ESSAYS ON THE TERM STRUCTURE OF INTEREST RATES

DISSERTATION

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* * * * *

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2003
This dissertation contributes to the study of the term structure of interest rates by addressing some of the gaps in this literature. Term structure is an important channel of monetary transmission. At the same time, it contains information about the intertemporal choice made by economic agents.

Expectations Hypothesis is the primary explanation in economics that links short term interest rates to long term interest rates. In the first essay I extend the literature by examining the expectations hypothesis in the newly developed financial markets. I find that the expectations theory is not rejected in these markets. This evidence is in sharp contrast to the evidence earlier presented for industrialized countries. Further, contrary to the simple expectations theory, term premium has high persistence, which is reflected in significantly autoregressive error terms. The evidence also supports the longstanding suggestion that the term premium could be related to the liquidity in the economy.

The next essay investigates the forecasting ability of the term spread for future output growth. There appears to be a sharp decline in the predictive power of the term spread in countries that have adopted monetary policy with a stronger response to inflation.

To explore the underlying economic reasons for these findings, I explicitly model the information content of the term spread for future output growth based on a structural model. Model calibrations suggest that the forecasting ability of the term spread changes with a change in the persistence and the variance of the underlying economic shocks and in the monetary policy preferences.
The last essay focuses on the term structure as a link between short term and long term interest rates in macroeconomic models. I integrate New Keynesian model and the model of term structure based on the Intertemporal Consumption Asset Pricing Model (I-CAPM). This is a more plausible description of the economy compared to the earlier models. In this model, the output responds to the interest rate that includes a time varying term premium which, in turn is associated with economic agents’ expectations about the future economic variables. Empirical results provide confidence for future research in this direction.
To my parents
I am deeply grateful to Prof. Paul Evans for his invaluable advice and constant encouragement. I would like to thank him for patiently reviewing and correcting my manuscript. It was a privilege to have him as my advisor.

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CHAPTER 1

INTRODUCTION

This dissertation contributes to the study of the term structure of interest rates by addressing some of the gaps in this literature. Despite the extensive research in economics and finance, many questions are yet unresolved.

Term structure is of interest to financial economists because it contains useful information about the intertemporal choice made by economic agents and sheds light on the efficiency of financial markets in utilizing information to form expectations. At the macroeconomic level, the term structure represents one channel of monetary transmission. The monetary authorities directly influence short-term interest rates, while long-term rates evolve on the basis of investors’ expectations of future path of the economic variables including short term interest rates and economic uncertainty. Investment and production are themselves affected by expectations of future real interest rates. Thus, the term structure transmits monetary policy effects to the real sector of the economy. In the global open economy, the term structure also affects international capital flows and hence exchange rate.

Expectations Hypothesis is the primary explanation in economics that links short term interest rates to long term interest rates. Even though it is one of the underlying assumptions in many macroeconomic models, the literature has often failed to obtain empirical evidence of the expectations hypothesis in the industrialized countries.

In the first essay, I extend the literature by examining the expectations hypothesis in the newly developed financial markets. These so far unnoticed economies have recently achieved an
important place in the global economy. Their economic characteristics and policies differ from the
industrialized world.

In the similar vein, I find that the spread between long-term and short-term rates does
have some significant power in predicting the changes in expected future short-term rates. In fact,
two-thirds of all the cases considered, the expectations theory is not rejected. This evidence is in
sharp contrast to the evidence earlier presented for industrialized countries. Further, contrary to
the simple expectations theory, term premium has high persistence, which is reflected in
significantly autoregressive error terms.

The evidence in this essay also supports the longstanding suggestion that the term
premium could be related to the liquidity in the economy. Yet again, this relationship could be
altered by the monetary policy actions.

Another area that is influenced by policy actions is the information content of the term
spread. Since the early 1980’s, there has been a keen interest in the leading indicator properties
of the term spread. Many earlier studies found strong empirical evidence of the predictive power
of the term spread. Though some recent studies cautioned against forecasting with term
spreads, theoretical justifications have been absent.

These issues are addressed in the second essay. The empirical evidence based on a
wider set of countries compared to the previous literature, indeed suggests that the relationship
between term spread and future output growth varies across countries and across time periods.
Further, there appears to be a sharp decline in the predictive power of the term spread in
countries that have adopted monetary policy with a stronger response to inflation.

To explore the underlying economic reasons for these findings, I explicitly model the
information content of the term spread for future output growth based on a structural model with
strong micro foundations. This model within the New Keynesian framework is enhanced by the
expectations hypothesis augmented with a time-varying term premium. Model calibrations
suggest that the forecasting ability of the term spread changes with a change in the persistence and the variance of the underlying economic shocks and in the monetary policy preferences.

The last essay focuses on the term structure as a link between short term and long term interest rates in macroeconomic models. New Keynesian models have been on the forefront in recent literature. Their Keynesian assumption of sticky price along with the behavioral equations based on the micro-foundations and rational expectations are very appealing. However, many of these models have abstracted from the term structure relationship. These models are often used in monetary policy analysis to give recommendations regarding optimal monetary policy. Hence it is important that such models portray a better understanding of the economy.

I integrate the New Keynesian model with a model of the term structure based on the Intertemporal Capital Asset Pricing Model (I-CAPM). This is a more plausible description of the economy compared to earlier models. In this model, output responds to an interest rate that includes a time varying term premium, which in turn is associated with economic agents’ expectations about the future economic variables. Thus, aggregate demand reacts not only to monetary policy actions but also to the expectations of the future state of the economy.

I find evidence that the output response to long term interest is larger than its response to short term rates. Further, the output is sensitive to the unobservable term premium contained in the long term interest rate as well as the expected sum of short rates. Drawing support from this evidence, I propose a structural model within the New Keynesian framework. The distinguishing feature of the model is the expectations hypothesis augmented with a time varying term premium which is a function of the conditional volatility of output and inflation. Empirical results provide confidence for future research in this direction.

The last chapter briefly concludes the salient points in this study. The discussion is wrapped up with some potential directions for future research.

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1 These models are also called as Dynamic Stochastic General Equilibrium (DSGE) models, optimizing IS-LM models and neoclassical synthesis models.
CHAPTER 2

THE EXPECTATIONS HYPOTHESIS OF THE TERM STRUCTURE
AND THE LIQUIDITY PREMIUM

2.1 Introduction

The term structure of interest rates has been a much-researched area in economics and finance. It is of interest to financial economists because it provides useful information about the intertemporal choice made by economic agents and sheds light on the efficiency of financial markets in utilizing information to form expectations. At the macroeconomic level, the term structure represents one channel of monetary transmission. The monetary authorities directly influence short-term interest rates, while long-term rates evolve on the basis of investors’ expectations of future real interest rates and inflation rate. Domestic investment and production are also affected by expectations of future real interest rates. Thus, the term structure transmits monetary policy effects to the real sector of the economy. In the global open economy, the term structure also affects international capital flows and hence exchange rate.

The expectations hypothesis of the term structure is one of the most intensively examined models in economics. The pure expectations theory posits that expectations of the future course of interest rates are the sole determinant of the term structure. Many researchers have empirically tested the information content in the yield curve to predict changes in interest rates. However, the joint hypothesis of rational expectations and pure expectations theory of term structure has been rejected in most studies. Yet, some studies, including Shiller, Campbell and Schenholtz (1983), Fama (1984), Mishkin (1988), Hardouvelis (1988, 1994) and Campbell and
Shiller (1991) provide empirical evidence that the term structure has predictive power regarding future short-term interest rates though less than required by the theory.

Surprisingly, the United States, the country with the most sophisticated and liquid financial markets, provides the weakest and most inconsistent evidence for the expectations theory. Mankiw and Miron (1986) and many researchers following their lead propose that the lack of evidence for the United States could arise because monetary policy smoothens interest rates. McCallum (1994) and Rudebusch (1995) explicitly model the interest rate targeting behavior of the Fed and show that this policy can result in the empirical failure of the expectations theory.

Kugler (1988), Hardouvelis (1994) Gerlach and Smets (1998) have also shown that expectations hypothesis of term structure works best for the cases when short-term rates are predictable, such as within the European Exchange Rate Mechanism, in which central banks respond systematically to exchange rate changes.

