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Carlo A. Favero

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By Carlo A. Favero*

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Abstract

The expectations model of the term structure of interest rates has been subjected to numerous empirical tests and almost invariably rejected. In fact, the vast majority of the empirical evidence is based on the estimation of single-equation models and on the assumption that realized returns are a valid proxy for expected returns. A recent strand of the macroeconomic literature has analyzed monetary policy by including the central bank reaction function in small empirical macro models. By simulating these models forward it is possible to derive the full forward path of short-term interest rates and hence to construct any long-term yields using model based forecasts. A test of the theory can then be performed by comparing observed long-term yield with those simulated and the associated 95 per cent confidence interval. The application of this framework to the analysis of US term structure in the nineties does not lead to the rejection of the expectations model.

Keywords: small macro-models, term structure of interest rates, expectations model

JEL classification: E44, E52, F41

*IGIER, Università L. Bocconi, Via Salasco 5, 20124 Milano, Italy and Centre for Economic Policy Research. E-mail: *carlo.favero@uni-bocconi.it*. I would like to thank Rudi Dornbusch, Alejandro Cunat, Francesco Giavazzi, Massimo Guidolin, Alessandro Missale, Tommaso Monacelli, Glenn Rudebusch, Guido Tabellini, Luca Stanca, and the participants of seminar at the Bank of Spain, at ECARES in Brussels, at the EMUConference at the State University of Milan and the Macroeconomic workshop at Bocconi University for helpful comments.

1 Introduction

The expectations model of the term structure states that the yields to maturity of long term bonds are equal to the average of expected future short-term bond yields.[1]

This venerable model has been subjected to numerous empirical tests and almost invariably rejected (see the textbook treatment in Campbell, Lo, MacKinlay, 1997, Chapter 10, or Patterson, 2000, Chapter 11). The bulk of the contrary evidence, shows that

i) high yield spreads fare poorly in predicting increases in long rates(see Campbell, 1995)

ii) the change in yields does not move one-to-one with the forward spot spread(see Fama and Bliss,1986)

iii) period excess returns on long-term bond are predictable using the information in the forward-spot spread(see Cochrane,1999).

The empirical failure is generally attributed either to systematic expectations errors, or to shifts in the risk premia. In fact, the vast majority of the empirical evidence is based on the estimation of single-equation models and on the assumption that realized returns are a valid proxy for expected returns. In a recent paper Elton(1999) clearly asserts that there is ample evidence against the belief that information surprises tend to cancel out over time and hence realized returns can be considered as an appropriate proxy for realized returns. Interestingly, Campbell(1999) finds that there is

[1]This relation is obtained directly when assuming that expected continously compounded yileds to maturity on all discount bonds are equal (see Fama,1984). It can also be derived as a linear approximation to any of the different non-linear expectations theory of the term structure (see Shiller, Campbell and Schoenholtz, 1983).

much more truth in the proposition that high yield spreads should forecast long-term increases in short-rates, especially at very short and very long maturities. The failure of the expectations model to predict long rate changes and the (partial) success in the prediction of short rate changes is explained by the role of measurement errors. In fact, in the regression of long rate changes onto the yield spread, changing rational expectations about excess long bond returns act like a measurement error that appears positively in the regressor and negatively in the dependent variable. Conversely, in the regression of short-rate changes onto the yield spread, changing rational expectations about excess long-bond returns act like a measurement error that appears only in the regressor. In the first case a small measurement error can change the sign of the relevant regression coefficient, while in the second case the measurement error biases the coefficient towards zero but cannot affect its sign. These findings on the effects of expectations errors on the tests of the model are confirmed by a number of papers which concentrates on expectations errors by relating them to peso problems or to the very low predictability of short term interest rates. In a famous study Mankiw and Miron, 1986, using data on a three and six month maturity, found evidence in favor of the expectation theory prior to the founding of the Federal Reserve System in 1915. They show that the shift in regime occurred with the founding of the Fed led to a remarkable decrease in the predictability of short-term interest rates. Rudebusch, 1995, and Balduzzi et al., 1997, expand on this evidence by looking at more recent data.

The claim of very low predictability of policy rates contradicts a growing body of empirical literature which has established interest rate rules as a convenient way to model and interpret monetary policy. Interest rate rules, which feature (very) persistent of policy rates responding to central bank's perceptions of (expected) inflation and output gaps (Taylor,1993, Clarida, Gali and Gertler, 1998, 1999, 2000) not only track the data well but are also capable of explaining the high inflation in the seventies in terms of an accommodating behaviour towards inflation in the pre-Volcker era. Rudebusch(2001) has recently addressed the issue of the (apparent) contradiction between interest rate persistence in policy rules and low predictability of policy rates to conclude that monetary policy inertia is an illusion.

The success of Taylor rules might help the interpretation of the results obtained by Campbell and Shiller (1987, 1991) when they implement a bivariate vector autoregressive (VAR) approach for evaluating present value models. The approach consists in projecting the average of expected future short-term yields onto a subset of the information set used by market participants. Such information set is built by assuming that the first difference of long-term bond yields and the excess holding period returns of long-term bonds on short term bonds are stationary. Under this assumptions, the first difference of the yield on long-term bonds and the yield spreads between long-term and short-term bonds form a bivariate stationary vector-stochastic process. By representing this process a finite order VAR a 'theoretical spread', i.e. the spread which would obtain if the expectations theory were true, can be constructed. The equality of the actual spread and the theoretical spread puts a set of nonlinear restrictions on the coefficients of the estimated VAR. When these restrictions are tested formally using a Wald test, they are rejected. However, despite these negative results, the authors find a strong correlation between the actual and theoretical spread and coclude that bivariate analysis suggests that there is an important element of truth to the expectations theory of the term structure.

The cointegrated VAR representation used by Campbell and Shiller is a re-parameterization of a VAR in levels for long-term and short-term interest rates. If we re-interpret such representation in the light of the success of Taylor rules, it is then clear that considering a bi-variate VAR representation is a first step forward from the traditional limited information approach, but it is only a first step in that within such a two-equation approach no macroeconomics variables are explicitly included in the information set. In principle, this omitted variable problem is capable of explaining the mixed results obtained by the two authors[2].

