ECON581 Mega Homework 2

Can the Term Structure of Interest Rates Predict Inflation?

Due Mar 9th 2007

Before 5:00 p.m. in my mailbox

A. GUIDELINE

i) You have to work as a group of two or three, and hand in the project as a group.
ii) The final output of this project should be a mini paper of 10 to 15 pages long (not counting tables, figures and the m-files). Write it in an organized and self-contained form that someone can read (or even enjoy) as an essay.
iii) The grade of the project depends on 1) your answers, 2) your interpretation of the answers and 3) the quality of the writing (e.g. avoid typos or long-winded sentences).
iv) If you want to include something relevant in addition to what I ask for, feel free to do so.

B. BACKGROUND

In this project, we study the empirical question of whether the term structure of interest rates can predict inflation[1]. Before we go into the literature, let's look at the famous **Fisher equation**[2]:

$$R_t^1 = E_t r_t^1 + E_t \pi_t^1$$

This equation says, the 1-month nominal rate R_t^1 (which is the **nominal return** from time t to time $t+1$) equals the sum of the expected real rate $E_t r_t^1$ (which is the **expected real return** from time t to time $t+1$) and the expected inflation $E_t \pi_t^1$ (which is **the expected rate of change of price level** from time t to time $t+1$). Notice the timing of the expectation: at time t you take expectation over things that realize at time $t+1$. The only thing that you know for sure at t is R_t^1.

[1] The term structure of interest rates is also called the yield curve. It is the relationship between the interest rate (or the yield) and the time to maturity. In this project only government bonds are considered, and no default risk is involved.
[2] If you are really interested, see Chapter 14 in his *Theory of Interest* (1930), which is not to be confused with his earlier edition of the book *Rate of Interest* (1907). UW has three copies of this book.

Fama (1975) points out that if i) the market is efficient and ii) in equilibrium the expected real rate is a constant $E\left(\bar{r}\right)$, then in the regression:

[1] $\pi_t^1 = \alpha + \beta R_t^1 + \pi_t^1 - E_t \pi_t^1 = \alpha + \beta R_t^1 + u_{t+1}$ (**Inflation Forecasting Equation**)

According to Fama's hypothesis, we should have $\alpha = -E\left(\bar{r}\right)$ and $\beta = 1$. In other words, at *t* the nominal rate R_t^1 increases one by one with inflation π_t^1 that occurs over the coming period. More clearly:

observe R_t^1	
make $E_t \pi_t^1$ and $E_t r_t^1$	observe π_t^1 and r_t^1
---------------------------time t	-------------------------------time t+1---------------------------

Fama puts forward another testable implication: if market is efficient, R_t^1 contains all information about future inflation, so when we in the regression:

[2] $\pi_t^1 = \alpha + \beta R_t^1 + \gamma \pi_{t-1}^1 + u_{t+1}$

According to Fama's hypothesis, it should be the case that $\gamma = 0$, or past inflation does not forecast inflation once the nominal rate is included. We did the same sort of test in the 1st mega homework.

Let's introduce some new notations:

[3] $\pi_t^m = \alpha_m + \beta_m R_t^m + u_{t+m}$

[4] $\pi_t^m = \alpha_m + \beta_m R_t^m + \gamma_m \pi_{t-m}^m + u_{t+m}$

This is the multi-period version of [1] and [2]. The term π_t^m is the inflation from time *t* to time *t*+*m*. <u>It is important in this project that you understanding the timing of variables perfectly.</u>

Fama tests his theory with one-month to six-month Treasury Bills and one-month to six-month change in CPI, for the period 1953:01 to 1971:07. The results strongly support his theory.

The other papers that you are about to replicate and extend are either objection (**Nelson and Schwert (1977)**) or extension (**Mishkin (1988, 1990)**) to Fama's idea.

After finishing project you will have a deep understanding of one of the most practical controversies in empirical macroeconomics (there are other impractical ones): Can we use to the term structure of interest rates to forecast inflation? How much information is contained in the term structure of interest rates?

