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978-1-107-04455-5 - Developments in Macro-Finance Yield Curve Modelling

Edited by Jagjit S. Chadha, Alain C. J. Durré, Michael A. S. Joyce and Lucio Sarno

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1 Editors' introductory chapter and overview

*J. S. Chadha, A. C. J. Durré, M. A. S. Joyce
and L. Sarno*

The on-going financial crisis continues to expose the limits of our collective knowledge and thereby motivate new avenues of research for academics, practitioners and policymakers and perhaps none more so than those that lie at the intersection of monetary and financial economics. As has been well documented, the origins of the crisis go back to problems in the US sub-prime market that became increasingly clear in the early part of 2007 and culminated in the announcement by BNP Paribas on 9 August 2007 of the suspension of a number of funds as it was no longer possible to value their assets. The BNP Paribas statement was a reflection of the fact that by that summer liquidity had all but evaporated in many securitised lending markets. But the statement itself triggered a further collapse in liquidity in many other markets and also a break-down in interbank lending markets. And what started as a liquidity crisis soon became a credit crisis as it became increasingly apparent that risk in many capital markets had been underpriced and that consequently much of the private sector was carrying too much debt, with many parts of the financial sector leveraged to an untenable degree. Subsequently, at various points in the crisis the very financial network itself seemed threatened with extinction, most notably after the collapse of Lehman Brothers in September 2008. Eventually, the interaction between banking and sovereign risk led to increasing spreads on government debt in many countries and full-blown sovereign debt crises in a number of euro area countries.

The crisis led to governments and central banks having to provide considerable levels of liquidity and capital to the financial sector, and ultimately to a fundamental rethink of many of our working assumptions about the appropriate degree and scale of interaction between the state and the financial sector. As well as providing direct support to the financial sector, policymakers found that they had to adopt extraordinary accommodative policies to help smooth the adjustment of private sector balance-sheets. These policies included the adoption of near-zero

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policy interest rates, various forms of extended open market operations, known as credit or quantitative easing, and running large and persistent fiscal deficits. Under these conditions, it is perhaps no surprise that the considerable progress that had been made in linking yield curve models to the state of the macroeconomy was going to be put under a great deal of scrutiny. As the chapters in this volume show, it turned out that many of the models developed in the preceding decade or so could not really address many of the key issues that needed to be accounted for in order to price bonds accurately. For example, the limited attention paid to credit and liquidity risk premia and our scant understanding of the implications of heightened uncertainty or disagreement about the macroeconomy or, indeed, policy was thrown into sharp relief; and meant that the specific impact of liquidity risk and portfolio reallocation on bond yields was hard to gauge and the importance of credit and sovereign risk was poorly understood.

Against this background, it was clear that when we planned a Modern Macroeconomic Policymaking conference on money and bond markets there would be considerable interest from the research community. But the quality of the papers we received and also of the extent to which the conference itself promoted a sustained and constructive dialogue greatly exceeded our expectations.¹ We are therefore pleased to be able to publish the papers presented at that conference, which have been thoroughly revised following the comments of the discussants, referees and editors. In this introductory chapter we provide a short summary of each chapter in the book and conclude with what we consider to be the main themes that emerged, which could usefully form the basis of a future research agenda.

The first four substantive chapters represent the keynote addresses given at the conference. In Chapter 2, Philip Turner (Bank for International Settlements) provides a wide-ranging discussion of the nature of the long-term interest rate, asking whether it is a policy victim, a policy variable or a policy lodestar. Turner begins by documenting the decline in long-term interest rates in the major international centres over the last couple of decades, which he suggests cannot be easily explained by the normal determinants of long rates. Turner argues that the long rate has become a policy victim to the extent that it has been affected by a number of different official policies that have all had the effect of increasing the demand for government bonds. This includes: the impact of the

¹ This conference was jointly organised by the Centre for International Macroeconomics and Finance (University of Cambridge), the IÉSEG-School of Management (Lille Catholic University) and the Money, Macro Finance Group. The conference papers can be found at www.econ.cam.ac.uk/MMPM/YieldCurve.html.