One common feature of all of these studies is that they examine the validity of the expectations hypothesis in the industrialized and OECD countries. An extensive study of the term structure model in the developing countries, particularly newly developed financial markets is noticeably absent.

The importance of this kind of study is twofold. This study is important to the policy-makers in the developing country itself. On the other hand, because of the huge financial investments, the investors and also the policy-makers in the industrialized world need to know the workings of the financial markets and monetary policy in these developing countries.

The monetary authorities in the emerging markets, particularly with financial flows across borders and limited exchange rate flexibility, are known to respond systematically to the changes in factors such as the exchange rate, foreign exchange reserves and the world interest rate. Thus, on the basis of Mankiw-Miron hypothesis, if the short-term interest rate is predictable, then the term structure should be able to predict future changes in interest rates.
Another alternative explanation put forward in the literature for the empirical failure of the expectations theory is the presence of time varying term premium. Indeed, some researchers including Engel, Lilien and Robins (1987), Lee and Tse (1991), Oh (1994), Tzavalis and Wickens (1998) present evidence of time varying term premia.

Various economic theories such as the liquidity premium theory, the preferred habitat hypothesis and the market segmentation hypothesis imply that the investors’ risk preferences, investment horizons and expectations are driving force behind the term premium. Hence, changes in monetary policy and other macroeconomic variables that influence agents’ expectations also affect the term premium.

However, the question whether the changes in monetary policy and other macroeconomic variables can explain the time varying term premium is yet unanswered.

This study is an attempt to fill the gap in the literature. I examine the evidence of the expectations hypothesis in the newly developed financial markets, during the last decade. Looking at the interest rates on financial assets such as Treasury Bills and inter-bank loans of maturities of three, six and twelve months. I find that the spread between long-term and short-term rates does have some significant power in predicting the changes in expected future short-term rates. In fact, two-thirds of all the cases considered, the expectations theory is not rejected. This evidence is in sharp contrast to the evidence earlier presented for industrialized countries. Further, contrary to the simple expectations theory, term premium has high persistence, which is reflected in significantly autoregressive error terms.

The time-varying nature of the term premium is once again supported by the second test examined in this paper. In fact, the growth rate of foreign asset holdings of the central bank is able to explain the liquidity premium in the Philippines, Portugal, Spain, Finland, the United States, Germany, France and Japan. The growth of the foreign assets of the central bank increases the liquidity in the financial markets and hence leads to a fall in the liquidity premium.
However, in the Czech Republic, Indonesia and Malaysia, contrary evidence is observed. It is argued that this puzzle may perhaps be resolved if monetary policy actions, particularly sterilization policy, are taken into account.

The paper is organized as follows; next section presents the theoretical framework. Section 2.3 briefly reviews related literature. Data, methodology and the empirical results are discussed in section 2.4. Section 2.5 presents the theoretical background on the liquidity premium. Section 2.6 discusses the results and their interpretation. The conclusions are presented in section 2.7.

### 2.2 Theoretical framework

The relationship between the yields to maturity on securities differing only in maturity date is known as the term structure of interest rates. The pure expectations theory posits that expectations of the future course of interest rates are the sole determinant of the term structure. The theory states that current long-term interest rate is just a simple average of the current and expected future short-term interest rates over the term to the maturity of the long-term security. For a discount bond,

\[
R^n_t = \frac{1}{k} \left[ r^m_t + E_t r^m_{t+1} + E_t r^m_{t+2} + \ldots + E_t r^m_{t+(k-1)m} \right]
\]

Where \( R^n_t \) = current long-term rate on discount bond of term \( n \) periods.

\( r^m_t \) = current short-term rate on discount bond of term \( m \) periods, with \( m < n \).

\( k = \frac{n}{m} \), assumed to be a positive integer.

\( E_t \) = expectations operator conditional on the information set available at time \( t \)
For a coupon bond, the long-term interest rate is approximately a weighted average of the current and expected future short-term interest rates, where the weights decline geometrically over the term to the maturity of the long-term bond.

However, J. R. Hicks argued early on that the pure expectations theory needed to be modified. The longer the maturity of the security, the greater is the risk of fluctuations in the value of the principal to the investor. The security market is supposed to be dominated by risk-aversers, who prefer to lend short unless offered a premium sufficient to offset the risk of lending long. Hence, he suggested that the pure expectations theory be modified slightly by adding a constant term premium, which is larger, the greater the term to maturity is. Equation [2] is thus modified as follows;

\[ R_t^n = \frac{1}{k} \left[ E_t^{m} + E_{t+1}^{m} + E_{t+2}^{m} + \ldots + E_{t+(k-1)m}^{m} \right] + tp^n \]

Where \( tp^n \) = constant term premium of bond with a term of \( n \) periods over a bond of term \( m \) periods.

Hick’s theory as expressed in equation [2] is known as the liquidity premium theory.\(^2\) It is assumed that \( tp^n \) to be positive and increasing in \( n \) and decreasing in \( m \).\(^3\)

This positive sign of the term premium is based on the assumption that the financial market is indeed dominated by risk averse short-term investors. However, more refined theory does require a positive premium increasing in \( n \) and decreasing in \( m \) unless economic agents’ risk preferences and investment horizons are specified. According to the preferred habitat

\(^2\) Keynes (1936), who introduced the term to economics, used liquidity preference to describe a reference of the market, abstracting from differences in yields, for assets that are immune to capital losses produced by interest rate changes.

\(^3\) Kessel (1965) finds that the fraction of the liquidity premium (which he calls nonpecuniary return) to the total return from securities is inversely related to term to maturity.
hypothesis of Modigliani and Sutch (1966), the term premium could be negative and the return on long-term security lower than short-term security, if there are more risk averse investors with long investment horizon.

Cox-Ingersoll-Ross (1985) model is another celebrated model of term structure of interest rates. This CAPM based general equilibrium model suggests that under most circumstances there will be a positive term premium embodied in the term structure, which will increase with maturity. On the other hand, McCulloch (1993) demonstrate that in an economy with risk-averse investors, the term premium could either increase or decrease with maturity, depending on whether the volatility of the innovations to expectations about future output increases or decreases with horizon.

After a little algebraic manipulation we get equation [3], which implies that the current yield curve contains information about the expected future changes in short-rate along with the constant term premium.

\[
R^n_t - r^n_m = E_t \left[ \sum_{i=1}^{k-1} \frac{k-i}{i} D_{i+im} \right] + tp^n
\]

Where \( D_t = r^m_t - r^m_{t-m} \)

Under the rational expectations hypothesis, market's expectations of the future economic variables do not deviate systematically from what will actually happen, i.e. these deviations are optimally predicted to zero. And hence the realized rate can be represented as a sum of expectations and a forecast error \( \epsilon_{t+im} \)

\[
D_{t+im} = E_t D_{t+im} + \epsilon_{t+im}
\]

This forecast error is orthogonal to the information set available at time t: \( E_t \epsilon_{t+im} = 0 \)

Thus the spread between current long-term and short-term interest rates reflects the path of future short-term interest rates. This hypothesis can be tested by regression analysis.
\[ \sum_{i=1}^{k-1} \frac{k-i}{k} D_{t+im} = \alpha + \beta (R^n_t - r^m_t) + \mu_{t+n} \]

Where \( \mu_{t+n} = \sum_{i=1}^{k-1} \frac{k-i}{k} \varepsilon_{t+im} \), \( \alpha = -\theta \) and \( \beta = 1 \)

An estimate of \( \beta \) insignificantly different from one would support the pure expectations hypothesis. A significantly positive estimate of any magnitude would provide evidence that the term structure has predictive power for future changes in interest rates. Moreover, the estimated residuals of equation [5] should be uncorrelated with all information available at time \( t \). In particular, they should not be serially correlated, except for the moving average correlation arising from the overlapping data. The theory specifies the order of the moving average terms.

2.3 Related literature

Expectations Hypothesis of Term Structure of Interest Rates is yet another economic theory that has failed to be consistent with empirical evidence. This theory has been expressed and examined in various forms. The expectations theory posits that the slope of the term spread reflects expected changes in short-term as well as long-term rates. The pure expectations hypothesis states that whenever a long bond yield exceeds short yield, the yield on long bond subsequently tends to rise over the life of the short bond and at the same time short yields tend to rise even more over the life of the long bond, closing the gap between the two. A similar proposition holds for the modified expectations hypothesis.