A recent strand of the macroeconomic literature has analyzed monetary policy by including the central bank reaction function in small empirical macro model of inflation and output (see, for example, Rudebusch, 2000, Rudebusch and Svensson,1998, 2001, Mc Callum and Nelson, 1999). Fuhrer(1996) uses a simple Taylor-rule type reaction function, the expectations model and reduced-form equations for output and inflation to solve for the reaction function coefficients that delivers long-term rates consistent with the expectations theory. He finds that modest and smoothly evolving time-variation in the reaction functions parameters is sufficient to reconcile the expectations model with the long-bond data. We use the same reduced forms estimated by Fuhrer and simulate them forward to derive the full path of model-based forecast for future short-term interest rates and hence to construct theory-consistent long-term interest rates using model based forecast in the expectations model. Stochastic simulation of the macro model allows to construct confidence intervals around theory consistent long-term rates. A direct test of the expectations model can then be implemented by

[2] Recently Bekaert and Hodrick(2000) have argued that the problem leading to the rejection of the theory could be the use of aymptotic inference rather than omitted variables. Their use of small sample distributions of the different VAR based tests leads to much less dramatic rejections than those implied by the aymptotic distribution.

assessing if observed long-term rates fall within 95 per cent confidence interval for simulated rates. Importantly, this procedure uses the macro model to derive directly by simulation the full path of forecast for future policy rates, which are risk-free. Therefore, the existence of risk-premia does not affect the derivation of theory consistent long-term rates, although it might explain discrepancies between these rates and observed rates. In fact, the presence of a risk-premium is one of the two factors capable of explaining the difference between observed and simulated rates, the second factors being the difference between model-based forecast and true, unobservable, expectations for future policy rates.

To our knowledge this full-information test has never been implemented so far[3].

The paper is organized as follows. Section 2 illustrates our testing framework. Section 3 applies it to the analysis of the term structure of US interest rates in the nineties. Section 4 discusses our results by illustrating the link between Taylor rules and the term structure, by interpreting the differences between our results and those generated by testing strategies based on limited-information approaches, by investigating the sources of uncertainty in our simulation and, finally, by addressing the issue of the potential illusion of monetary policy inertia.

[3] In fact, Fuhrer and Moore(1995) have inserted a term structure equation in a small structural model of the U.S. economy. However, they do not exploit the opportunity for testing the expectations theory. They rather concentrate on explaining the observed correlation between real output and short-term interest rates in terms of the correlation between long-term real interest rates and nominal short-term rates.

2 A (New) Testing Framework For The Expectations Model.

Our testing framework is based on the relation between long-term yields and policy rates and on a small macroeconomic model relating policy rates to macroeconomic variables. We consider government bonds as assets whose price is determined by aggregate economic information, as we regard the price impact of any asset-specific information as negligible. Define the term premium per period rather than over the full life of a bond, then the difference between one-period expected return of a multi-period bond[4] and the risk-free rate can be written as:

$$E_t\left(p_{t+1,T} - p_{t,T}\right) = i_{t,t+1} + RP_{t,T} \tag{1}$$

where $p_{t,T}$ is the (log of) price at time t of a bond with maturity at T , $i_{t,t+1}$ is the one-period return of the policy rates[5], $RP_{t,T}$ is the time varying term premium for a bond with maturity T. As the relation between $p_{t,T}$ and the continuously compounded return yield to maturity of a bond with maturity T, $i_{t,T}$, is

$$p_{t,T} = -\left(T - t\right) i_{t,T}, \tag{2}$$

we have

$$i_{t,T} - \left(T - t - 1\right) E_t\left(i_{t+1,T} - i_{t,T}\right) = i_{t,t+1} + RP_{t,T}. \tag{3}$$

Most empirical tests of the expectations model are based on the estimation of some version of (3)where observed returns are used as a proxy for expected returns. We follow an alternative route and use a macro model to

[4]We consider zero-coupon bond for the sake of exposition, but the reasoning can be extended to bonds paying coupon

[5]As we consider the policy rate as the safe asset, the period-return of such asset coincides with the yield to maturity.

derive proxies for expected returns. To illustrate our approach note that, by recursive substitution, we can write:

$$i_{t,T} = \frac{1}{T-t}\sum_{j=1}^{T} E_t i_{t+j-1,t+j} + \frac{1}{T-t}\sum_{j=1}^{T-1} E_t RP_{t+j-1,t+T}. \tag{4}$$

We propose to use forecast generated from a macro model as proxies for expected returns. In practice, we consider the following specification for the macro model:

$$\begin{bmatrix} \mathbf{Z}_t \\ i_{t,t+1} \end{bmatrix} = A_t\left(L\right)\begin{bmatrix} \mathbf{Z}_{t-1} \\ i_{t-1,t} \end{bmatrix} + \begin{bmatrix} \mathbf{u}_{1t} \\ u_{2t} \end{bmatrix}, \tag{5}$$

(5) is a (possibly) time-varying parameter unrestricted VAR in the macroeconomic variables and policy rates. This is a general specification which nests the reduced form of structural VARs and small backward-looking and forward-looking macro models. Note that, as we shall use the macro model for forward simulation, we need to concentrate just on the reduced form. The interpretation of the reduced form could be different but different interpretation do not affect the resulting forecast for future short-term policy rate. Consider for example interpreting our VAR as a reduced form of the forward-looking model proposed by Rotemberg and Woodford(1999). The two authors use a VAR representation to estimate the way in which output, inflation and interest rates respond to stochastic disturbances to the monetary policy rule. They then proceed to propose a simple forward-looking structure consistent with the VAR reduced form representation. In other words they propose a parsimonious parameterization of a forward-looking model on output and inflation determination, in which the structural parameters are estimated so as to make the model's prediction regarding the effects of monetary policy shock fit those estimated by the unrestricted VAR as closely as possible. This means that the structural model is parameterized

in such a way that its forecasts are as close as possible to the VAR based forecasts. Therefore the VAR can be validly used for forecasting purposes even if the true structure is forward-looking. Of course, structural model and reduced form cannot be indifferently used when different policy regimes are simulated, but this is not what we do here. Our strategy goes as follows: in each period t, we estimate the VAR using data available up to time t. Given the results of the estimation, we proceed to stochastic dynamic simulation of the estimated macro model. We use the estimation results to determine the variance-covariance matrix of the joint normal distribution of the residuals and the mean and the variance-covariance matrix of the estimated parameters, i.e. the stochastic components of the model. The model is then solved repeatedly for different draws of the stochastic components of the model. If coefficient uncertainty is included in the model, then a new set of coefficients is drawn before each repetition. During the repetition, errors are generated for each observation in accordance with the residual uncertainty and the exogenous variable uncertainty in the model. This allows to generate point estimates and confidence interval for all the forecasted variables. We then use the path of model-consistent forecasts to generate long-term rates under the null of the validity of the pure expectations model as follows:

$$i^*_{t,T} = \frac{1}{T-t}\sum_{j=1}^{T} i^F_{t+j-1,t+j} \tag{6}$$

The relation between $i^*_{t,T}$ and $i^F_{t+j-1,t+j}$ is deterministic, but the uncertainty on $i^F_{t+j-1,t+j}$ is reflected in $i^*_{t,T}$. Therefore we can generate point estimates and confidence intervals for $i^*_{t,T}$ at any maturity. As we estimate a model at monthly frequency, then the generation of starred values for the ten-year maturity requires the full path of one-hundred and twenty forecasts for policy rates. Starred valued at shorter horizon are obtained similarly by using the appropriate subset of forecasts. Given that values for $i^*_{t,T}$ are obtained under the null hypotheses of no risk premium and model based expectations for future policy rates, our stochastic simulation can be used to evaluate the expectations model. To see this point, combine (4) and (6) to write:

$$i_{t,T} = i^*_{t,T} + \frac{1}{T-t}\sum_{j=1}^{T}\left(E_t i_{t+j-1,t+j} - i^F_{t+j-1,t+j}\right) + \frac{1}{T-t}\sum_{j=1}^{T} E_t RP_{t+j-1,t+T} \tag{7}$$