C. READINGS

To finish this project, you should study the following papers thoroughly. They are all available online.

1. **Eugene F. Fama** (1975): "Short-Term Interest Rates as Predictors of Inflation" (*American Economic Review*, Vol. 65, No. 3)
2. **Charles R. Nelson and G. William Schwert** (1977): "Short-Term Interest Rates as Predictors of Inflation: On Testing the Hypothesis that the Real Rate of Interest is Constant" (*American Economic Review*, Vol. 67, No. 3)
3. **Frederic S. Mishkin** (1988): "What Does the Term Structure Tell Us About Future Inflation?" (*NBER Working Paper* No. 2626)
4. **Frederic S. Mishkin** (1990): "The Information in the Longer Maturity Term Structure About Future Inflation" (*Quarterly Journal of Economics*, Vol. 105, No. 3)

D. DATA

The excel file **termstructure.xls** contains 8 variables: end-of-the-month 3-month to 5-year zero-coupon yields (Y3M, …,Y5Y) and the Consumer Price Index (excluding food and energy) over the period 1959:07 – 2003:12. Data for the 3-month yield, 6-month yield and CPI are from Economagic[3], and data for the 1-year to 5-year yields are from John Cochrane's website[4]. Since all are zero-coupon yields, we can treat them as nominal rates without worrying about coupon payments.

[3] www.economagic.com
[4] http://faculty.chicagogsb.edu/john.cochrane/research/Data_and_Programs/Bond_Risk_Premia/

E. WHAT TO DO

I. Replicating and Extending Fama (1975) – Notice that we use inflation rate in the regressions, which is the opposite of what Fama uses in the paper.

1) Using the CPI series, create future *j*-month annualized inflation rate, for *j*=3, 6, 12, 24, 36, 48 and 60. For example, we generate for the date 1985:01 the 3-month inflation over the period 1985:01 – 1985:04.

2) Estimate [3], for *m*=6 months and *n*=3 months over the whole sample period. Do the results agree with Fama's (the estimates and the residuals)? Re-estimate the regressions for the sample 1959:07 – 1971:07, the one similar to Fama's. Do you get different results? Should you correct for serial correlation?

3) Estimate [4], for *m*=6 months and *n*=3 months over the whole sample period. Be careful with the meaning of lagged inflation for each horizon. Do the results agree with Fama's? Re-estimate the regressions for the sample 1959:07 – 1971:07, the one similar to Fama's. Do you get different results? Should you correct for serial correlation?

4) Perform rolling-window regressions on 3-month and 6-month yields for [4], with a window size of 60 months. Plot the estimates for β_m and γ_m and their 95% confidence intervals. How robust are Fama's results? Do the same thing with correction for AR(1) error.

5) Though Fama's theory is rejected, can we say that the financial market is inefficient? Why or why not?

6) Now conduct a Monte Carlo experiment for the case of a non-constant real rate. To simplify the analysis, consider the following DGP for the one-month rate:

$$R_t^1 = E_t r_t^1 + E_t \pi_t^1$$

$$E_t r_t^1 = 2 + w_t,\ w_t \sim N(0,1)$$

$$E_t \pi_t^1 \sim N(4,4) \text{ and } \pi_t^1 = E_t \pi_t^1 + v_t,\ v_t \sim N(0,1)$$

Generate 200 observations from the DGP, and run regression [1]. Do it 10,000 times. Are the estimates for the constant α close to the true value of -2? Are the estimates for β close to the true value of 1? Explain analytically why you get biased results.

II. Replicating and Extending Nelson and Schwert (1977) – In this section we study the time-series properties of inflation, and create a better predictor of inflation than π_{t-m}^{m}. Intuitively, Nelson and Schwert think π_{t-m}^{m} in [3] may not be a good proxy for inflation expectation. To make Fama's test more powerful, they propose fitting inflation as a time series model to generate an optimal extrapolative predictor for inflation.

