PREDICTING INFLATION AND OUTPUT WITH THE TERM STRUCTURE (AND VICE VERSA)

EXTENDED ABSTRACT

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The relation between the term structure of interest rates, inflation and economic growth has long been recognised as central to both macroeconomic and finance theory and as critical in formulating economic policy and investment decisions. Expectations of inflation and real activity also play a key role in pricing financial instruments as well as in determining the actions of governments and central banks in attempting to smooth business cycle fluctuations. This relation is reciprocal, in the sense that changes in asset prices and economic policies change current levels of inflation and real growth and, therefore, expectations about their future path.

This paper investigates the forecasting ability of the term structure of interest rates for future inflation and output using the general equilibrium model and econometric method developed in Berardi (1998). Applying this approach, we provide estimates for the United States, United Kingdom, Japan, Germany, France, Italy and Canada over the sample period 1987-1999. The empirical estimates allow us to: (i) study the cross-sectional relations which link the term structure to output growth and inflation; (ii) obtain endogenous expectations for these macroeconomic variables and test their forecasting ability for future inflation and output (industrial production) growth; (iii) fit the actual term structure of nominal interest rates and use nominal bond prices to derive estimates for the implicit real term structure; (iv) recover from observed data estimates of unobservable variables, such as the instantaneous real interest rate and expected inflation rate and their time-varying central tendencies, which give us some information about market expectations of future monetary policy.

This approach extends the range of the analysis with respect to previous contributions and presents a new tool for predicting inflation and output growth using bond prices information.

Extensive theoretical and empirical work has been devoted to the study of the relation between real activity, inflation and interest rates. However, so far there is neither a commonly accepted theoretical framework nor unanimity on empirical regularities.

The links between real activity and the term structure of interest rates have been analysed, among the others, by Harvey (1988 and 1989), Estrella and Hardouvelis (1991), Plosser and Rouwenhorst (1994), Chapman (1997), Kamara (1997) and Roma and Torous (1997). According to these studies, the shape of the term structure reflects information about future economic growth. In particular, a positive slope of the yield curve predicts an increase in the level of real activity, whereas a flattening or a negative slope of the yield curve is associated with a future recession.

A related field of research looks at the information content of the term structure of interest rates for future inflation. Results presented, for example, by Fama (1990) and Mishkin (1990) suggest that only the long end of the term structure of interest rates contains information about future inflation, whereas the short end of the term structure provides almost no information about the future path of inflation.

All the studies cited above are related to the theory of interest rates but are not specifically designed to address the problem of specifying a complete model of the term structure within which the links between inflation, economic growth and bond prices may be analysed and used for forecasting purposes.

The inclusion of these macroeconomic relations in a general equilibrium term structure framework dates back to the continuous time model of Cox, Ingersoll and Ross (CIR, 1985a and 1985b), which describes a complete economy with production and a stochastic investment opportunity set and endogenously determines optimal consumption, portfolio choices and equilibrium asset prices. This model has led to a large number of contributions which use the general equilibrium approach to price bonds and other interest-rate-sensitive instruments.

However, not all the term structure models based on the CIR approach explicitly consider the role of inflation. In this respect, significant exceptions are Breeden (1986), Foresi (1989), Pennacchi (1991), Sun (1992), Pearson and Sun (1994), Bakshi and Chen (1996) and Buraschi (1996). Some of these models enforce the inflation neutrality hypothesis by assuming that the price level plays no role in affecting the real economy (this is the case in CIR (1985b) and Pearson and Sun (1994)), whereas some other models

(Breeden (1986), Foresi (1989), Pennacchi (1991), Sun (1992), Bakshi and Chen (1996) and Buraschi (1996)) allow for non-neutral effects of inflation.