Equation (7) makes clear that deviation of $i_{t,T}$ from $i^*_{t,T}$ can be explained by the effect of the risk premia or by differences between model based forecasts and agents' expectations. Confidence intervals from stochastic simulations are generated under the null that agents form their expectations using our small macro model and the expectations theory holds. If $i_{t,T}$ always falls within such confidence intervals we can conclude that uncertainty on the macroeconomic model does not allow us to reject the null hypothesis. In other words stochastic simulation allows to measure explicitly the range of our ignorance and to assess the extent to which we can reject the expectations model. Comparison between $i_{t,T}$ and $i^*_{t,T}$ at different maturities and assessment of the forecasting errors on macro variables might also shed some light on the relative importance of expectations errors and term premia in explaining deviations of long-term rates from those predicted by the expectations model.

3 The Term Structure of US Interest Rates In The Nineties.

To apply our framework to the analysis of the US term structure we consider a standard specification (Bernanke and Mihov,1998, Rudebusch and Svensson, 1999, Mc Callum and Nelson) of the macroeconomic structure by including in $\mathbf{Z}_t$ the log of the IMF world commodity price index, $lpcm_t$, the annual US CPI inflation at time t, π_t, the US output gap at time t, x_t,defined as $\ln\left(X_t^{US}\right) - ln\left(X_t^{US}\right)^*$, X_t^{US} is the seasonally adjusted industrial production and $ln\left(X_t^{US}\right)^*$ is the Hodrick-Prescott filtered log of industrial productions[6] , we consider the one-month interest rate, $i_{t,t+1}^{US}$ as the policy rate. We consider data at monthly frequency and estimate a four-lags VAR model with a rolling procedure starting from the sample 1980:1-1992:1. The choice for the initial sample period is driven by the willingness to consider an homogenous monetary policy-regime and by the results in Clarida, Gali and Gertler,1999, 2000 and Favero and Rovelli,2001, who show that the Volcker-Greenspan era features an important break in the US monetary policy maker preferences[7]. Estimation is implemented using information on (revised) variables available at the time of the last observation of the sample, hence the output gap is constructed applying the HP filter within the sample considered for estimation. Given the results of estimation, the variance covariance-matrix of the estimated residuals is retrieved and the model is stochastically simulated for an horizon up to one-hundred and twenty observations to generate observation in 1992:1 for $i_{t,T}^*$, with $T = 3, 6, 12, 24, 36, 50, 84, 120$. Starred variables and their confidence intervals are then to be compared with observed yields to maturity[8]. We then shift the horizon forward by one period, re-estimate the VAR over the sample 1980:1-1992:1 to re-run our stochastic simulation

[6] We use the one-side version of the HP filter built in E-Views with a smoothing parameter set to 14400.

[7] The empirical analysis of these papers shows that monetary policy was far less aggressive in fighting inflation in the pre-Volcker era than in the later period, since it was relatively more focused on output stabilization and it allowed real interest rates to decrease in presence of inflationary shocks.

[8] All the macroeconomic time-series are taken from DATASTREAM, while interest rates at all maturities are taken from the FRED database at the website of the Federal Bank of St.Louis.

and construct starred variables in 1992:1 and their associated confidence intervals. The procedure is repeated until the last sample for estimation is 1990:5-2002:05 for a total of 125 model estimation and simulation.

We report in Figures 1-2 the time-series of 125 observations on $i^*_{t,T}$, the associated two standard errors confidence intervals and $i_{t,T}$,with $T = 3, 6, 12, 24, 36, 50, 84, 120$. Starred variables and the uncertainty surrounding them are recursively obtained following the procedure described in the previous section with stochastic simulations based on one-thousand replications for each sample points.[9]

Insert Figures 1-2 here

The Figures show clearly that the uncertainty on the macroeconomic structure does not allow rejection of the expectations model at all sample points and at all frequencies. Moreover, there is a clear tendency for the observed interest rates to co-move with the simulated interest rates at the mid-point of the 95 per cent confidence interval. Clearly, the 95 per cent confidence intervals get larger as the maturity of the relevant interest rate gets longer, but the observed interest rates get nowhere near the upper and the lower band.

It is interesting to consider the time-series behaviour of the difference between actual,$i_{t,T}$, and simulated, $i^*_{t,T}$, series, which, according to equation (7) depend on risk premia and on the differences between model based forecasts and agents' expectations.

We report in Figures 3 these time-series organized by maturity. Their statistical properties are described in Table 1.

[9]The recursive simulation procedure based on the rolling estimation of the VAR has been implemeted in E-Views 4. Programmes and the original data-set are available from the author's upon request

Insert Figures 3 and Table 1 here

The statistics reported in Table 1 indicate that the average, taken over the whole simulation sample, of the difference between actual and simulated yields is zero at the three-month maturity, than it becomes negative with a declining pattern to reach a minimum -29 basis points at the 2-year maturity, from the three-year maturity onward the pattern becomes increasing to reach a positive value of 16 basis points at the 7-year maturity and a maximum of 20 basis points in correspondence of the 10-year maturity. Given that risk premia cannot be negative, consistency of this evidence with equation (7) requires that deviations of simulated from actual variables reflect persistent expectations error for policy rates. The relative importance of the expectations errors should be hump-shaped, reaching a peak between the one-year maturity and the two-year maturity. For maturities higher than 2-year the behaviour of variables is consistent with a relative weight of the risk premia increasing with maturity. The time series behaviour of differences between actual and simulated yields at the 3-month, 1-year and 10-year maturities, reported in Figure 2, shows the behaviour of a persistent but mean reverting series. Interestingly, the standard deviation of the series increases from 0.20 to 0.59 from the 1-month to the 1-year maturity, then it flattens out around a value 70. In fact, the standard deviation at the 10-year maturity is lower than at the 2-year maturity.

4 Interpreting Our Empirical Evidence

In the introduction of this paper we claimed that a simulation based test of the expectations model could be constructed by augmenting a Taylor-type monetary policy reaction function with a small model for the macroeconomic determinants of monetary policy. We have implemented this procedure in a (time-varying parameters) VAR framework to find that the uncertainty on the macroeconomic structure does not allow rejection of the expectations model at all sample points and at all frequencies. In commenting the differences between actual and simulated yields at different maturities we have illustrated how the consistency of our results with the expectations model requires the existence of persistent expectations error for policy rate. In fact, some restrictions on the pattern of expectations errors are necessary: the relevance of expectations error should be first increasing with maturity, to reach a peak between the one-year and the two-year maturity, and then declining with maturity.

