaging over the resulting draws.

Table 4. Relative MSFEs of conditional forecasts (yield only model)

Maturity	**Conditional vs DNS**				**Conditional vs RW**			
	h=3	h=6	h=9	h=12	h=3	h=6	h=9	h=12
3	0.42***	0.58*	0.70	0.83	0.79***	0.84*	0.90	1.00
6	0.56***	0.65**	0.73*	0.82	0.68***	0.75**	0.82*	0.89
9	0.65**	0.70*	0.76	0.85	0.77**	0.81*	0.85	0.91
12	0.72*	0.75	0.79	0.87	0.83*	0.85	0.89	0.94
15	0.77	0.78	0.82	0.89	0.88	0.89	0.92	0.97
18	0.80	0.81	0.84	0.91	0.91	0.93	0.96	1.01
21	0.83	0.84	0.86	0.93	0.94	0.96	1.00	1.04
24	0.84	0.86	0.88	0.94	0.96	0.99	1.03	1.08
30	0.85	0.89	0.91	0.97	1.00	1.05	1.11	1.15
36	0.86	0.91	0.94	0.99	1.04	1.10	1.18	1.22
48	0.87	0.95	0.98	1.03	1.09	1.17	1.28	1.33
60	0.91	0.98	1.01	1.05	1.10	1.18	1.31	1.38
72	0.95	1.01	1.05	1.08	1.07	1.15	1.28	1.35
84	1.01	1.05	1.09	1.10	1.04	1.11	1.22	1.28
96	1.07	1.10	1.13	1.13	1.04	1.08	1.14	1.19
108	1.14	1.15	1.17	1.15	1.12	1.07	1.08	1.10
120	1.19	1.19	1.22	1.18	1.24	1.10	1.06	1.04

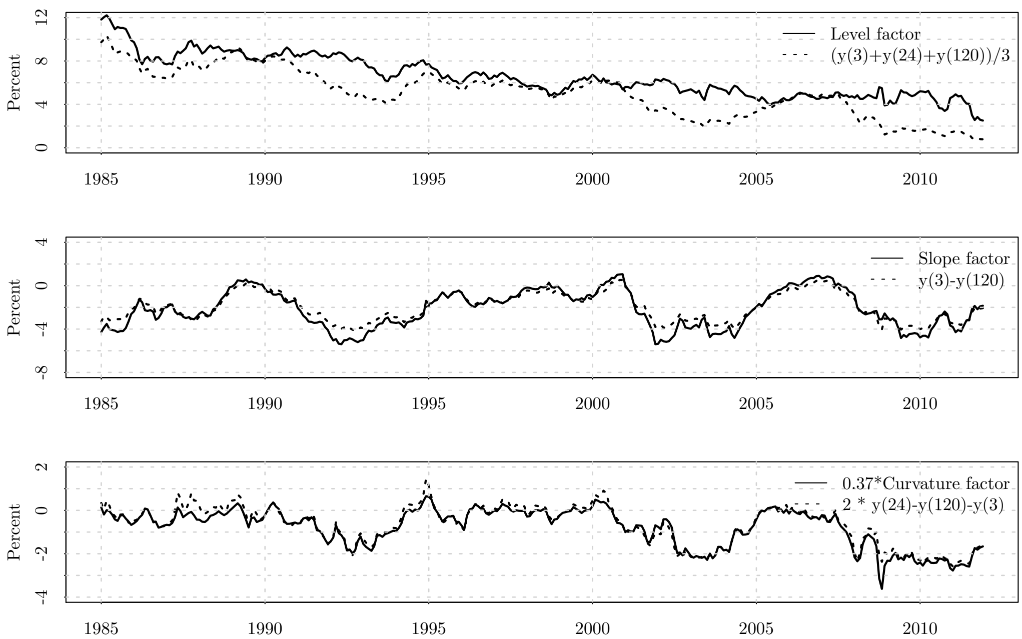
Notes: The table reports the ratios of MSFE of the conditional forecasts to the random walk forecasts and to the yields only DNS model. The asterisk indicates significance according to the Diebold and Mariano (1995) test of equal accuracy against the alternative that the anchored forecast is more accurate ('***' at the 1%, '**' at the 5%, and '*' at the 1%). The Diebold and Mariano test was implemented using an HAC estimator with $h-1$ truncation parameter.

4 In sample fit of DNS model

Here we report results regarding the estimation and the in-sample fit of the state-space version of the DNS model. For brevity we only report the yields only model. Fit statistics for the macro model are qualitatively similar.