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'saving glut' and the associated choice by Asian countries to accumulate large foreign exchange reserves and invest them in US Treasuries; the impact of regulatory policies on insurance companies and the banking industry; and changes in the valuation of pension funds, which have all led to these institutions increasing their demand for government securities. The consequence of these official policies has been to lower long rates and also to make them more sensitive to the business cycle, insofar as institutional investors have been given greater incentives to increase their government bond holdings when economic prospects deteriorate and to reduce them when growth prospects improve. The long-term interest rate has also become a policy variable in the current crisis. Central banks through their balance sheet policies and governments through their debt management policies have both tried to influence long-term rates. Turner argues there is nothing new in the idea that policy can influence bond yields, with Keynes the best known advocate. The key issue is the degree of imperfect substitutability across the yield curve, which will depend on uncertainty about the future path of interest rates. High government debt and deficits are likely to increase this uncertainty, but they also make the yield curve vulnerable to excess volatility, which reduces the ability of central banks to steer long-term rates for any length of time. Lastly, Turner asks whether the long-term interest rate should be used as a lodestar to guide policy. While the yield curve is often used to measure expectations of inflation and growth and can be central to many micro-economic policies because of its influence on the discount rate, Turner argues that great caution is required in drawing policy implications from its current level. This is because we do not know the extent to which it has been distorted by the effects of government and other policies, nor how persistent these effects will be. Overall large fiscal deficits and high levels of government debt mean that there is a significant risk of instability in bond markets, which may pose threats to financial stability because of the sharply leveraged position of financial firms and create awkward tensions for monetary policy in setting short rates and deciding the extent of central bank holdings of government bonds.

In Chapter 3, Alain Durré (European Central Bank and IÉSEG-School of management) and Frank Smets (European Central Bank and KU Leuven) pick up the theme of the interaction between fiscal policy and monetary policy, with an emphasis on developments in the euro area. They begin by reviewing the theoretical and institutional framework that existed before the recent financial crisis. From a theoretical perspective, they show why the pursuit of price stability requires fiscal policy to be sustainable. This leads to the desirability of an 'active monetary and passive fiscal policy' framework that avoids the risk of

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fiscal dominance, i.e. the risk that unchecked fiscal policy and rising government debt endangers the ability of the central bank to maintain price stability. They suggest that institutional fiscal and monetary policy arrangements in the euro area were designed to ensure such a stability-oriented framework in a monetary union with many national fiscal authorities. They go on to review fiscal developments during the recent crisis and show how the interaction between banking and sovereign risks has led to increasing spreads on government debt and a sovereign debt crisis in a number of euro area countries. They also discuss the ECB's policy response, which has included (in addition to the standard easing of policy rates) the use of non-standard policy measures geared at addressing malfunctioning financial markets and repairing the monetary transmission process. As a result of its role as a market maker of last resort, the ECB's balance sheet has increased in size, which has brought with it increased risks. The authors argue that the interaction between financial stability, fiscal sustainability and monetary policy seen during the European sovereign debt crisis make it clear that the EMU framework needs to be deepened and extended.

In Chapter 4, Dan Thornton (Federal Reserve Bank of St Louis) turns to the unconventional monetary policy actions taken by the Federal Reserve in response to the crisis, providing a critical review of where he believes these actions were appropriate and where they were not, and offering his own views of what policies should have been implemented. In the pre-Lehman's phase of the crisis, the Fed brought about a large reduction in the funds rate target and a large expansion of lending, mainly through the Term Auction Facility (TAF). Thornton believes the former was appropriate but largely ineffective, given the weakness of the interest rate and credit channels of monetary policy. The latter was rendered ineffective because the lending was sterilised by the Fed selling equivalent amounts of Treasuries, ensuring that the volume of credit did not rise overall. The Fed did this, Thornton believes, because Chairman Bernanke believed that the composition of its balance sheet was more important than its size. The Fed was apparently trying to undo an inefficient allocation of credit by lending to the institutions it deemed to be in most need of liquidity. Thornton views this as a major policy error and in his assessment the policy produced no noticeable effects. Instead he believes the Fed should have engineered a large expansion in the monetary base. This is indeed what happened after the collapse of Lehman's, when Thornton notes there was an explosion of primary credit borrowing and TAF lending, which the Fed did not attempt to sterilise, possibly because its holdings of Treasuries were too low. Thornton believes that, whatever the rationale, this action was appropriate and