In this section we provide some further interpretation of our empirical evidence by discussing in turn a number of issues which are naturally raised by our results. First, what is the relation between VAR based monetary policy reaction functions and forward-looking Taylor rules. Second, how our non-rejection of the expectations theory is related to the previous different results in the literature. Third, how can we explain uncertainty and what is the pattern of forecasting errors for policy rates generated by our model.

4.1 Taylor-rules and VAR-based reaction functions

VAR based reaction functions can be interpreted as reduced form of forward-looking Taylor-type rules. Therefore, VAR based reaction functions and forward-looking Taylor rules are equivalent when used in model solved forward for forecasting purposes.

Consider our VAR specification (5), the implicit monetary reaction function is:

$$
\begin{aligned}
i_{t,t+1} &= a_o + \sum_{j=1}^{4} a_{1,j} i_{t-j,t+1-j} + \sum_{j=1}^{4} a_{2,j} \pi_{t-j} + \\
&\quad + \sum_{j=1}^{4} a_{3,j} x_{t-j} + \sum_{j=1}^{4} a_{1,j} lpcm_{t-j} + u_t
\end{aligned} \tag{8}
$$

Consider now a forward looking-Taylor rule specified as follows:

$$
i_t = \beta_1 i_{t-1} + (1-\beta_1)(\beta_0 + \beta_2 E_t(y_t - y_t^*) + \beta_3(E_t \pi_{t+12})) + \epsilon_t \tag{9}
$$

If expected macroeconomic variables are instrumented by four lags of inflation, the output gap and the commodity price index, then (5) can be viewed as the (unrestricted version) of the reduced form of (9). Therefore the deviation of monetary authority from the rule should coincide with the VAR residuals. To illustrate this point we have estimated a typical forward-looking Taylor rule using our data over the sample 1987-2001 (the Greenspan era) to obtain the following results:

$$
i_{t,t+1} = \underset{(0.03)}{0.93} i_{t-1,t} + (1-0.93)(\underset{(0.41)}{4.19} + \underset{(0.25)}{0.60}(y_t - y_t^*) + \underset{(0.42)}{1.30}(E_t \pi_{t+12})) \tag{10}
$$

where(10)has been estimated by GMM with a correction for MA residuals, choosing the appropriate instruments to deliver the same reduced form as in the equation for the policy rate in our VAR model. We have then estimated a VAR(4) for $lpcm_t, \pi_t, (y_t - y_t^*)$, $i_{t,t+1}$, over the same sample. VAR-based monetary policy shocks and deviations from our fitted forward-looking rule, reported in Figure 4, feature a correlation of 0.84 and cannot be visually distinguished.

Insert Figure 4 here

4.2 Why are our results different?

The main reason for our different results lies in the fact the vast majority of the empirical evidence is based on the estimation of single-equation models and on the assumption that realized returns are a valid proxy for expected returns. To illustrate the point we have considered the 1-year maturity and derived the yields to maturity consistent with the expectations model by using our approach (we label the resulting rates ex-ante) and by averaging ex-post observed policy rates, and by therefore assuming no expectations error (we label the resulting rates ex-post).

We report in Figure 5 the actual 1-year rates along with the ex-ante and ex-post rates and the confidence intervals from our simulations.

Insert Figure 5 here

A number of remarks are in order. First, as originally observed by Shiller(1979), the actual rates are more volatile than the ex-post rates. However, the reverse is true for the ex-ante rates, which are more volatile than the actual. Therefore, expectations errors play an important role in the rejection of the expectations theory based on the assumption that realized returns are a valid proxy for expected returns. Moreover, while the observed one-year rate is always within the 95 per cent confidence interval generated by our simulation, the same is not true for the ex-post rates. This is interesting in that it shows that our approach has (at least) the power to reject testing methods based on limited information.

4.3 Uncertainty

Our simulation produce wide confidence intervals. It is therefore important to analyze the sources of uncertainty and to provide evidence that we do not reject the expectations theory just because we have used a test with low power. To this end, our analysis of the differences between actual and simulated rates across maturities suggest that the reconciliation of our evidence with the expectations theory imposes some restrictions on the pattern of forecasting errors for policy rates at different horizon.

Figure 6 reports actual values for the commodity prices, CPI inflation, the output gap and policy rates along with forecasts up to 120-steps ahead taken at different sample points.

Insert Figure 6 here

The comparison of forecasts with realized values for all variables confirms the presence of persistence in forecasting errors. Forecasting errors are small at very short horizon, then they increase with maturity but eventually they decrease again with maturity. Forecasting errors at longer horizon are smaller than forecasting errors at shorter horizon, as the model seem to deliver good (time-varying) estimates for the long-run equilibria of all variables but does not perform as well in describing the short-term dynamic adjustments towards equilibria. As a consequence, simulated rates at the one-year maturity, being determined by projected off-equilibrium policy rates, tend to feature larger deviations from the observed values than simulated rates at the ten-year maturity, which depend much more heavily on projected equilibrium rates.

Further insight on the sources of uncertainty and on its importance for our results can be gained by analyzing the forecasting performance of our small macro model for policy rates at different future horizons. We report in Figure 7 actual policy rates at time t with predicted policy, based on model simulation run at time $t - j$, with j= 1,3,6, 9,12, 24, 36 months. Table 2 reports the results of the estimation of the following predictive regression:

$$i_{t,t+1} = \hat{\beta}_0 + \hat{\beta}_1 \, {}_{t-j}i^F_{t,t+1} + \hat{u}_t, \tag{11}$$

where ${}_{t-j}i^F_{t,t+1}$ is the model based prediction for $i_{t,t+1}$ based on the information set available at time $t - j$.

Insert Figure 7 and Table 2 here

The graphical and the econometric evidence show clear an hump-shape pattern in the performance of the model to forecast future policy rates. The model does very well at short horizons: the null $\hat{\beta}_0 = 0, \hat{\beta}_1 = 1$ cannot be rejected for the 1-month and the 3-month horizon and the R^2 from these regression is respectively of 0.96 and 0.88. However the forecasting performance deteriorates rapidly with estimates of $\hat{\beta}_0$becoming increasingly higher and more significant and estimates of $\hat{\beta}_1$becoming increasingly lower and less significant. The worst results for the predictive regressors are obtained for the 1-year horizon where $\hat{\beta}_0 = 3.18, \hat{\beta}_1 = 0.33$ and the R^2 from the predictive regression is 0.06. Interestingly, the performance of the predictive regressions improves again for forecasting horizons higher than 1-year: at the three-year horizon $\hat{\beta}_0$ is again not significantly different from zero, $\hat{\beta}_1 = 0.60$ and the R^2 is 0.17

This evidence makes clear that realized returns are a very bad proxy for expected returns, when expectations are formed using our macro model. Moreover, the pattern of expectations error allows to rationalize the time-series behaviour of the difference between actual,$i_{t,T}$, and simulated, $i^*_{t,T}$ in terms of the expectations model. This evidence also supports the explanation, based on the pattern of forecasts errors, of the results of single-equation tests of the expectations model based on the regression of yield spreads on future short rate changes[10]

The results of our regressions in Table 2 are also comparable with the empirical results recently provided by Rudebusch(2001). Rudebusch runs predictive regressions using expected policy rates implicit in Federal Funds future contracts. Given the availability of future contracts, he considers forecasting horizons up to nine months to obtain results very similar to ours. The very low predictability of policy rates at the six-months and the nine-months horizon is taken as a strong argument supporting the conclusion that monetary policy inertia is an illusion.