Following these two implications of the expectations theory, many researchers have empirically tested the information content in the yield curve to predict expected changes in long-term rates and short-term rates. The joint hypothesis of rational expectations and pure
expectations theory of term structure i.e. the hypothesis of $\beta = 1$ in the estimation of equation [5] or its counterparts in other versions of the theory has been rejected in most studies.

And yet later, many researchers, including Shiller, Campbell and Schenholtz (1983), Fama (1984), Mishkin (1988), Hardouvelis (1988,1994), Campbell and Shiller (1991), and Longstaff (2000) have found that the yield curve does contain some information regarding future short term interest rate changes over particular horizons, even though not as strongly as the expectations theory requires.

Shiller, Campbell and Schenholtz (1983) showed that yield curve between 3 and 6 months Treasury Bills rates in the U.S helps to forecast the change in the 3-month Treasury bill rate. However, for very large n and very small m, the hypothesis was rejected.

Using a new approach, Fama (1984) found some evidence that the slope of term structure predicts interest rate changes over a few months when the actual change over one month in the one-month rate is regressed on the predicted change. But the predictive power seemed to decay rapidly with the horizon. On the other hand, working with forward premia, Fama and Bliss (1987) found that the forecasting power of the term structure improves as the horizon of long term rate increases.

Campbell and Shiller (1991) show that when the yield spread is high, longer-term rates behave contrary to the expectations theory whereas shorter-term rates behave in accordance to the theory. In fact, at the long end of the term structure, the expectations theory is not rejected for forecasting changes in the short rates. To resolve the contradiction between the evidence for the two implications of the theory, they propose a possibility of time-varying risk premia which are correlated with expected increases in short-term rates or alternatively overreaction model of the yield curve. The latter model says that the long rate differs from the short rate in the direction implied by the theory, but the spread is larger than can be justified by the rational expectations of future short rate changes.
A similar result that the spread predicts a wrong direction in the subsequent change in the long rate is also observed by many other studies including Shiller, Campbell and Schenholtz (1983), Mankiw and Summers (1984), Mankiw (1986). Hardouvelis (1994) is able to resolve this puzzle for Canada, Germany, Japan and U.K. by adding a white noise error to the long rates and hence using instrumental variables technique. However, the puzzle is unresolved in the case of United States, the country with the most sophisticated and liquid financial markets. The only hypothesis that could explain this evidence is the overreaction hypothesis of Froot (1989) and Campbell and Shiller (1991).

Based on VAR methodology, Tzavalis and Wickens (1998) find evidence that the short-run tests of the expectations hypothesis are rejected in the U.S. because of the existence of stationary time varying term premia.

Mankiw and Miron (1986) initiated a stream of new ideas in the literature. Examining the US data over a long period of time- 1890 to 1979 and various monetary regimes, they find the expectations theory works much better for the data prior to the founding for the Federal Reserve but fails for more recent data. In the regressions of the change in 3-months rate on the term spread between 3 and 6-month rate, the only slope coefficient significantly different from zero and positive though less than unity is during 1890-1914. They argue that the failure of the theory for the post-Fed period stems from interest rate smoothing, which made short-term interest rates approximately random walks. Hardouvelis’s (1988) study supports the Mankiw-Miron hypothesis during the recent monetary regime in the United States. When the Fed allowed interest rates to fluctuate relatively freely during the period of non-borrowed reserve targeting, the predictive power of forward rates increased substantially. However, the predictive power did not decrease after October 1982, as the Fed used the Federal Funds rate merely as its policy instrument in targeting the inflation rate and economic activity.

Most of the empirical failures to the expectations model have been for the U.S data. Kugler (1988), Hardouvelis (1994) Gerlach and Smets (1998) show that the expectations
hypothesis works better in European countries than in US. Gerlach and Smets (1998) suggest that the hypothesis works best for the cases where monetary policy is restricted by an intermediate exchange rate target as in the European Exchange Rate Mechanism. The systematic policy response makes short rates more predictable and leads to a good performance of the expectation theory.

Further support for the Mankiw-Miron hypothesis comes from Simon (1990) who shows that the spread between three-month Treasury bill and federal funds rate has significant predictive power for the future changes in the federal funds rate, during the period when the Fed does not smooth the impact of shocks on the funds rate. He proposes that the increased reliance of monetary policy on rules rather than discretion allowed market participants to predict future changes in funds rate more accurately.

McCallum (1994) is able to rationalize the empirical failure of the expectations hypothesis by a theoretical model. His model explicitly includes an exogenous random term premium and monetary policy reaction function responding to the prevailing term spread and involving interest rate smoothing.

Similarly, generalizing Mankiw-Miron hypothesis, Rudebusch (1995) explicitly models the relationship between the term structure and the behavior of the Federal Reserve. His theoretical model can account for the empirical findings in different studies of the varying ability of the term spread to forecast future interest rates at different horizons. The model characterizes the Fed’s interest rate behavior as daily deviations from the target, gradual adjustment of the target and persistent targets. Thus, interest rate smoothing by the Fed is implied only in the medium term such as three to six months.

Another side of Mankiw-Miron hypothesis is examined by Favero and Mosca (2001). They jointly estimate a forward looking interest rate rule for the three-month rate and a forward-looking term structure relationship linking the six-month interest rate to current and future three-month interest rate. They find that the recent emphasis on Taylor type interest rate rules,
reduction in the uncertainty and increase in the transparency of policymaking in the U.S. did improve the predictions of expectations model.

This increased transparency of policy formulation could be contributing to the improved predictability of policy changes and hence the term spread, according to Lange, Sack and Whitsell (2001). They show that the serial correlation in first difference of the federal funds rate has increased since late eighties.

Longstaff (2000) finds new and surprising evidence to the expectations hypothesis at the extreme short end of the term structure using short-term repo rates. Using a different specification for the single equation estimation and VAR-GARCH approach, his results show that longer-term rates are nearly unbiased forecasts of average overnight rate during the term of the longer rate with zero term premium. Longstaff argues that the large time varying premia found in the studies of Treasury bills market could be arising from other factors such as liquidity. And hence repo rates could be better measures of short-term riskless term structure than Treasury bills rates.

The variations in the findings in the literature partly reflect the differences in their specifications, empirical approaches and data. Yet on the whole, there seems to be a general conclusion that the very short end of the yield curve displays some ability to predict changes in short-term rates, though this predictive power fades as the horizon lengthens. However, disagreements remain regarding the extent to which the term spread has information content and the horizon over which that predictive power exists.

One of the most noticeable similarities in all these studies is that they test the validity of the expectations hypothesis in various forms in the industrialized countries. Many researchers examine the post-war U.S. interest rate data while a few researchers like Kugler (1988), Hardouvelis (1994) and Gerlach and Smets (1998) look at European data, again mainly for the countries with well-developed financial markets.

Dahlquist and Jonsson (1995) study the empirical relationship between implicit forward rates and corresponding interest rates in the short-end of Swedish term structure. In contrast to
the other studies, they find that the joint hypothesis of rational expectations and no term premium cannot be rejected. The interest rates on 1, 2, 3, 6 and 12 months Treasury Bills during January 1984 to July 1992 is used for regressions based on the cointegrating relationship between the interest rates. For all the different regressions and various maturities, the slope coefficients are significant and in fact close to one. However, they also find parameter instability in some sub-periods of the sample.

The Spanish term structure is examined by Serna and Arribas (2000). Using weekly data from the Spanish public debt market for maturities ranging from one month to ten years for the period 1993-1998, they test the expectations theory for short as well as long rates. Again, unlike for developed countries, the hypothesis $\beta = 1$ is not rejected in any of the case for short rates and in most cases for long rates.

This rare empirical support to the expectations hypothesis in the newly developing financial markets strengthens the idea that some distinctive characteristics of such markets would lead to different empirical evidence of the term structure of interest rates. These characteristics could be the predictability of the short rates resulting from systematic monetary policy actions.

In short, there is a large potential for an extensive study of the expectations theory particularly in the newly developed financial markets.