Figure 2 shows the estimated time series of the three factors and their empirical counterparts. The first graph plots the level factor $\hat{\beta}_{1,t}$ against the average of short-, medium- and long-term yields, $(y_t(3) + y_t(24) + y_t(120))/3$. The middle panel plots $\hat{\beta}_{2,t}$ against the empirical slope of the yield curve $y_t(3) - y_t(120)$. Finally, the bottom panel shows the behavior of $0.37\hat{\beta}_{3,t}$ and

Figure 2. Estimated DNS factors and empirical counterparts



Note: The first factor β_{1t} controls the yield curve level, as it can be verified that $\lim_{\tau \to \infty} y_t(\tau) = \beta_{1t}$. The second factor β_{2t} is related to the yield curve slope, defined as the difference between the 10-year and three-month yields. The third factor β_{3t} governs the curvature of the yield curve, defined as twice the two-year yield minus the sum of the 10-year and three-month yields.

the empirical curvature proxy $2y_t(24) - y_t(3) - y_t(120)$. The curvature factor closely matches the dynamics of its empirical counterpart: the difference between the two series has a mean of 12 basis points and a standard deviation of 19 basis points. Also, the slope factor matches very closely the empirical proxy for the slope with a correlation of 0.98. The level factor shows instead a marked departure from the empirical counterpart. Importantly, this departure is most noticeable in the period 2000-2011. In particular, from January 1985 to December 2001, the correlation between $\hat{\beta}_{1,t}$ and $(y_t(3)+y_t(24)+y_t(120))/3$ is 0.81, from February 2002 to December 2011 the correlation drops to 0.29. The mean and standard deviations of the difference increase from 119 basis points to 196 basis points and from 93 basis points to 124 basis points, respectively.

Table 5 presents summary statistics of the residuals for each of the 17 maturities considered. Both the mean and the standard deviations of the residuals are small for all maturities. The largest means are observed at the shortest and longest maturities, respectively 21 and 24 basis points, respectively. For the other maturities, the residual means oscillate between 1.4 and 9 basis points. Similarly, the residuals' standard deviation is fairly stable, with largest values at the beginning and at the end of the curve.

Table 5. In-sample fit of the DNS model

Maturity (months)	Mean	SD	Min	Max	MAE	RMSE	$\hat{\rho}(1)$	$\hat{\rho}(12)$	$\hat{\rho}(30)$
3	-2.1e-01	2.4e-01	-1.6e+00	4.7e-01	1.0e-01	2.4e-01	0.86	0.29	-0.0385
6	-4.9e-02	6.3e-02	-2.7e-01	2.2e-01	6.4e-03	6.3e-02	0.86	0.29	-0.0448
9	-1.7e-02	1.9e-02	-7.7e-02	5.7e-02	6.8e-04	1.9e-02	0.87	0.33	-0.0377
12	-4.3e-08	4.8e-08	-2.2e-07	1.3e-07	4.1e-15	4.7e-08	0.44	0.25	0.1146
15	6.7e-03	6.2e-03	-1.2e-02	2.9e-02	8.4e-05	6.2e-03	0.89	0.39	-0.0064
18	5.9e-03	5.2e-03	-7.7e-03	2.5e-02	6.1e-05	5.2e-03	0.90	0.41	0.0126
21	1.8e-09	6.0e-08	-2.8e-07	2.8e-07	3.6e-15	6.0e-08	0.41	0.11	0.0080
24	-8.9e-03	7.3e-03	-3.6e-02	5.8e-03	1.3e-04	7.3e-03	0.91	0.45	0.0493
30	-3.0e-02	2.4e-02	-1.2e-01	2.0e-02	1.5e-03	2.4e-02	0.91	0.47	0.0803
36	-5.0e-02	3.8e-02	-1.9e-01	3.5e-02	3.9e-03	3.8e-02	0.92	0.48	0.1054
48	-7.1e-02	5.3e-02	-2.6e-01	5.4e-02	7.9e-03	5.3e-02	0.92	0.49	0.1425
60	-6.6e-02	4.8e-02	-2.3e-01	5.3e-02	6.7e-03	4.8e-02	0.92	0.49	0.1689
72	-3.9e-02	2.8e-02	-1.3e-01	3.3e-02	2.4e-03	2.8e-02	0.92	0.48	0.1891
84	1.0e-08	2.0e-08	-3.2e-08	1.6e-07	5.1e-16	2.0e-08	0.32	0.19	-0.0160
96	4.6e-02	3.2e-02	-4.0e-02	1.4e-01	3.1e-03	3.2e-02	0.92	0.46	0.2182
108	9.3e-02	6.4e-02	-8.1e-02	3.0e-01	1.3e-02	6.4e-02	0.91	0.45	0.2282
120	1.4e-01	9.4e-02	-1.2e-01	4.4e-01	2.8e-02	9.4e-02	0.91	0.44	0.2351

Note: In-sample fit statistic of the two step DNS model. The descriptive statistics refer to the residuals of the equation for yields at the corresponding maturities. The last three columns present residual sample autocorrelations at lag 1, 12, and 30, respectively.