7) As shown in the paper, the first difference of the annualized 1-month inflation can be fitted well as an MA(1) process. Based on this result, work out analytically the time series structure for 3-month and 6-month inflations. Using EViews, fit the 3-month and 6-month inflations over the whole sample with the models you have just derived. Save the fitted values.

8) Estimate [3] for 3-month and 6-month yields, and use the fitted values $\hat{\pi}_{t-m}^{m}$ in 7) to replace π_{t-m}^{m}, for the whole sample. Compare the result to that in 3)?

III Replicating and Extending Mishkin (1988) – Instead of using the term structure to predict future inflation, **Mishkin (1988)** extends Fama's hypothesis and uses the term structure to forecast future *path* of inflation. Using our notations Mishkin proposes a slightly modified version of [3]:

[5] $\pi_t^m - \pi_t^n = \alpha_{m,n} + \beta_{m,n}\left(R_t^m - R_t^n\right) + u_{t+m}$ where $m > n$ (**Inflation Change Equation**)

In words, looking at the *n*-period and *m*-period yields today at time *t*, we can predict the path of inflation between time *t+n* and time *t+m*. This is just the difference between the Fisher Equations for two different horizons, so if the Fisher Equation is true:

$\alpha_{m,n} = E\left(\bar{r}^n\right) - E\left(\bar{r}^m\right)$ and $\beta_{m,n} = 1$

Mishkin (1990) extends **Mishkin (1988)** by including yields of longer maturities.

9) Estimate [5] for n = 3 months, and m = 6 and 12 months by OLS with and without Newey-West correction for the error. Explain analytically why "forecasting" regressions like [5] lead to serial correlation in the error when m>1 month.

10) Estimate [5] for n = 3 months, and m = 24, 36, 48 and 60 months by OLS with and without Newey-West correction for the error. Do you results agree with Mishkin's finding that the term structure predicts inflation path better for longer maturities?

11) Replicate the Monte Carlo studies as described in the Appendix in Mishkin (1990) for the null $\beta_{m,n} = 0$ for n=3 and m = 6, 12, 24, 36, 48 and 60 months. Do it only for the case where the error terms are ARCH(1) process, and the error terms for inflation and term spread are independent. Based on the Monte Carlo critical values, do you change your conclusions in parts 9) and 10)?

12) Instead of running the regression [5] separately for each yield, Mishkin points out that estimating them as in a seemingly unrelated regressions (SUR) model brings some efficiency gain. Estimate such a model for n=3 months and m = 6, 12, 24, 36, 48 and 60 months in EViews. To use the same number of observations for each regression, estimate this model using the sample 1959:07 – 1998:12.

13) Now we do some out-of-sample forecasting "horserace". First, run the following regressions:

a) Run [5] for m=6 months, use the sample in which the last observation for π_t^m is the inflation rate from 1998:09 to 1998:12. Use the result to forecast $\pi_{1998:12}^{1999:06} - \pi_{1998:12}^{1999:03}$.

b) Run [5] for m=12 months, use the sample in which the last observation for π_t^m is the inflation rate from 1997:12 to 1998:12. Use the result to forecast $\pi_{1998:12}^{1999:12} - \pi_{1998:12}^{1999:03}$.

…

f) Run [5] for m=60 months, use the sample in which the last observation for π_t^m is the inflation rate from 1993:12 to 1998:12. Use the result to forecast $\pi_{1998:12}^{2003:12} - \pi_{1998:12}^{1999:03}$.

By doing the above you use data up to 1998:12 to forecast the inflation path for different horizons.

The second method of forecast is the "random walk hypothesis", which simply uses the previous inflation path as forecast. For example, to forecast $\pi_{1998:12}^{1999:06} - \pi_{1998:12}^{1999:03}$, you use the inflation path $\pi_{1998:06}^{1998:12} - \pi_{1998:06}^{1998:09}$ that you observe now.

Compare the forecasts from the two methods with the actual inflation paths in the data. Which method does a better job?