2.4 Estimation

2.4.1 Methodology

The pure expectations theory states that the spread between current long-term and short-term interest rate is linear combination of the future changes in short term interest rates. Since this simple theory is based on the assumption of rational expectations, the forecast error is orthogonal to the information set available at time t. As the regression error term is uncorrelated with the regressors, Ordinary Least Squares would provide consistent estimates.
Apart from a few exceptions such as Kown (1992), Hardouvelis (1994), Oh (1994) and Driffill (1997), most of the studies of term structure are based on OLS estimation. And mostly all of these studies reject the simple expectations hypothesis.

Various explanations are offered for the empirical failure of the simple theory. One possibility is that the joint hypothesis of rational expectations with market efficiency is not a valid hypothesis. A time-varying term-premium is an alternative. The term premium could contain a stochastic element $\zeta_t$ that varies over time:

$$R^n_t = \frac{1}{k}\left[r^m_t + E_t r^m_{t+m} + E_t r^m_{t+2m} + \ldots \ldots E_t r^m_{t+(k-1)m}\right] + \left(\tau^n_t + \zeta_t\right)$$

This would change equation [5] into

$$\sum_{i=1}^{k-1} \frac{k-i}{k} D^n_{t+i} = \alpha + \beta \left(R^n_t - r^m_t\right) + \mu^n_t - \zeta_t$$

Thus, the regression error in the term structure estimation could contain a stochastic element, apart from the orthogonal forecast error. This stochastic element could be due to a deviation from rational expectations or to a time-varying term premium. Hardouvelis (1994) interprets it as possibly a measurement error.

The presence of measurement error in the interest rates and yields, particularly in the emerging markets is a strong possibility. Further, these financial markets are not well developed and deep. A thin market or strong influence of monetary or fiscal authorities could affect the interest rates and the information content in them.

With the inclusion of an error term, which may not be orthogonal to the regressors, OLS may no longer provide consistent estimates of the term structure relationship. A consistent estimation can be achieved with the method of two stage least squares.

The test of expectations hypothesis is carried out by estimating regression equation (5) by two-stage least square method. It is a special case of instrumental variables method. The
instruments used here are the current and two lags of changes in all short-term interest rates and
two lags of the other spreads between long and short-term rates. A point to note is that the lags of
the term spread used in the regression equation are not used as instruments since because of
the possibility of time-varying term premium, the regression error would be correlated with this
spread.

However, there is a caveat to this method. All the term spreads are highly correlated.
Even though the lags of the term spread used in the regression equation are not used as
instruments, the lags of the other spreads could be correlated with the term premium and hence
the regression error. Thus, there is an eventual problem of finding appropriate instruments. A
possible solution to this problem is addressed further in the later discussion.

Driffill, Psaradakis and Sola (1998) note another point of caution. Based on the Monte
Carlo evidence, they conclude that tests based on instrumental variables (IV) estimates of the
slope parameter in a regression of the change in the short rate on the lagged yield spread have
been found to be severely biased towards rejecting the expectations hypothesis when there is a
random component in the term premium. In contrast, tests based on IV of the slope parameter in
a regression of the yield spread on future changes in the short rate reject at approximately
theoretically correct frequency.

The expectations hypothesis states that regression errors are orthogonal to the
regressors. However, in these regressions, without the ARMA terms, there was large serial
correlation in the residuals and hence estimates could not be consistent. Some of this serial
correlation comes from the overlapping data in the estimation. The nature of this would be
particularly moving average of the order k-1. Yet the autoregressive nature of serial correlation in
the residuals would not be consistent with the expectations theory, especially with constant term
premium. This could be another evidence of time-varying term-premium or the existence of
explanatory factors other than the term spread.
To remove the serial correlation in the residuals ARMA terms are added in all the regressions. In most of the cases, particularly in the newly developed financial markets, low orders of p and q terms suffice. For developed countries, higher-order ARMA terms are required to remove serial correlation from the residuals. The ARMA terms are added to produce acceptable LM statistics from Breusch-Godfrey test for serial correlation at up to 12 lags. Only the significant terms are retained in the final regression.

Adding ARMA terms transforms equation [5] into

\[ \sum_{i=1}^{k} \frac{k-i}{k} D_{t+i} = \alpha + \beta (R_t^n - r_t^m) + \mu_{t+n} \]

where

\[ \mu_{t+n} = \rho_1 \mu_{t+n-1} + \rho_2 \mu_{t+n-2} + \ldots + \rho_p \mu_{t+n-p} + \phi_1 \varepsilon_{t+n-1} + \phi_2 \varepsilon_{t+n-2} + \ldots + \phi_q \varepsilon_{t+n-q} \]

A point to note is that nearly all the other studies correct the variance-covariance matrix and hence standard errors for the implicit MA serial correlation originating from the overlapping data, rather than fitting ARMA terms. However, in this method, the effect of the serial correlation in the residuals due to time varying term premium may be overlooked.1

The ARMA model is estimated by using nonlinear regression techniques. The nonlinear least square estimates are asymptotically equivalent to maximum likelihood estimates and are asymptotically efficient.

2.4.2 Data

The lack of availability of relevant data is one of the important problems in the case of emerging market studies. Long-term rates are either not available or do poorly reflect changes in market conditions as long-term bond markets are not yet fully developed. Hence we are restricted only to the use of short-term interest rates.
The frequency of data is monthly observations. The sample period varies from country to country depending on the data availability and changes in monetary and economic regimes. Special care is taken to avoid the periods of financial crises or regime switches. During these periods, usually a structural break in the relationship of economic and financial variables is expected. For example, for the Southeast Asian countries the sample is restricted till June 1997 whereas for the European countries from January 1994 till December 1998.

A wide range of countries is selected to represent various degrees of development of financial markets. The sample of countries selected, particularly for the newly developed financial markets, is primarily based on the availability of the data. Some developed countries are also examined to compare the results of the countries with the newly developed financial markets.

Interest rates for various maturities are obtained from Datastream. The financial assets related to these rates are not the same for all the countries. Only for the Philippines, Sweden and the United States are the rates the yields on 91-day, 182-day and 364-day Treasury Bills i.e. pure discount bonds. Treasury Bills rates are not available for other countries and hence other types of interest rates need to be considered. For Indonesia and Malaysia the short-term rates used are 12, 6, and 3-month maturity deposit rates. The interest rates on deposits would also be related to money market rates. The interest rates for all other countries are 12, 6 and 3 months inter-bank rates.

The data on macroeconomic variables such as central bank foreign assets and foreign liabilities and Consumer Price Index, are obtained from the IMF CD-ROM September (2000). From this information, DLRNFA is constructed to measure the growth rate of real net foreign assets of the central bank as the first difference of the log of real net foreign assets.

A more detailed description of the data used for this analysis is presented in the appendix.
Before turning to the term structure tests, we need to examine the univariate time-series properties. The ADF test is used to test for unit-root stationarity. For this test, the choice of the lag length is crucial. Enough lags should be included to remove any serial correlation in the residuals.

For nearly all the interest rates and log of real net foreign assets, the null hypothesis of nonstationarity cannot be rejected in levels (not reported here). However, the first difference of interest rates, the various spreads between long-term and short-term rates and the growth of log of real net foreign assets are found to be stationary. The results of ADF test are presented in Table 2.1 This evidence is in the line with theoretical hypothesis that the interest rates and the log of real net foreign assets are I(1) series. Least square estimates are consistent only with the stationary series.

However, a point of caution is that ADF test has poor small sample properties.

2.4.3 Empirical results

In this analysis, seventeen countries are considered, with three spreads for each market. For the ease of discussion and interpretation, the countries are arbitrarily divided into two tables as the newly developed and developed financial markets. This is a very broad classification. It can be correctly argued that financial markets like Singapore and Hongkong are much developed than the other Asian markets where as Spain, Portugal, Norway and Finland are the markets in the European Union, though less developed than their counterparts. A glance at the Table 2.2 and Table 2.3 is sufficient to notice that the hypothesis of $\beta = 1$ is more often rejected in the latter.

Out of the 33 $\beta$ coefficients in the first table, nearly two-thirds do not differ significantly from one by the Wald test. In fact, for Czech Republic, Malaysia, Hongkong and Spain, for all the three spreads i.e. 12-6, 12-3 and 6-3 months $\beta = 1$ is not rejected. In Singapore, Norway and
Mexico, the hypothesis is rejected for only one spread. For Indonesia, the Philippines and Portugal $\beta = 1$ is not rejected for only the spread between 12 and 3 months rates. This evidence indicates that the expectations hypothesis is broadly consistent with the data.

