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The term structure of interest rates in an estimated New Keynesian policy model[☆]

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ABSTRACT

We jointly estimate a New Keynesian policy model with a Gaussian affine no-arbitrage specification of the term structure of interest rates, and assess how important inflation, output and monetary policy shocks are as sources of fluctuations in interest rates and the term premium. We work with observable pricing factors and utilize the computationally convenient normalization of Joslin et al. (2013b). This allows us to estimate the model without needing to restrict the parameters driving the market prices of risk. Using data for the U.S. from 1962:Q1 to 2014:Q2, we find that inflation and the output gap account for around 80% of the unconditional forecast error variance of bond yields at the short and medium end of the term structure, while monetary policy shocks account for around 20%. Bond yields respond to macroeconomic shocks only gradually, peaking after about 4 quarters. This is due to sizable monetary policy inertia estimates in our model. At the peak of the response, inflation shocks increase bond yields by more than one-to-one, and output shocks by less than one-to-one, which is consistent with a Taylor type monetary policy rule. Our term premium estimate is strongly counter-cyclical and can capture salient features of the term structure that constitute a puzzle in the expectations hypothesis.

1. Introduction

Since the seminal work by Ang and Piazzesi (2003), interest in so called *'macro-finance models'* which incorporate macroeconomic variables into an affine Gaussian no-arbitrage term structure model to assess the effects of macroeconomic information on the yield curve has increased tremendously.[1] Studies that analyze macro-finance relations using such a structural approach are, among many others, (Rudebusch and Wu, 2008; Hördahl et al., 2006; Bekaert et al., 2010) and Bikbov and Chernov (2013). These studies formulate small New Keynesian type models jointly with a dynamic no-arbitrage model for bond yields. Rudebusch and Wu (2008); Hördahl et al. (2006), Bekaert et al. (2010) summarize interest rate movements with inflation, output and two latent yield curve factors, while Bikbov and Chernov (2013) use inflation, output and the short rate. In all of these studies, some or all of the parameters that determine the prices of risk are restricted to zero. For instance,

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[1] There exist earlier studies that have modelled the relationship between yields and macroeconomic variables, nevertheless *without* imposing no-arbitrage restrictions on bond prices.

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Rudebusch and Wu (2008) restrict risk prices such that only entries related to the latent factors are non-zero. Hördahl et al. (2006) and Bikbov and Chernov (2013) estimate their model first without restrictions on the price of risk, and then re-estimate the model with all the *'insignificant'* parameters found in the first step set to zero. Bekaert et al. (2010) restrict *all* risk prices to zero, such that the Expectations Hypothesis holds exactly. While these zero-restrictions enable the authors to mitigate some of the well known estimation difficulties inherent in these models, such *'arbitrary'* zero-restrictions produce numerically and economically significant differences in policy relevant outcomes related to term premia, inflation expectations and the like. In this context, Bauer (2014a) has recently pointed out, that the approach by Hördahl et al. (2006) and Bikbov and Chernov (2013) might be unappealing for several reasons: First, choosing restrictions based on individual standard errors amounts to imposing a joint restriction without considering joint significance. Second, the choice of significance is necessarily arbitrary. Third, different choices of zero-restrictions on the risk factors lead to economically significant differences in policy relevant variables, with their two-step approach providing no guidance with respect to which results are deemed more credible. Finally, the approach of Bekaert et al. (2010) may seem difficult to justify empirically because there exists strong evidence that the Expectations Hypothesis is rejected in the data (see, for instance, the seminal papers by Campbell and Shiller (1991) and Cochrane and Piazzesi (2005)). Recent reduced-form studies that emphasize the importance of the choice of zero restrictions on the prices of risk are Joslin et al. (2014) and Bauer (2014a).