Importantly, the fact that the predictive regressions based on model projections and Federal Fund future give very similar results does not contradict the assumption that there is no major discrepancy between the information set used by agents and that implicit in our econometric specification. However, our results are against the conclusion that monetary policy inertia is an illusion. In fact, we predict policy rates using a model which features strong persistence and we still find very little predictability for policy rates at horizons between six-months and one-year. Persistence is only a necessary conditions for predictability of policy rates when they are set according to a rule which react to macroeconomic conditions. In this case stability of the rule, precision in the estimation of parameters, and predictability of macroeconomic conditions are required along with persistence to generate predictability. Our model-based simulations suggest that these conditions do not occur at frequencies between six-months and one-year. Interestingly, predictability

[10]In commenting this type of regression Campbell, Lo and McKinley(1997,p.423) state "... The U-shaped pattern of regression coeffcients in Table 10.3 may be explained by reduced forecastability of interest rates movements at horizons around one-year. There may be some short-run forecastability arising from Federal Reserve operating procedures, and some long-run forecastability arising from business-cycle effects on interest rates..."

improves notably for horizons higher than one-year where business-cycle and its effects on interest rates become more predictable.

5 Conclusions

In this paper we have provided a new framework for the assessment of the validity of the expectations model of the term structure of interest rates. We base our test on the information generated by small macro models. Our approach differs from the limited information approach taken commonly in the literature in that the future path of policy rates is derived consistently with the adopted macro model rather than by taking realized returns as a proxy for expected returns. Our empirical results show that the hypothesis that yields on long-term bonds behave consistently with the expectations theory, where projected future policy rates are obtained by forward simulation of the macroeconomic model, cannot be rejected. In fact the whole term structure of US policy rates behave in a way which is statistically consistent with the expectations model. Moreover, the different performance of the expectations model at different maturities can be explained by the different performance of our small macro models in capturing the dynamics of policy rates at different forecasting horizons.

We find that model based expectations are volatile and that expectations errors are sizeable and persistent. Our results are capable of explaining why observed yield to maturity are too volatile with respect to theoretical yields obtained by using ex-post realized returns as a proxy for expected returns.

Our model-projected long-term rates feature sizeable uncertainty, as our forward projections of policy rates depend both on the uncertainty on monetary policy and on its macroeconomic determinants. However, the predictive regressions for policy rates based on model projections give very similar results to those based on Federal Fund futures, such evidence does not contradict the assumption that there is no major discrepancy between the information set used by agents and that implicit in our econometric specification. We also find an hump-shaped pattern in the performance of our model for the prediction of policy rates with evidence of predictability at short and long horizons but no evidence for predictability at horizons around the one-year. This evidence matches the hump-shape profile of the discrepancies between actual yield and simulated yields as a function of maturity. Finally, given that we predict policy rates using a model which features strong persistence, we conclude that low predictability at horizons around one-year does not necessarily imply that interest rate smoothing is an illusion.

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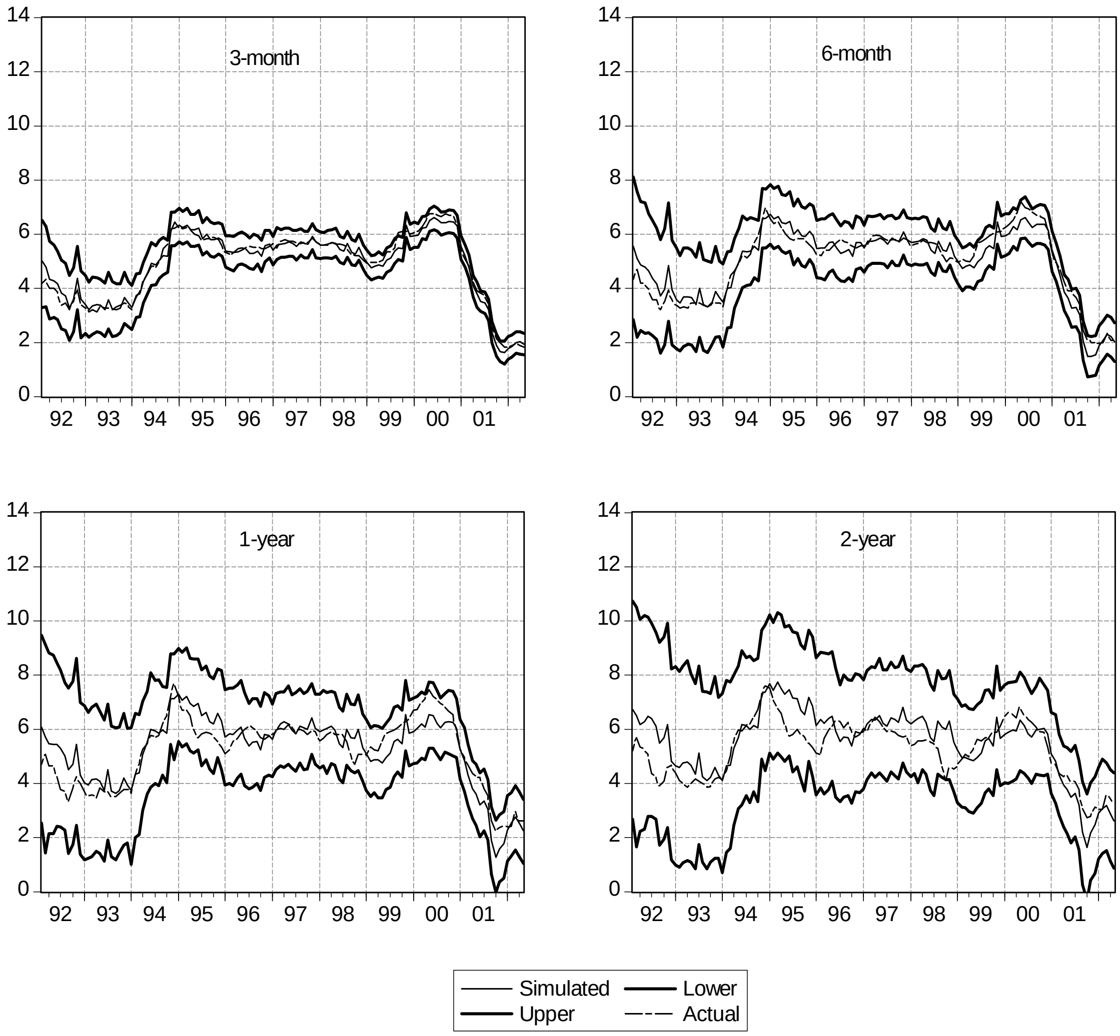
Table 1: The statitistical properties of $\left(i_{t,T} - i^{*}_{t,T}\right)$ at different maturities