On the other hand, the empirical results for Finland reject the theory for all the spreads. For the other cases where the hypothesis of $\beta = 1$ is rejected, there is no particular pattern observed. Indonesia, the Philippines and Portugal it is the 12-6 month spread as well as 6-3 month spread while for Singapore 12-3 months. Norway 12-6 month spread and Mexico 6-3 month spread also do not support the hypothesis.

Looking at Table 2.3, the hypothesis of $\beta = 1$ is rejected for all but the 12-6 month spread in France.

Even when $\beta = 1$ is rejected by the Chi square test, the estimate for $\beta$ typically differs from zero and is positive in most cases, particularly in Table 2.2. The current term spread therefore has predictive power for future expected changes in the short rate.

Among all the significant $\beta$ coefficients, the highest is 2.32 for Philippines 6-3 spread and lowest is 0.21 for the same spread in Finland. Many of the estimates of $\beta$ are close to 1.

The expectations hypothesis implies that $\alpha = -\theta$ in equation [8]. A negative sign of the constant in this regression would mean that there is a positive term premium as stated by the Hicksian liquidity premium theory.

The estimates of $\alpha$ and their standard errors are not presented in here in order to make the tables easier to read. These estimates in fact, do not reject the liquidity premium hypothesis. For the Philippines, Portugal, Spain, France and Japan the intercept is significantly different from zero and negative for all the spreads. Similar evidence is found for only the spread between 6 and 3 months in Singapore, Hongkong, Finland, Sweden and United States whereas in Indonesia the regression of 12-3 months spread results in a significant and negative intercept. In Malaysia,
both 6-3 months and 12-3 months spreads give the similar results. Only in Czech Republic, Norway, Mexico, Germany and U.K. the intercept does not differ from zero statistically.

The Standard Error of regression varies a lot from country to country. It is comparatively higher for Czech Republic, Philippines and Mexico while lower for all other countries.

ARMA terms in all the regressions are very significant and quite large. In fact, quite often they are close to one. This indicates high serial correlation in the error terms, though some of this correlation comes from the overlapping data, particularly of the type of moving average. The highly autoregressive residuals may indicate a highly persistent time varying term premium.

A point of caution is that the estimates of $\beta$ are not always robust to different specification of ARMA terms.

Thus, it is observed that, the empirical test for the expectations hypothesis finds more support in the newly developed financial markets than the industrialized countries.

The reason for this difference in the performance of the test may lie in the Mankiw-Miron Hypothesis. The central banks in the newly developed financial markets may not be adopting interest rate smoothing and thus leaving some predictability in the short-term rates.

2.4.4 A comparison with the earlier studies

The predictive power of the yield curve for changes in future short rates in the U.S data is found for the 6-3 months spread. This is in contrast of the evidence presented by Mankiw and Miron(1986) of the post-Fed data.

The evidence supporting the expectations theory observed for Spain is very similar to the study by Serna and Arribas (2000) for nearly the same sample period. This is very heartening as the specification used is similar though the empirical approach is slightly different.
The expectations hypothesis is rejected in Sweden for all the spreads though 12-3 and 6-3 months spreads seem to have predictive power. However, Dahlquist and Jonsson (1995) could not reject the joint hypothesis of rational expectations and no term premium during January 1984 to July 1992. In fact, their evidence could be interpreted as the support of the expectations theory in a newly developing financial market as the Swedish capital market was highly undeveloped and regulated in the early eighties.

Some information content is also found in most of the spreads in U.K, Japan and France. Hardouvelis (1994) presented some evidence of the predictive power of the yield curve for the changes in short rates in U.K., Germany, Japan and France. However, it cannot be compared directly with the evidence in this paper as the long-term rate used was the interest rate on ten-year security and the beginning of the sample period ranged from early 1950s to late 1960s.

2.5 Liquidity premium.

The expectations theory traditionally assumes a constant term or liquidity premium. However, the theory does not postulate the sign of this constant term premium unless economic agents’ risk preferences and investment horizons are specified. The term premium could be negative and the return on long-term security lower than short-term if the bond market were dominated by risk-averse investors with long investment horizons such as insurance companies acting as agents for their policy holders. If an investor is risk averse and has long investment horizon, she requires a higher return to invest in a sequence of short paper since the interest rates in the coming period are uncertain. On the other hand, if the investor is uncertain about her investment horizon, she may regard the investment in long term security as more uncertain than the sequential investment and hence would demand positive term premium.

Various economic theories proposed in the literature have different implications for the term premium. According to the pure expectations hypothesis the term premium is identically zero, which is the result of market equilibrium created by rational, risk-neutral and wealth-
maximizing investors. The Hicksian liquidity preference theory (1946) asserts that the liquidity premium is positive. The basic assumption is that the investors typically are risk averse and have short investment horizon. The preferred habitat hypothesis of Modigliani and Sutch (1966) argues that the term premium may be positive of negative, depending on the investment horizons of investors. If investors are concerned with returns over a long time horizon, they will demand premium to invest in short-term securities. According to the market segmentation hypothesis by Culbertson (1957), the long-term and short-term markets are unrelated and are solely determined by the segmented maturity preferences of borrowers and lenders. So no particular statement can be made about the term premium. On the other hand, the celebrated theory of Cox, Ingersoll and Ross (1985) based on a general equilibrium model suggests that under most circumstances there will be a positive term premium embodied in the term structure.

Kessel (1965) and McCulloch (1975, 1985) find significant positive liquidity premium in U.S. data though without significant the time variation. Thus Hick's theory of constant liquidity premium is not rejected.


The autoregressive residuals found in the previous section can also be viewed as an evidence of time varying term premia.

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4 According to Kessel (1965), the Keynesian and Hicksian views, that the market prefers short to long term securities o avoid risks of capital loses, do not imply that participants in this market need to be characterized as risk avoiders generally. An enterprise that is quite willing to speculate in what it considers as its principal line of economic activity may rationally be unwilling to run risks of capital losses on its holdings of money substitutes.
More clear-cut empirical evidence for whether term premia vary over time could be examined by the properties of the difference between the current term spread and future changes in the short rate. The expectations hypothesis states that the current long-term rate is just an average of expected future short-term rates and a constant term premium. Thus, if we subtract an average of expected future short rates from the current long rate or equivalently, appropriate linear combination of expected future changes in the short rate from the current term spread, the resulting quantity should equal a constant term premium and a forecast error.\(^{5}\) The serial correlation observed in the residuals, particularly of autoregressive nature, would be related to the term premium.

Once we accept the possibility of time varying term premium, the interesting question arises of which economic variables this term premium is related to? As the name suggests, is this liquidity premium related to liquidity variables?

Hicks' liquidity premium theory proposed a liquidity premium since the security market is supposed to be dominated by risk-aversers, who prefer to lend short unless offered a premium sufficient to offset the risk of lending long. Thus it would imply that if the risk of lending long were low, liquidity premium would decrease.

The loanable funds theory states that if the supply of loanable funds i.e. liquidity in the financial markets increases, ceteris paribus, interest rates in the money market would fall. A widely held rationale for investor behavior based on Keynes’s theory suggests that risk in the loan market varies with overall level of interest rates. If the interest rates in general were believed to have reached a high level and were not expected to rise further, risk would seem to be relatively moderate and hence risk avverting investors would require a lower liquidity premium to lend long. In short, liquidity premium would fall with the increase of liquidity in the market. If overall interest

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\(^{5}\) This method generates moving average serial correlation in the error terms due to the overlapping data points. Alternatively, the term premium could be measured by comparing holding period yields across maturities for common, non-overlapping holding periods. This approach eliminates moving average serial correlation in the error terms. Yield-to-Maturity (YTM) term premium can be expressed as a linear combination of Holding Period Yield (HPY) premia. See McCulloch (1975), Kwon (1992) and Oh(1994).
rates were believed to be low and expected to rise, risk averters would demand higher term premiums in the forward rates. The term premium would then be inversely related to liquidity in the financial system.

Next question we face is how to measure liquidity in the financial system? A number of economic variables seem to be possible candidates such as growth of domestic credit, growth of foreign assets of the central bank, growth of money supply, the ratio of banking system’s loans to private sector to its deposits and so on.