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successful in reducing risk spreads. He is critical, however, of the Fed's use of so-called forward guidance that began at the end of 2008 and its quantitative easing (QE) or large-scale asset purchases policy. He argues that the former is based on the expectations hypothesis, which is strongly rejected in the data and he cites evidence suggesting there is no evidence that forward guidance improves central banks' control over longer-term rates. He also argues that the Fed's QE policy was ineffective in reducing long-term interest rates and stimulating aggregate demand, while at the same time unnecessary. Although not disputing the event study evidence that asset purchases affected yields, he argues that these effects were short-lived and not visible in the monthly data. He also notes that to the extent that larger effects on yields reflect greater segmentation than pass-through to the rest of the economy is likely to have been smaller. In his view, by March 2009 when the Fed decided to expand its large-scale asset purchases to include longer term Treasuries, as well as increased amounts of MBS and agency debt, there were already signs that financial markets had stabilised and economic recovery was underway, something he attributes to the earlier expansion of credit. The further expansion of the Fed's balance sheet was therefore unnecessary and likely to have been counterproductive.

In Chapter 5, Patrik Edsparr and Paul Fisher (Bank of England) take a different look at what has been learned from the crisis, by focusing on the design of financial contracts from a financial stability perspective. In particular, they look at contracts which fail to take into account how the financial system as a whole operates, which leads to the true value of a contract being different than expected for at least one of the counterparties in stressed conditions. They discuss and give practical examples of two ways this can happen and consider what lessons can be drawn. The problem arises in the first category of contracts because the correlation structure may be very different for tail events, so that the insurance provider is not in a position to pay out at the time the investor wants to exercise the contract. Examples of this kind of contract include where a bank hedges its corporate lending by purchasing offsetting CDS protection on a portfolio of loans from another leveraged market participant. In this case, the bank needs to take into account the correlation between the risk profile of the corporate borrower and the provider of CDS protection, which can be very different in stressed conditions. Moreover, if all big banks follow similar strategies, they will all end up with similar portfolios of risk. In such an interconnected financial system, a big shock affecting one bank will affect all banks. The second category of contracts considered is where the perceived payoff in the tail event is offset by unforeseen costs. This occurs where a market participant may choose

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not to enforce a contract because the repercussions for its reputation of doing so will cause more damage than will be gained by enforcing the contract. The problem this creates is that it is hard to determine *ex ante* what such contracts are worth. The authors cite many examples, including banks accepting responsibility for the distressed assets of the off-balance-sheet Structured Investment Vehicles (SIVs) they had set up, banks not enforcing 'break clauses' in derivative contracts which would entitle them to earlier payment, and money market funds making up losses to avoid 'breaking the buck'. If the reputational and signalling implications of exercising a contract are too damaging in cases of extreme stress, this is something regulators need to take into account when determining the risk profile of an institution and its appropriate capital buffer. They draw two main lessons from their analysis. The first is that there is a need to critically evaluate contingent exposures with proper stress tests that capture tail events. The second is that contract design features that are exclusively reliant on extreme tail events are best avoided, as such features, which do not normally matter, end up being treated as if they never matter. They also argue that it would be worthwhile to assess where these tail risks should be held, as leveraged financial institutions pose larger systemic risks than more traditional unlevered investor categories, though such considerations need to be carefully weighed against other investor protection concerns.

A number of chapters consider methodological or technical innovations to term structure or credit models. The financial crisis has provided considerable momentum to the development of new techniques and results that will take researchers and practitioners some years to absorb. A common theme was the need to move away from linear models. An example is explored by Jean-Sébastien Fontaine (Bank of Canada) in Chapter 9, who shows how moving to a more accurate description of central bank operating procedures – treating them as lumpy rather than continuous – leads to a significantly better characterisation of the yield curve.

Most central banks, he argues, effect changes to their target or policy rate in discrete increments (e.g., multiples of 0.25 percentage points) following public announcements on scheduled dates. Yet most researchers rely on the assumption that policy rates change linearly and do not distinguish between dates with and without scheduled announcements. This assumption, it turns out, is not innocuous when estimating the policy rule at a daily frequencies. He examines a daily sample from 1994 to 2011 and finds that accounting for discrete changes, as opposed to the Gaussian alternative, in an otherwise standard term structure model leads to significantly different estimates of the price of macroeconomic

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risk. Only the model based on discrete changes depicts a picture that is consistent with the evidence of the response of the term structure to monetary policy announcements and the recent behaviour at the lower zero bound, including liquidity and open market operations.