	3-m	6-m	1-y	2-y	3-y	5-y	7-y	10-y
Mean	0.008	-0.02	-0.05	-0.29	-0.21	-0.02	0.16	0.20
Std. Dev.	0.20	0.37	0.59	0.72	0.81	0.82	0.77	0.70
Skewness	-0.28	-0.33	-0.28	-0.45	-0.42	-0.33	-0.24	-0.18
Kurtosis	4.64	3.04	2.45	2.40	2.17	2.15	2.17	2.15
Correlations	3-m	6-m	1-y	2-y	3-y	5-y	7-y	10-y
3-m	1.0	0.91	0.82	0.70	0.65	0.57	0.56	0.46
6-m		1.0	0.96	0.84	0.80	0.71	0.68	0.58
1-y			1.0	0.93	0.89	0.82	0.79	0.68
2-y				1.0	0.98	0.93	0.91	0.84
3-y					1.0	0.98	0.96	0.91
5-y						1.0	0.99	0.97
7-y							1.0	0.98
10-y								1.0

Table 2: Predictive regressions for the US monetary policy rate. Sample 1995:1 2002:5					
	$\hat{\beta}_0$	$\hat{\beta}_1$	R^2	DW	S.E:
j=1 months	0.12 (0.11)	0.97 (0.02)	0.96	1.80	0.24
j= 3 months	0.32 (0.18)	0.90 (0.035)	0.88	0.66	0.43
j=6 months	0.60 (0.34)	0.80 (0.06)	0.64	0.28	0.74
j=9 months	0.95 (0.68)	0.70 (0.11)	0.31	0.12	1.02
j=12 months	3.18 (0.87)	0.33 (0.14)	0.06	0.06	1.20
j=24 months	2.66 (0.87)	0.40 (0.13)	0.09	0.06	1.18
j=36 months	1.30 (0.92)	0.60 (0.14)	0.17	0.07	1.13

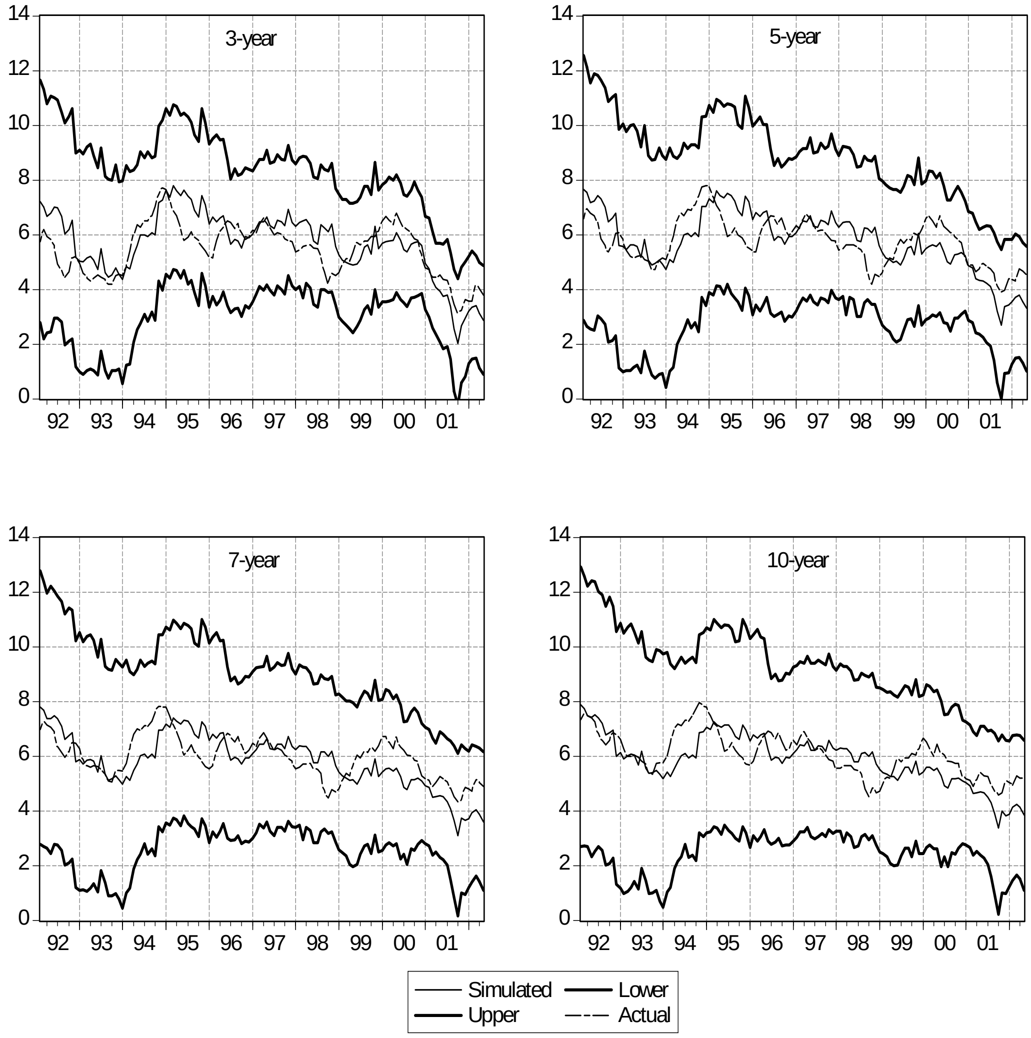
The estimated model is $i_{t,t+1} = \hat{\beta}_0 + \hat{\beta}_1 \, {}_{t-j}i^F_{t,t+1} + \hat{u}_t$, where ${}_{t-j}i^F_{t,t+1}$ is the model based prediction for $i_{t,t+1}$ based on the information set available at time $t-j$.

Figure 1: Actual and simulated interest rates for the 3-month, 6-month, 1-year and 2-year maturities.



Simulation are stochastic so actual and (average) simulated rates are reported with upper and lower bounds of their ninety-five per cent confidence interval.

Figure 2: Actual and simulated interest rates for the 3-year and 5-year, 7-year and 10-year maturities.



Simulation are stochastic so actual and (average) simulated rates are reported with upper and lower bounds of their ninety-five per cent confidence interval.