At this stage, I choose the growth of foreign assets of the central bank. It seems to have more interesting implications than the others, as it is discussed later in detail. Further, the growth of foreign assets of the central bank has been an important economic variable in the emerging markets, particularly in the early 1990’s. As the interest rates fell down in the industrialized world, there were huge capital flows in search of higher returns to the newly developing financial markets, particularly in South-East Asia and Latin America. The ability of the monetary authorities to manage these capital flows in the developing financial markets with limited flexibility of exchange rates has been an important issue with the policy makers as well as in the academic literature.

The accumulation of foreign assets of the central bank is very closely related to the liquidity in the financial system. A simplified balance sheet of the central bank has foreign and domestic assets on the asset side and reserve money and other liabilities to the financial system as a whole, on the liabilities side.

<table>
<thead>
<tr>
<th>Balance Sheet of the Central Bank</th>
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<tr>
<td><strong>Assets</strong></td>
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<tr>
<td>Foreign assets</td>
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<tr>
<td>Domestic assets</td>
</tr>
</tbody>
</table>
Foreign assets include foreign exchange reserves as well as foreign securities while domestic assets mainly include Treasury bills and Government bonds. As an elementary accounting principle, the equality of assets and liabilities is an identity. Thus, an increase in foreign assets holdings of the central bank, ceteris paribus, would increase monetary liabilities of the central bank. It would mean an increase in the loanable funds and hence the liquidity in the financial markets.

In short, an increase in the foreign assets holdings of the central bank may lead to a decrease in the liquidity premium demanded in the financial markets. We can represent this hypothesis by a regression equation such as:

\[
R_t^n - R_t^m - \left( \sum_{i=1}^{k} \frac{k-i}{k} D_{t+i} \right) = \delta + \gamma_1 DLRNFA_t + \gamma_2 DLRNFA_{t-1} + \gamma_3 DLRNFA_{t-2} + \nu_t
\]

Where DLRNFA= growth of foreign assets of the central bank, and \( \nu_t \) is assumed to be an orthogonal error term.

Negative and statistically significant \( \gamma \) coefficients would support the hypothesis. Further, if any of the \( \gamma \) coefficients differ significantly from zero, it would mean that the growth of foreign assets could explain the difference between the current term spread and the expected future changes in short-term rates. This would describe how the term premium varies over time.

2.6 Empirical results and interpretation.

This hypothesis is tested only for a limited sample of countries such as Czech Republic, Indonesia, Malaysia, Philippines, Portugal, Spain, Finland, Sweden, United States, France, Germany and Japan. Some of the countries from the earlier section had to be dropped, as data on net foreign asset holdings of the central bank were not available.

Once again lot of serial correlation is observed in the residuals. Hence ARMA (p, q) terms are included in the regression to remove serial correlation from the residuals. The ARMA terms
are added such that to reduce the LM statistics from Breusch-Godfrey test for serial correlation up to 12 lags. For most of the cases, maximum order of ARMA terms is 2. Only the significant terms are included in the final regression.

Again, adding ARMA terms transforms equation [9] into

\[
\left( R_i^n - r_i^m \right) - \left( \sum_{i=1}^{k} \frac{k-i}{k} D_{t+i} \right) = \delta + \gamma_1 DLRNA + \gamma_2 DLRNA_{t-1} + \gamma_3 DLRNA_{t-2} + \nu_t
\]

where \( \nu_t = \rho_1 \nu_{t-1} + \rho_2 \nu_{t-2} + \ldots + \rho_p \nu_{t-p} + \eta_t + \phi_1 \eta_{t-1} + \phi_2 \eta_{t-2} + \ldots + \phi_q \eta_{t-q} \)

Looking at the results presented in Table 2.4, it is clear immediately that there is mixed evidence. However, even at a glance it is noticed that for ten out of the twelve countries considered, for at least two term spreads, the growth of real net foreign assets of the central bank significantly explains the liquidity premium. This evidence along with the serial correlation in the residuals indicates that the hypothesis of a constant term premium can be rejected.

When we look at the sign of the coefficients, all the countries except for the Czech Republic, Indonesia and Malaysia, have negative coefficients for at least one lag of DLRNFA indicating that with an increase in foreign asset holdings of the central bank, liquidity premium falls. The strong evidence is found in the Philippines, Portugal, Finland and Germany. The most negative, statistically significant estimate of \( \gamma \) is \(-5.68\) for the first lag of DLRNFA for 12-3 months spread in Germany. The least negative, significant coefficient is \(-0.13\) for 12-6 months spread in Japan.

On the whole, this evidence suggests that the growth of foreign asset holding of the central bank can explain some of the variation in the term premium.

However, for Czech Republic, Indonesia and Malaysia coefficient of the growth of real net foreign assets of the central bank is surprisingly positive and significant for most of the spreads.

In Czech Republic, for 6-3 months spread, the current and first lag of DLRNFA is significant while for both the other spreads all the lags are significant and positive. The
coefficients are quite large. Their range is from 3.87 to 17.26. In Indonesia, for all the spreads, second lag of DLRNFA is significantly different from zero. For 12-6 and 12-3 spreads the \( \gamma \) coefficient is positive but surprisingly for 6-3 spread it is negative. The positive significant coefficients of DLRNFA are 1.27 and 1.45. For the 12-3 months spread in Malaysia, DLRNFA is not significant. The first lag of DLRNFA is significant for the 12-6 months spread and the first and second lags are significant for 6-3 months spread. All the significant coefficients are positive and range from 0.64 to 1.22.

The standard error of regression is comparatively high again for Czech Republic and Philippines while is lower for all other countries considered.

Again ARMA terms are very significant and quite large. Many times they are nearly one. Some of the serial correlation in the residuals, particularly of autoregressive nature may be an indication of time varying term premium.

The empirical results for Czech Republic, Indonesia and Malaysia seem to be a puzzle. Why would an increase in the liquidity as indicated by the growth of real net foreign assets of the central bank lead to an increase in the liquidity premium? Taking into account the effects of monetary policy might resolve this puzzle.

An increase in the foreign assets holdings of the central bank, ceteris paribus, would increase monetary liabilities of the central bank, in the absence of any action by the central bank itself. However, the central bank could avoid any increase in the monetary liabilities by reducing its holdings of the domestic assets and thus could accommodate an increase in the foreign assets. This policy is known as 'sterilization policy'.

In fact, it was observed that the central banks in many emerging markets including Indonesia, Korea, Malaysia, Philippines, Thailand, Mexico, Chile and transition economies like Czech Republic and Hungary used sterilization in the early 1990's. The empirical evidence to this effect is provided by many studies in another strand of the literature emphasizing capital flows such as Frankel and Okongwu (1995), Siklos (1997), Bond (1998), Montiel and Reinhart (1999).
During this time period many of the emerging markets in South-East Asia and Latin America along with the newly developing transition economies like Czech Republic and Hungary faced heavy capital inflows. With low interest rate in the industrialized countries, the investors turned to the emerging markets in the search of higher returns. At the same time, most of these countries had limited exchange rate flexibility. To avoid exchange rate appreciation, the central banks had to resort to intervention in the foreign exchange markets leading to large foreign reserves. Without any policy action by the central bank, this would have resulted in excess liquidity in the economy fuelling aggregate demand, creating inflationary pressures.

So to avoid the short-term expansionary consequences of capital inflows, many of the central banks sterilized the increase in foreign reserves by selling domestic securities in open market operations. In some countries, particularly Malaysia, open market operations were supplemented by increases in the reserve requirement imposed on the banking system. In short, monetary policy was tightened, at least relative to what it would otherwise have been.

Indeed, if the central bank adopts sterilization, the growth of its foreign assets could be associated with a decrease rather than an increase in the liquidity in the financial markets. With rising interest rates, risk-averting investors would demand a higher liquidity premium to lend long. Hence liquidity premium would increase.

Thus, the empirical evidence presented in Table 3 may be rationalized. The positive and significant coefficients for Czech Republic, Indonesia and Malaysia could have perhaps resulted from the sterilization policy adopted by the central banks.

2.7 Liquidity premium and a model of sterilization.

This is an appropriate juncture to relate the empirical results discussed in the earlier section to a model of sterilization presented in the earlier literature.
Caballero and Krishnamurthy (2000) emphasize on the international liquidity management aspect of sterilization policy in illiquid financial markets. They argue that the impact of sterilization of the asset side of the government’s balance sheet and the liabilities side of the private sector’s balance sheet is more important than any other implications.