Only Pennacchi (1991), Sun (1992) and Buraschi (1996) provide some empirical evidence. Pennacchi (1991) and Sun (1992) use data on inflation along with data on bond yields in estimating their term structure models. However, these authors do not appear to have exploited fully the connection between bond yields, inflation and real growth implicit in their general equilibrium framework, as they (i) ignore the potentially useful information contained in output or consumption, and (ii) use only short-term bonds (the longest maturity is one year) and do not take into account the information in the long end of the term structure. The subsequent work of Buraschi (1996) extends the empirical analysis by including also data on consumption and stock returns. This study provides useful insights about the existence of common factors explaining the dynamics of the bond market and the stock market, but fails in predicting consumption growth. Neither Pennacchi (1991) and Sun (1992) nor Buraschi (1996) produce estimates for the real term structure or use the closed form solution of their models to work out implicit expectations of inflation and economic growth and assess their predictive ability for future actual values.

The analysis we propose in this paper differs from those studies in many significant aspects. In particular, (i) it uses data on output along with data on bond yields and inflation, so that in the econometric work the model is completely specified and the term structure equations and the structural equations for output growth and inflation are estimated simultaneously; (ii) it uses data for all the maturities of the yield curve, including very long-term yields; (iii) it allows for time-varying central tendencies in the real interest rate and the expected inflation rate; (iv) it measures the effect of the covariance between inflation and output growth on the dynamics of the nominal term structure; (v) it derives implicit estimates of the real term structure from nominal bond prices and studies its relation with economic growth rates; (vi) it provides (endogenously) estimates of the implicit expectations of inflation and output growth rates over different time horizons and evaluates their predictive ability for future inflation and industrial production.

Considering data on variables such as inflation and output along with data on bonds implies placing more emphasis on the macroeconomic aspects underlying the dynamics of the yield curve and on the feedback effects which run from interest rates to the fundamentals. Such a "macro" approach would be more suitable for both medium-term investment and economic pol-

icy purposes, as it also permits information contained in the term structure of interest rates to be used in predicting inflation and economic growth.

The theoretical model (see Berardi (1998)) is based on a general equilibrium economy whose dynamics are determined by four state variables: the instantaneous real interest rate and expected inflation rate and their time-varying central tendencies. Moreover, a time-varying parameter is introduced, which influences the dynamics of output. The model accounts for non-neutral effects of inflation. Real and monetary variables are interrelated and jointly influence the term structure of interest rates, while bond yields convey information about expectations of economic fundamentals, such as production, consumption and inflation. Closed form solutions for the equilibrium value of nominal and real bonds and for expectations of inflation rates and output growth rates over any future time interval are derived. These enable us to analyse the cross-equation restrictions which link the real and nominal term structure of interest rates to the dynamics of production, consumption and price level and use the model to forecast inflation and output.

Although monetary policy is not explicitly introduced in the model, the presence of time-varying central tendencies for the real interest rate and the expected inflation rate allows us to get some insights on market expectations about medium-long term Fed target rates. Recent work in this area includes, among the others, Jegadeesh and Pennacchi (1996), Clarida, Gali and Gertler (1998), Piazzesi (1999).

The model is estimated using monthly data for the G7 (United States, United Kingdom, Japan, Germany, France, Italy and Canada) over the sample period 1987-1999. Estimation is carried out using a maximum likelihood approach where the Kalman filter algorithm is applied to compute the unobservable variables. The model fits the nominal term structure well and provides estimates for the real term structure and for the unobservable state variables, including market expectations about future monetary policy.

The estimated model shows that significant connections exist between interest rates, inflation and real growth and that the dynamics of these variables are highly interdependent. In general, the non-zero covariance between output growth and inflation can have a relevant impact on medium-long term bond prices.

The empirical evidence shows that the cross-equation restrictions imposed by the model on the dynamics of inflation, output, term structure of interest rates and underlying state variables provide accurate in-sample and out-of-

sample forecasts for inflation and industrial production. The model outperforms alternative forecasting approaches, such as random walk and ARIMA processes and Mishkin's (1990) inflation-change model for inflation and Harvey's (1989) model for output. Given its ability in predicting future inflation and output growth rates, the model might indeed represent a powerful tool for both monetary policy and investment decisions.

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