James Steeley (Aston Business School) in Chapter 7 reminds us that prior to the sharp reduction in the UK Bank Rate between October 2008 and March 2009, cubic spline and Nelson–Siegel models were equally adept at fitting the cross section of gilt yields. Subsequent to the unprecedented level of rates after March 2009, both models required a substantially increased number of parameters to achieve comparable levels of fit and smoothness; as much as a six-fold increase in the case of the Nelson–Siegel model. While the smoothness of the yield curve does not seem to respond to market events associated with quantitative easing (QE), it turns out that the estimation errors are significantly greater on days featuring gilt purchases. Enhanced undulations in the forward curve can be thought of as a fourth factor corresponding to changes in curvature. These event days point to the need for more flexibility in yield curve modelling, and foreshadow the results of principal components analysis that finds a significant increase in the explanatory power of the fourth principal component since the encroachment of the lower zero bound. Finally, based on his analysis of average forward curves estimated on QE auction days and non-auction days, Steeley finds that there does not seem to be any obvious relationship between the maturity of the bonds purchased by the Bank of England and the response of yields, which he suggests may indicate that QE may have difficulty working through a portfolio rebalancing channel. He finds, however, that after the Bank extended the range of maturities it purchased in August 2009, auctions generally tilted the long end downwards, possibly consistent with a change in inflation expectations because the differences do not show obvious differences with the bonds being purchased this may indicate that QE may work more through the signalling channels than through portfolio rebalancing. Furthermore, he argues that the effects coincide with the extension of the maturity ranges in August 2009 after which the auctions generally tilted the long end downwards.

In Chapter 6, Alain Monfort (CREST) and Jean-Paul Renne (Banque de France) outline a discrete-time modelling framework for defaultable-bond yields. They show that a compound autoregressive (Car) process makes it possible to account for sophisticated dynamics of yields and spreads, under both the risk-neutral and the historical dynamics. This framework is applied to bonds in the euro area and both credit and liquidity premia are estimated.

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In Chapter 8, Yvan Lengwiler (Basel) and Carlos Lenz (Swiss National Bank) apply the intelligible factors decomposition of the yield curve to data from 1999 to 2010 for the USA, UK and Germany in order to identify some common stylised facts. This decomposition relies on an orthogonality identification scheme for each of the three factor's innovations and gives profoundly different loadings at each horizon when compared to the standard level, slope and curvature factors found in the standard literature on factor models. The resulting stylised facts present something of a puzzle for the standard view that the central bank determines the short end of the curve and thereby exercises some leverage over long-term rates. The authors find that the long-term factor interacts little with the other factors and seems related to international drivers and that the dominant factor in yield curve movements is the medium-term, or business cycle factor, which also plays a dominant role in explaining the variance of shorter-term rates. The results are shown to maintain their stability over the recent financial crisis.

In Chapter 10, Michael Dempster (University of Cambridge), Jack Evans (evalueFE) and Elena Medova (Cambridge Systems) outline some of the problems with various approaches to yield curve modelling, which leads them to implement a model of the term structure based on an idea from Fisher Black. This idea asserts that interest rates generally come with a 'stuff it under the mattress' option in which investors just keep their money when faced with a negative interest rate. This means that we can model interest rates as options on some more fundamental, but possibly hard to observe, shadow rates which guarantee positive rates or set minimum rates. The original idea is described, but not implemented, in Fischer Black's last (posthumously) published paper. The corresponding yield curve model has been implemented a number of times before, often with Japanese interest rates in mind. But all previous examples have used two factors; the authors here develop a three-factor version in which forward rates are a non-linear function of the state space related to the option value of the short rate. The model is simulated and shown to match the required stylised facts of any yield curve model.

As stressed by Philip Turner (Chapter 2), the yield curve can be a useful tool to extract inflation and growth expectations, at least in normal times. But the current financial crisis has highlighted that many of the necessary conditions for extracting these expectations accurately may not always be met over time. The purpose of the analysis reported in the next two chapters is therefore to quantify empirically the main driving forces behind the evolution of the yield curve before and during the

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financial crisis in both the United States and some European countries, focusing on the implementation of the monetary policy at the short end of the yield curve (or the agents' expectations about what might drive the monetary policy decisions).