In the model, domestic and international liquidity is required to fulfill investment plans. The domestic agents import material from the rest of the world by pledging their international liquidity and borrowing abroad. In this context, sterilization by issuing domestic bonds refers to the swap of the private sector’s international liquidity for the government’s own liquidity. Through sterilization the government wants to crowd out private investment while acquiring all the international liquidity of the private sector. A building block of this model is the illiquidity of government bonds market. Since the bonds are illiquid, the government has to offer a high discount on their prices i.e. long-term interest rate rises significantly.

In other words, this model implies that sterilization policy in illiquid financial markets leads to a steep term structure and high liquidity premium. The empirical evidence presented in the earlier section is at least partly in line with this story.

However, in reality the story is slightly different in the emerging markets. It is a fact that the government bond market is very thin and illiquid in these countries. However, the central banks typically used short-term instruments such as Treasury bills, the central bank’s own short-term securities and most often repurchase operations (repo market) for sterilization in open market operations. Thus the crucial assumption of illiquid long-term bonds in the Caballero-Krishnamurthy model was absent.

Yet, the story can be retold in another way. The sterilization with short-term instruments increases the short rates. If the investors expect the interest rates to rise, particularly the short rate with the contractionary monetary policy, risk-aversers would demand higher term premiums in the forward rates. And thus, the yield curve would be steeper.
2.8 Conclusions.

The pure expectations theory implies that the expectations of the future course of interest rates are the sole determinant of the term structure. However, the joint hypothesis of rational expectations and pure expectations theory of term structure i.e. the hypothesis of the slope coefficient of term spread being equal to one, has been rejected in most studies. The explanations proposed in the literature for this empirical failure of the theory are either the presence of time varying term premium, or a measurement error in the interest rates or the interest rate smoothing of the monetary policy. Many studies have shown a strong evidence of time varying term premium.

Nearly all of these studies examine the validity of the expectations hypothesis in the industrialized and OECD countries. This paper examines the evidence of the expectations hypothesis in the newly developed financial markets, during the last decade. Looking at the interest rates on financial assets of maturities of three, six and twelve months. I find that the spread between long-term and short-term rates does have some significant power in predicting the changes in expected future short-term rates. In fact, for the two-thirds of the cases considered, the expectations theory is not rejected. This evidence is in sharp contrast to the evidence earlier presented on industrialized countries. Further, contrary to the simple expectations theory, the term premium has high persistence which is reflected by the significant autoregressive and moving average terms in the estimation.

The time varying nature of the term premium is once again supported by the second test examined in this paper. In fact, the growth of the foreign asset holdings of the central bank is able to explain at least partly, the liquidity premium in the Philippines, Portugal, Spain, Finland, the United States, Germany, France and Japan. This growth of foreign assets of the central bank would increase the liquidity in the financial markets and hence lead to fall in the liquidity premium.
However, in Czech Republic, Indonesia and Malaysia, contrary evidence is observed. This puzzle could be perhaps resolved if the monetary policy actions, particularly sterilization policy, is taken into account.

This study has important implications for the monetary policy in the newly developed financial market itself. On the other hand, because of the huge financial investments, the investors and also the policy-makers in the industrialized world need to know the workings of the financial markets and monetary policy in these developing countries.
2.9 References


2.10 Tables

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Table 2.1
ADF test for unit root.

$H_0$: variable is nonstationary
For all regressions, constant and 4 lags of the dependent variable included. A deterministic trend included wherever indicated by *
***, ** and * at 1%, 5% and 10% significance level respectively for MacKinnon critical values.
### Table 2.2

Test of Expectations Hypothesis of Term Structure: Newly developed financial markets

\[
\sum_{i=1}^{k-i} \frac{k-i}{k} D_{t+i|m} = \alpha + \beta (R^n_t - r^m_t) + \mu_{t+n}
\]

where \(\mu_{t+n} = \rho_1 \mu_{t+n-1} + \rho_2 \mu_{t+n-2} + \ldots + \rho_p \mu_{t+n-p} + \epsilon_{t+n} + \phi_1 \epsilon_{t+n-1} + \phi_2 \epsilon_{t+n-2} + \ldots + \phi_q \epsilon_{t+n-q}\)

n and m =maturity in months of long-term and short-term rates respectively. 
For Malaysia and Indonesia deposit rates, for the Philippines, Sweden and United States Treasury bills rates and for all other countries inter-bank rates used as interest rates for the test. 
Estimation by two-stage lease square method with ARMA (p,q) terms. Instruments used: S_{t-1} and S_{t-2} (two other spread) and D_t, D_{t-1}, D_{t-2} of all short-term rates. 
Standard errors below the coefficient values

Chi square statistic from Wald test with \(H_0: \beta = 1\)

LM statistic from Breusch-Godfrey test for serial correlation up to 12 lags

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Test of Expectations Hypothesis of Term Structure: Newly developed financial markets

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Table 2.3
Test of Expectations Hypothesis of Term Structure: developed financial markets

\[
\sum_{i=1}^{k} \frac{k-i}{k} D_{t+i} = \alpha + \beta (R_t^n - r_t^m) + \mu_{t+n}
\]

where $\mu_{t+n} = \rho_1 \mu_{t+n-1} + \rho_2 \mu_{t+n-2} + \ldots + \rho_p \mu_{t+n-p} + \epsilon_{t+n} + \phi_1 \epsilon_{t+n-1} + \phi_2 \epsilon_{t+n-2} + \ldots + \phi_q \epsilon_{t+n-q}$

n and m = maturity in months of long-term and short-term rates respectively.
For Malaysia and Indonesia deposit rates, for the Philippines, Sweden and United States Treasury bills rates and for all other countries inter-bank rates used as interest rates for the test.
Estimation by two-stage least square method with ARMA (p,q) terms. Instruments used: St-1 and St-2 (two other spread) and Dt, Dt-1, Dt-2 of all short-term rates.
Standard errors below the coefficient values
Chi square statistic from Wald test with $H_0 : \beta = 1$
LM statistic from Breusch-Godfrey test for serial correlation up to 12 lags
***, ** and * at 1%, 5% and 10% significance level respectively.
a: MA(6) required to reduce serial correlation in the residuals
Table 2.3 - continued

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Test of Expectations Hypothesis of Term Structure: developed financial markets

- b: MA(6)
- c: MA(5)
- d: MA(3)
- e: also AR(3)=0.29***(0.08) fitted to remove serial correlation in the residuals
- f: also MA(3)=0.21***(0.09) and MA(5)=-0.13***(0.08) fitted to remove serial correlation in the residuals.
- n: Newey-West heteroscedasticity consistent standard errors and covariances
- w: White-heteroscedasticity consistent standard errors and covariances
## Table 2.4
Test for the evidence of liquidity premium

\[
(R_t^n - r_t^m) - \left( \sum_{i=1}^{k-i} \frac{k-i}{k} D_{t+i} \right) = \delta + \gamma_1 DLRNF_{A_t} + \gamma_2 DLRNF_{A_{t-1}} + \gamma_3 DLRNF_{A_{t-2}} + \nu_t
\]

\[
\nu_t = \rho_1 \nu_{t-1} + \rho_2 \nu_{t-2} + \ldots + \rho_p \nu_{t-p} + \eta_t + \phi_1 \eta_{t-1} + \phi_2 \eta_{t-2} + \ldots + \phi_q \eta_{t-q}
\]

n and m = maturity in months of long-term and short-term rates respectively.

For Malaysia and Indonesia deposit rates, for the Philippines, Sweden and United States Treasury bills rates and for all other countries inter-bank rates used as interest rates for the test.

