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A macro-finance term structure model with multivariate stochastic volatility☆

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ABSTRACT

This article examines some consequences of the presence of non-affine structures of multivariate stochastic volatility in a dynamic Nelson–Siegel model with macroeconomic variables. The results indicate that this non-affine model achieves superior in-sample fit for the observed yields, captures persistence patterns more consistent with stylized facts and empirical measures and also has greater explanatory power for the conditional volatility observed in yields compared to affine models and models without macroeconomic variables.

1. Introduction

The connection between financial variables and the macroeconomic environment is an indisputable fact in the economic analysis. Because of this fundamental relationship between finance and macroeconomics the macro-finance literature has become increasingly important in analyzing problems such as the motivations of the recent global financial crisis, determining the economic fundamentals of risk premiums in debt instruments, and the macroeconomic expectations present in financial assets.

The use of financial variables in macroeconomic analysis also has practical motivations, such as the difficulty of using some macroeconomic variables due to substantial lags in the construction and disclosure of these measures, as discussed in Dewatcher, Iania, and Lyrio (2014). Financial variables quickly incorporate expectations about macroeconomic variables, and thus can be used to retrieve macroeconomic information in high frequency, using daily data on financial assets.

A fundamental set of financial information is present in the term structure of interest rates. The observed relationships between so-called factors of the yield curve — level, slope and curvature and macroeconomic variables enables the construction of predictions about inflation, monetary policy transmission and the business cycle. Another key aspect of this relationship is

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that it is bidirectional — financial variables affect macroeconomic aggregates, and expectations about these variables directly impact asset prices, in particular the term structure of interest rates. The change in expectations about variables such as inflation, output and fiscal variables, generate significant changes in returns and volatilities of financial assets.

The modeling of the relationships between financial and macroeconomic variables has generated a broad class of models. As recent examples we have Diebold, Rudebusch, and Aruoba (2006), using a generalized version of Nelson and Siegel (1987) model to capture the links between the term structure and macroeconomy. Huse (2011) presents a dynamic Nelson–Siegel model based only on macroeconomic variables as state variables, achieving better results in terms of out-of-sample forecasting and finite-sample performance of estimators. Mumtaz and Surico (2009) find evidence that shocks in the level of the yield curve are responsible for most of the volatility of inflation, specially in the period before 1992. It is also important to note the large literature that uses the yield spread to forecast business cycles (e.g., Stock and Watson (1989), Estrella (2005) and more recently Rudebusch and Williams (2009), Kauppi and Saikkonen (2008) and Adrian, Estrella, and Shin (2010). Koivu, Nyholm, and Stromberg (2007), Pericoli and Taboga (2012) and Chen and Tsang (2013) analyze the use of the term structure models in forecasting exchange rates. Lange (2013) estimates a dynamic latent factor model of the yield curve for Canada and relates it to the Canadian macroeconomy and found relatively strong bidirectional causality between latent yield-curve factors and the macroeconomic fundamentals for Canada using the dynamic latent factor approach of Diebold and Li (2006).

A significant part of the macro-finance models using the term structure of interest rates is based on so-called affine models, starting from the seminal work of Ang and Piazzesi (2003). This class of models have been used to predict the yield curve (Hordahl, Tristani, and Vestin (2006)), to verify the impact of inflation expectations in long-term interest rates (Dewachter and Lyrio (2006)) and for the analysis of the monetary policy regimes in Rudebusch and Wu (2007). However an important omission in these affine models is the treatment of conditional volatility. In the field of macro-finance commonly used models assume constant volatility, as the works of Diebold et al. (2006) and Rudebusch and Wu (2007) mentioned earlier. We can also highlight Ang and Piazzesi (2003), Ang, Piazzesi, and Wei (2006) and Ang, Dong, and Piazzesi (2005).

These models usually describe the dynamics of states of the macrovariables and factors of the yield curve using vector autoregressive (VAR) models. In particular, models that impose no-arbitrage conditions provide a powerful tool for understanding the joint dynamics in a coherent and parsimonious way. But these macro-finance models with no-arbitrage conditions are usually confined to the class of affine models with constant variance–covariance matrix of innovations in the VAR. However, assuming constant volatility is against important stylized facts in financial assets, such as the presence of clusters of volatility, heavy tails and extreme events caused by the presence of structures of time-varying conditional volatility. Affine models also ignore fundamental changes in the patterns of macroeconomic series observed in the last decades. The changing patterns of volatility of macroeconomic series can be explained by the so-called Great Moderation, as defined in Stock and Watson (2002), page 161:

> *The decline in volatility has occurred broadly across the U.S. economy: since the mid-1980s, measures of employment growth, consumption growth, and sectoral output typically have had standard deviations 60% to 70% of their values during the 1970s and early 1980s. Fluctuations in wage and price inflation have also moderated considerably. For variables that measure real economic activity, the moderation generally is associated with reductions in the conditional variance in time-series models, not with changes in the conditional mean; in the language of autoregressions, the variance reduction is attributable to a smaller error variance, not to changes in the autoregressive coefficients.*

One possibility to incorporate stochastic volatility models in affine models is the use of square root volatility in yields, generalizing CIR square root models, as in Christensen, Lopez, and Rudebusch (2010). This specification, although analytically tractable and including the no-arbitrage restrictions, has very limited explanatory power on the conditional volatility observed in yields, as shown in Collin-Dufresne, Goldstein, Robert, and Jones (2009), Jacobs and Karoui (2009), Andersen and Benzoni (2010), Christensen et al. (2010) and Diebold and Rudebusch (2013). The results in these articles show that the variation in yields predicted by affine models of the term structure cannot explain the observed volatility in yields, a phenomenon known as unspanned volatility, even with the use of a large number of factors. This limitation points to the need for non-affine structures in the modeling of the term structure of interest rates.

Although the no-arbitrage condition is important in asset pricing models, many studies indicate that in practical applications the imposition of no-arbitrage restrictions may not be relevant. A key result was obtained by Joslin, Singleton, and Zhu (2011), showing that in the class of Gaussian affine term structure models the conditional predictions are invariant to inclusion of no-arbitrage conditions. Also, another important result was found by Coroneo, Nyholm, and Vidova-Koleva (2011), showing that in the Nelson–Siegel family models with and without the no-arbitrage conditions are statistically equivalent. Nyholm and Vidova-Koleva (2012) showed that the out-of-sample forecasts of three factor affine models and dynamic Nelson–Siegel model are statistically equivalent. A summary of this discussion can be found in Diebold and Rudebusch (2013). This results supports the use of non-affine models, especially when affine models has an inadequate empirical performance.

Besides the financial problems related to the misspecification in the volatility structure, this also leads to other relevant econometric problems. Hamilton (2008) points out that even when the main objective is to estimate the conditional mean, have a correct description of the conditional variance can be quite important, since hypothesis testing in models in which the variances are misspecified can be invalid. The correct specification of the stochastic volatility structure is of fundamental importance in the pricing of derivatives and the hedge of interest rate curves, as discussed in Cotton, Sircar, Fouque, and Papanicolaou (2004) and Li and Zhao (2006).