In Chapter 11, Morten Bech (Bank for International Settlements), Elizabeth Klee and Viktors Stebunovs (Federal Reserve Board) examine the relationship between various segments of the US overnight money market before and during the financial crisis. More specifically, they analyse the transmission of the US monetary policy stance from the overnight federal funds market to overnight US Treasury general collateral repurchase agreements. These segments of the money market play a key role in the first stage of the monetary policy transmission chain. From the viewpoint of central banks, transmission of monetary policy decisions between the unsecured and secured segments of the money market allows monetary policy to influence the long end of the yield curve, possibly aligning expectations with the desired policy stance. Bech, Klee and Stebunovs discuss the implications of relying on larger-than-normal repo operations to inject liquidity into the federal funds market and analyse the effectiveness of monetary policy transmission with three main tools: (i) a mean-reversion process – namely the speed of adjustment to the long-term relationship between the overnight federal funds rate and the repo rate; (ii) the width of spread between both interest rates; and (iii) the sensitivity of both interest rates to liquidity provided by the US Federal Reserve. They find that the pass-through from the federal funds rate to the repo rate fractured from the onset of the financial crisis in August 2007. Although both rates stayed together during the first stage of the crisis, the speed of adjustment to their long-run relationships slowed considerably with respect to the period before the crisis. The authors argue that growing credit risk concerns, capital limitations of banks and changes in the demand for reserve balances may explain why some arbitrage opportunities were left unexploited during the crisis period. In the later stage of the crisis, the two rates actually appear to have decoupled. The authors conclude that non-conventional measures are justified because the effectiveness of traditional monetary policy has weakened during the crisis.

In Chapter 12, Andrea Buraschi (University of Chicago), Andrea Carnelli and Paul Whelan (Imperial College, London) analyse the perceptions of economic agents of US monetary policy from 1986 to 2011. Within a Taylor-rule setting, they wonder whether economic agents really believe the US Federal Reserve follows a given policy function. This is an important question as the results may, for instance, help

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us understand the power of announcements by the central banks on financial asset prices. By deriving implied consensus and individual measures of output and inflation – based on forecasts relying on surveys of professional economists from leading financial institutions – this chapter disentangles the three main sources of uncertainty about the future path of the policy rate, namely: the expected path of state variables, the parameter values of the rule and the functional form of the rule itself. First the authors find substantial differences in the value of the estimated coefficients between traditional Taylor rules in the literature and those using survey measures. Second, there exists time-dependent variation in the policy parameters implied by agents' expectations based on survey forecasts. Third, from estimating the degree of dispersion around the parameters of the Taylor rule, agents' perceptions also appears heterogeneous. They show in particular that the cross-sectional dispersion in the perceived parameters of the policy model is highly correlated with the average individual uncertainty about the parameters. Two possible interpretations are of relevance from a policy viewpoint. On the one hand, their evidence suggests that agents' expectations of the monetary policy stance of the US Federal Reserve have evolved over time on account of increased non-linearities and state dependence, e.g. expecting more aggressive tightening decisions when inflation is high and more accommodative decisions when the output gap is negative. On the other hand, standard results obtained under the rational expectations framework may differ substantially from those obtained with subjective response functions, since individuals may disagree about the expected path of parameters in the rule and the functional form of the rule. Among the possible implications for the conduct of monetary policy, these results may encourage central banks to use market participants' views to help formulate better strategies for the communication of their policies.

The next three chapters focus more specifically on term structure models and their role in the context of central banks' operating procedures. In Chapter 14, Hans Dewachter, Leonardo Iania (National Bank of Belgium and KU Leuven) and Marco Lyrio (Insper Institute for Education and Research) revisit the common practice of using yield spreads to forecast inflation, which has been popular in the academic literature as well as with central banks and practitioners. They address two main issues. First, they assess the importance of decomposing yield spreads into an expectations component and a term premium component in order to predict inflation. Secondly, they quantify the impact of financial shocks on the dynamics of each of these components. The yield spread decomposition is achieved through the use of a no-arbitrage macro-finance model that incorporates both macroeconomic