Apart from the problems related to the imposition of arbitrary zero restrictions on the prices of risk in previous macro-finance terms structure models, there exist also some concerns related to the empirical specification of the New Keynesian type macroeconomic models that are employed. For instance, both, Hördahl et al. (2006) and Rudebusch and Wu (2008), work with monthly data for Germany and the U.S., respectively. Due to difficulties in adequately capturing the empirically observed dynamics in the data when switching to a monthly sampling frequency, these authors modify the original lag specifications in the New Keynesian models and add an arbitrary number of lags to the inflation and output gap equations in their formulations.[2] Moreover, as GDP is only published on a quarterly basis, Rudebusch and Wu (2008) work with industrial capacity as a measure of the output gap. In this paper, we work with a quarterly time horizon. This enables us to use standard GDP based measures of the output gap. Furthermore, we bypass the need to modify the lag structure describing the dynamics in New Keynesian models, which allows us to relate the parameter estimates that we obtain to those found in, for instance, Cho and Moreno (2006) or in Buncic and Melecky (2008). These two studies estimate New Keynesian type policy models without an arbitrage free dynamic term structure model for bond yields, and thus can be used as a reference point for our structural macro parameter estimates.

The objective of this study is to estimate a Gaussian macro-finance term structure model using a small scale New Keynesian policy model to capture the dynamics of the macroeconomic variables and an affine no-arbitrage term structure model for bond yields. In order to mitigate computational difficulties inherent in the estimation of such models, we work with *observable* pricing factors only, and impose the computationally convenient normalizations suggested by Joslin et al. (2011) and Joslin et al. (2013b) to price the cross-section of bond yields. An advantage of our approach is that we do not need to impose any arbitrary restrictions on the parameters that determine the market prices of risk, yielding a more flexible parameterisation of our model. Our study thus contribute to the existing literature on structural Gaussian macro-finance term structure models (MTSMs) by estimating a model without imposing any zero restrictions on the prices of risk. Using this unrestricted framework, we provide an analysis of the effects of macroeconomic variables on bond yields and term premia.

Using quarterly data from 1962:Q1 to 2014:Q2 for the U.S., we find that inflation and the output gap account for about 80% of the total forecast error variance of yields at the short and medium ends of the yield curve, and that monetary policy shocks account for about 20%. Real economic activity explains (at most forecasting horizons) a larger part of the forecast error variance than inflation. Results for term premia lead to qualitatively similar results. Our impulse response function analysis shows that positive shocks to inflation and the output gap decrease the term premium instantaneously. In line with market participants' expectations, we find an instantaneous increase in the expectations hypothesis component of interest rates. These two effects offset each other initially, with the term premia responses reverting back to zero relatively quickly, while the responses of the expectations hypothesis term are longer lasting. The response of bond yields to macroeconomic shocks peaks after about 4 quarters, with inflation shocks increasing bond yields by more than one-to-one, while output shocks do so less than one-to-one.

Our term structure model implied pricing errors are on average around 65 basis points, with pricing errors increasing with maturity. These pricing errors are correlated with the slope of the yield curve, indicating that the inclusion of a factor correlated with the slope could reduce the pricing errors. Our estimated term premium is strongly counter cyclical, with a correlation of -0.83 between the term premium and real activity (the output gap). Moreover, our estimated term premium allows us to capture salient features of the term structure of interest rates that represent a puzzle for the Expectations Hypothesis, that is, LPY(i) and LPY(ii) of Dai and Singleton (2002), particularly for longer maturities.

The rest of the paper is organised as follows. Section 2 outlines in detail the structural macro-finance term structure model (MTSMs) that we estimate and the assumptions that we impose. In Section 3, we describe our estimation strategy and the data, with a discussion of the empirical results being presented in Section 4. Finally, we conclude our study in Section 5 and offer some extensions for future research.

[2] Note that most standard New Keynesian type dynamic macroeconomic models assume a quarterly time horizon so that the dynamics as well as parameters such as elasticities and discount rates are calibrated with a quarterly horizon in mind.