Figure 3: differences between actual and simulated interest rates at different maturities

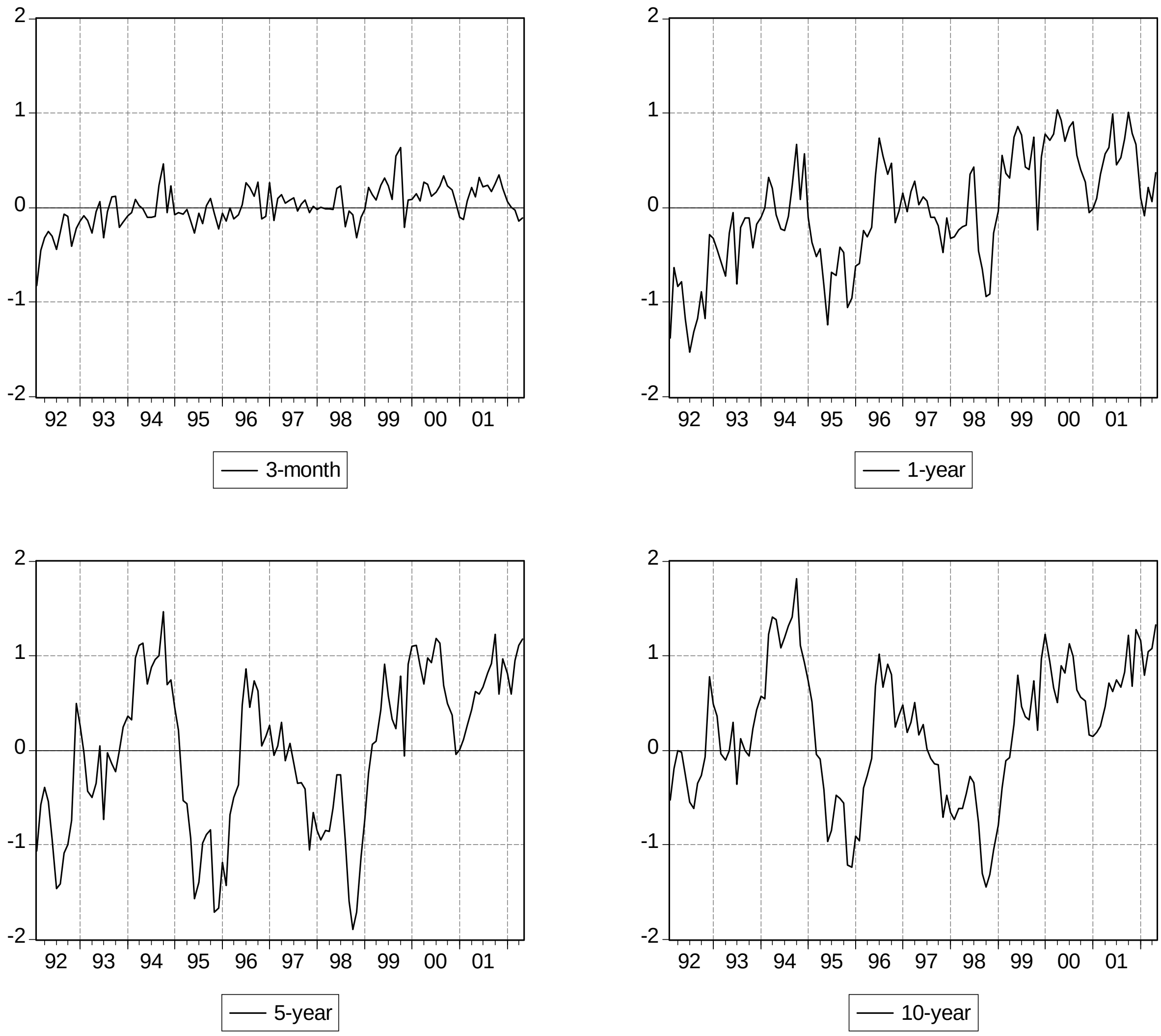


Figure 4: VAR monetary policy innovations and residuals from a forward-looking Taylor- rule

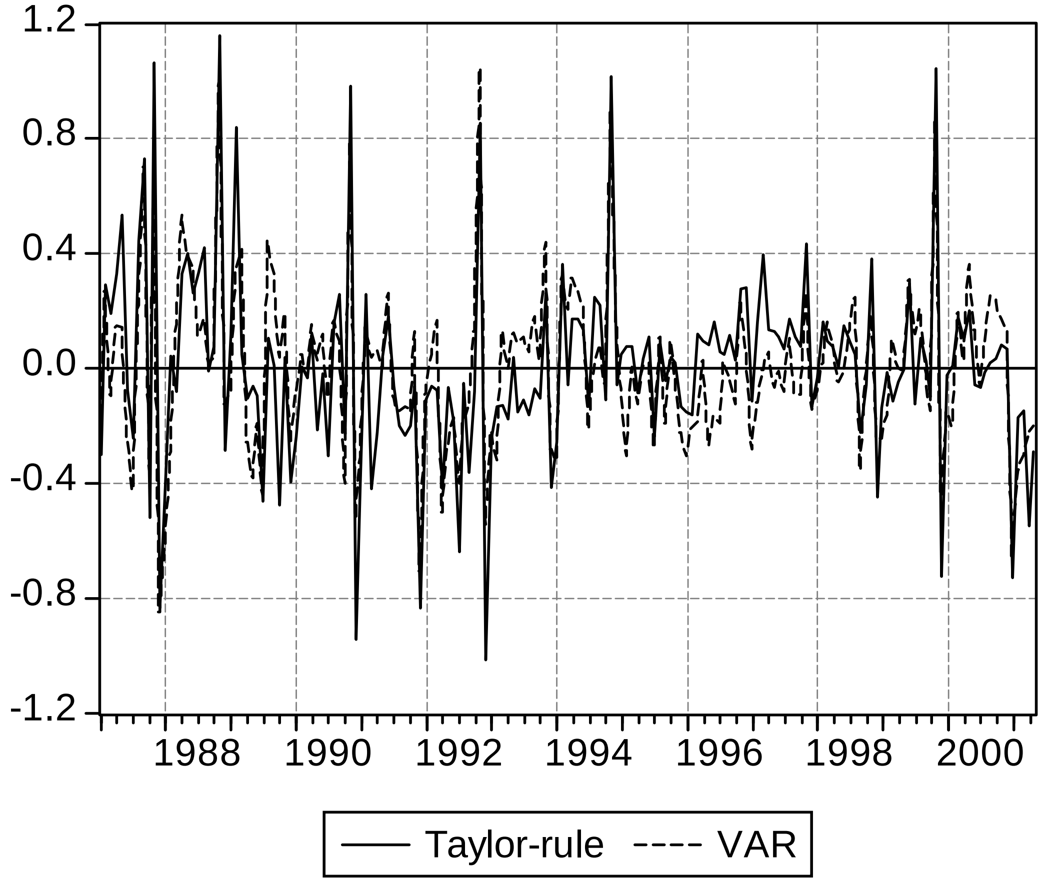
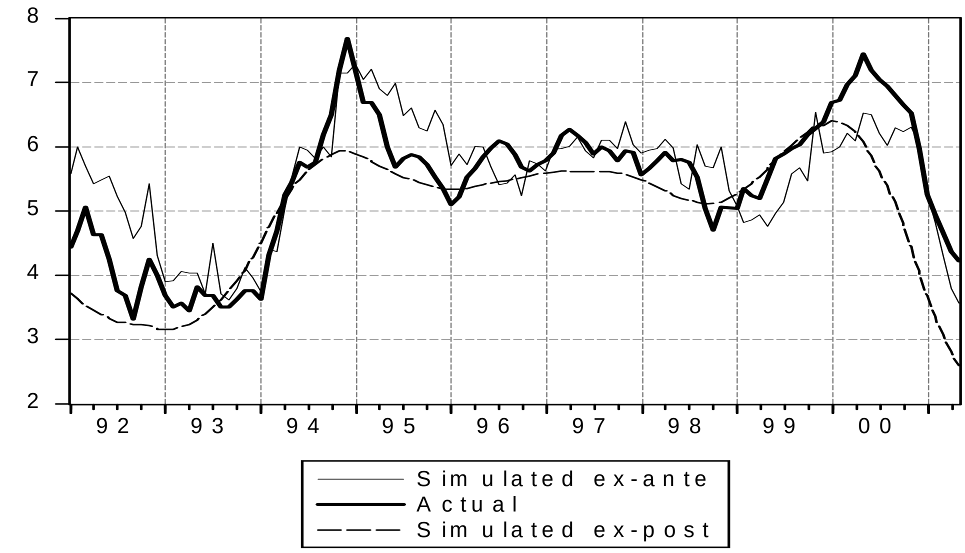
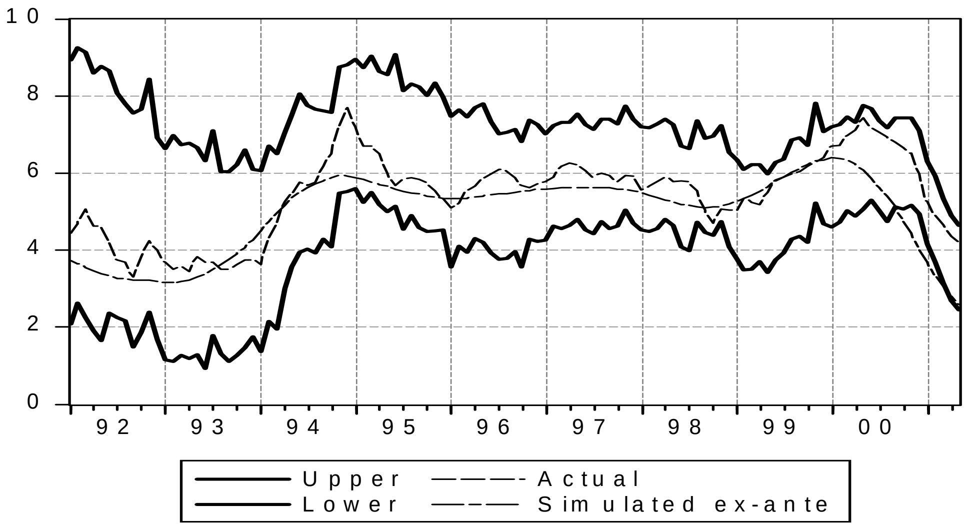


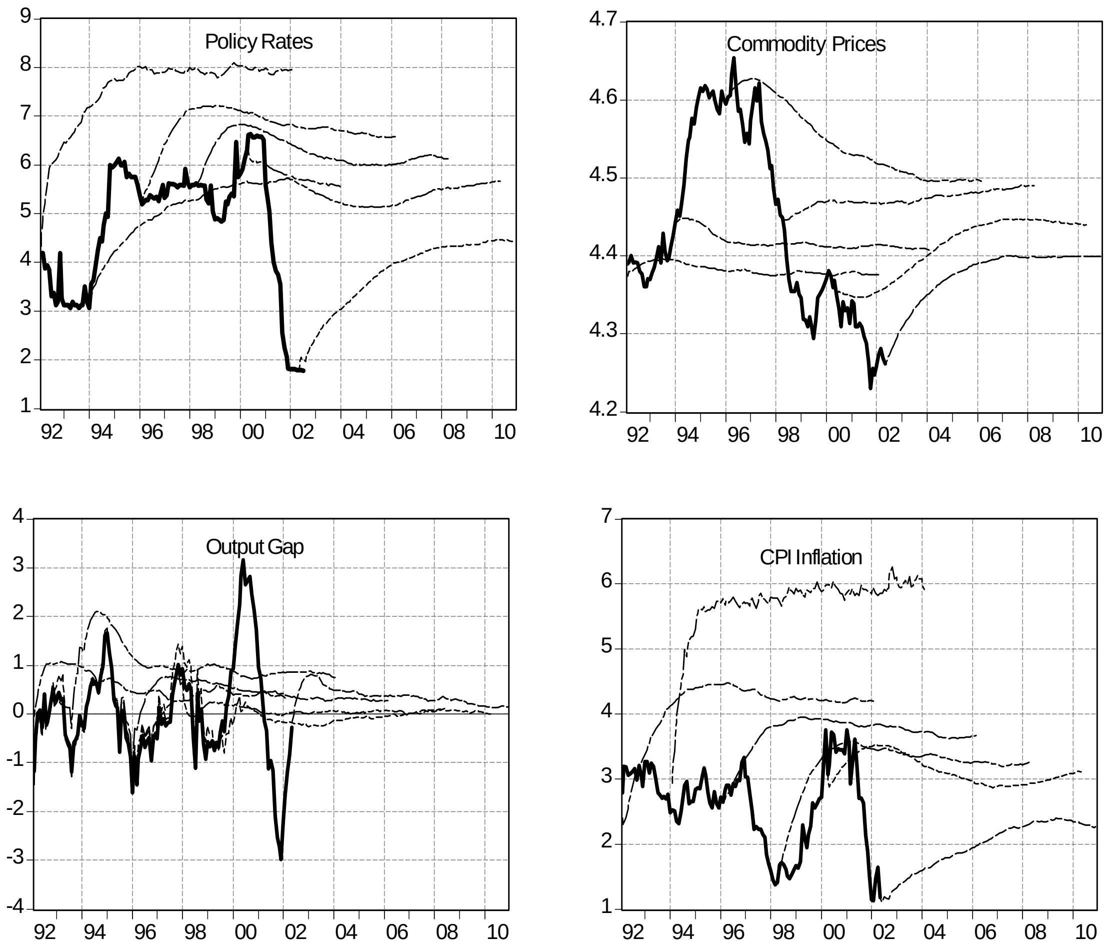
Figure 5: Understanding the difference.
1-year maturity





Actual one-year rate, with simulated ex-ante(model based) rates, simulated ex-post rates (average of actual policy rates), and upper and lower bounds of the confidence intervals of simulated rates.

Figure 6: Actual and forecasted US series



The figure reports actual values for the series in the VAR along with forecasts up to 120-steps ahead taken at different sample points.

Figure 7: Model based predictions for US monetary policy rates at different horizons.