Estimation by two-stage least square method with ARMA (p,q) terms. Instruments used: St-1 and St-2 (all spreads), Dt, Dt-1, Dt-2 of all short-term rates and DLRNF{A_{t-1}, DLRNF{A_{t-2}}

Standard errors below the coefficient values

LM statistic from Breusch-Godfrey test for serial correlation up to 12 lags

***, ** and * at 1%, 5% and 10% significance level respectively.

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Test for the evidence of liquidity premium

a: MA(6)
b: also MA(3)=0.29***(0.06) and MA(4)=0.14***(0.07) fitted to remove serial correlation in the residuals
c: MA(3)
d: also MA(3)=0.79***(0.09) and MA(4)=0.43***(0.08) fitted to remove serial correlation in the residuals
2.11 Data Appendix

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<td>Finland</td>
<td>1994:01-1998:12</td>
<td>3, 6, and 12 months Inter-bank interest rates</td>
</tr>
<tr>
<td>France</td>
<td>1994:01-1998:12</td>
<td>3, 6, and 12 months Inter-bank interest rates</td>
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<tr>
<td>Germany</td>
<td>1994:01-1998:12</td>
<td>3, 6, and 12 months Inter-bank interest rates</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>1990:01-1997:06</td>
<td>3, 6, and 12 months Inter-bank interest rates</td>
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<tr>
<td>Indonesia</td>
<td>1990:01-1997:06</td>
<td>Interest rates on 3, 6, and 12 months deposits</td>
</tr>
<tr>
<td>Japan</td>
<td>1990:01-2001:4</td>
<td>3, 6, and 12 months Inter-bank interest rates</td>
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<tr>
<td>Malaysia</td>
<td>1990:01-1997:06</td>
<td>Interest rates on 3, 6, and 12 months deposits</td>
</tr>
<tr>
<td>Mexico</td>
<td>1996:01-2001:4</td>
<td>3, 6, and 12 months Inter-bank interest rates</td>
</tr>
<tr>
<td>Norway</td>
<td>1990:01-1998:12</td>
<td>3, 6, and 12 months Inter-bank interest rates</td>
</tr>
<tr>
<td>Philippines</td>
<td>1990:01-1997:06</td>
<td>Interest rates on 3, 6, and 12 months Treasury Bills.</td>
</tr>
<tr>
<td>Portugal</td>
<td>1994:10-1998:12</td>
<td>3, 6, and 12 months Inter-bank interest rates</td>
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<tr>
<td>Singapore</td>
<td>1990:01-1997:06</td>
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<tr>
<td>Spain</td>
<td>1990:01-1998:12</td>
<td>3, 6, and 12 months Inter-bank interest rates</td>
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<tr>
<td>United Kingdom</td>
<td>1994:01-1998:12</td>
<td>3, 6, and 12 months Inter-bank interest rates</td>
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Interest rate data are obtained from Datastream
CHAPTER 3

CAN THE TERM SPREAD PREDICT OUTPUT GROWTH?

3.1 Introduction

There has been a keen interest in term spreads as leading indicators of economic activity. The adage that an inverted yield curve signals a recession and an upward-sloping yield curve precedes an expansion is quite popular in the media as well as academic circles. Kessel (1965) noticed this correlation between interest rate cycles and business cycles.

The financial innovations since the early 1970’s have greatly reduced the forecasting ability of the monetary aggregates for future output growth and inflation. As a result, interest in asset prices as predictors of future economic activity has increased. For example, Stock and Watson (1989) recommended the term spread as a leading indicator of the economic activity.

Extensive research into the predictive power of the term spread for future activity followed in the 1990’s as a natural reaction. Most of the literature found strong evidence of the forecasting ability of the term spread. However, it has only recently been observed that the relationship between the term spread and real activity is not as reliable as believed to be earlier. Some authors such as Estrella (1997), Estrella and Mishkin (1997b), Smets and Tsatsaronis (1997), Kotlan (2001) have suggested that this relationship may be neither time-invariant nor policy-independent.
In this paper, I offer an interesting insight regarding the forecasting ability of the term spread for future output growth. The empirical evidence based on a wider set of countries indeed suggests that this relationship varies across countries and across time periods. The notable difference in the earlier studies and this paper is the occasional presence of a negative regression coefficient in this empirical relationship. Further, there appears to be a sharp decline in the predictive power of the term spread in countries that have adopted monetary policy with a stronger response to inflation.

To investigate the underlying economic reasons for these findings, I explicitly model the information content of the term spread for future output growth based on a structural model with strong micro foundations. This model includes a New Keynesian Phillips curve, a forward-looking IS curve, a Taylor (1993) type monetary policy rule, Fisher’s equation and the expectations hypothesis augmented with a time-varying term premium.

The model is calibrated heuristically by assigning different values to the structural parameters. These simulations suggest that the forecasting ability of the term spread changes with a change in the persistence and the variance of the underlying economic shocks and in the monetary policy preferences.

The most revealing implications of these results is that any change in the policy response to output gap or inflation changes only the size of the correlation between output growth and the term spread without changing its direction. The sign of this correlation and hence the direction of the information content in the term spread depends mainly on the persistence of the underlying economic shocks. The earlier literature, such as Estrella (1997) and Kotlan (2001), has focused mainly on the monetary policy parameters. This paper appears to be the first one to point out the importance of the persistence and the variance of the shocks.

Shocks to the term premium seem to have the most interesting implications for the predictive power of the term spread. The contribution of the term premium shock to the
information content of the term spread is significant. A stronger policy response to inflation tends to reduce this contribution and hence the forecasting ability of the term spread for future output growth.

The contribution of shocks to aggregate supply and aggregate demand tends to depend on their persistence. At a high persistence, supply shocks have positive while demand shocks have negative contribution to the covariance between the term spread and output growth. The effect of policy shocks is negative and very small.

In fact for some parameter values, the relationship between the term spread and future output growth can even become negative.

Since the relationship between the term spread and output growth is found not to be a structural relationship, all the economic agents, particularly the policy makers, need to interpret the movements in the yield curve more carefully. This model can perhaps help them in deciphering the information content in the term structure. Accurate forecasts of the future economic scenario are crucial for all economic agents.

The paper is organized as follows. Section 3.2 surveys the existing empirical literature. The existing evidence is extended in section 3.3. The various theories proposed in the literature are summarized in section 3.4. Section 3.5 presents the structural model, the basic solution to this model and the theoretical predictive power of the term spread. A qualitative analysis of the theoretical forecasting ability of the term spread in different scenarios is proposed in section 3.6. The implications of different policy regimes and the levels of persistence of the exogenous shocks are discussed in Section 3.7. The last section presents conclusions.
3.2 Existing empirical evidence.

There is a vast literature on the forecasting of future economic activity with asset prices. Interest rates and particularly term spreads are extensively examined for their predictive power. This interest in term spreads as leading indicators of output growth seems to have evolved, at least partly, due to the instability in 1970’s and early 1980’s of the forecasts based on monetary aggregates.

The most often used term spread in the literature is the difference between long-term i.e. 10 year government bond rate and short term i.e. three month Treasury bill rate. Sometimes the long bond rate minus an overnight rate such as Federal Funds rate in U.S. is also used.

There is no single agreed methodology to assess the question of predicting future output. Many of the studies use in-sample estimates i.e. estimating the model over full sample period. Less commonly, some authors construct out-of-sample forecasts.

The investigations of the forecasting ability of the term spread for output growth was initiated by Laurent(1988,1989), Stock and Watson(1989), Chen(1991) and Estrella and Hardouvelis(1991). Most of these studies find highly significant positive relationship between the term spread and real activity. These results have been confirmed further by Bomhoff (1994), Davis and Henry (1994), Davis and Fagan (1997) and Hamilton and Kim (2000). The international evidence has been examined by Plosser and Rouwenhorst (1994), Davis and Henry (1994), Davis and Fagan (1997), Bonser-Neal and Morely (1997), Kozicki (1997), Estrella and Mishkin (1997b), Bernard and Gerlach (1998) and Campbell (1999). Most of these studies conclude that the term spread has significant predictive power for output growth, particularly over short horizons.

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7 The cyclical behavior of interest rates was first noted by Kessel (1965). He found that the yield differentials between short term and long term government securities widened during the expansions. Further, liquidity preference produced asymmetry in the relationship between short term and long term rates at cyclical peaks and troughs. However, he could not find any evidence of the ability of the market to predict turning points in specific cycles of interest rates.
Subsequent work has focused on whether this relationship between the term spread and the real output is stable across time and if it holds up in international evidence. Hess and Porter (1993), Haubrich and Dombrosky (1996) and Dotsey (1998) conclude that the predictive content of the term spread for economic activity has diminished since mid 1980’s. Estrella, Rodrigues and Schich (2000) also find some evidence of instability in this relationship in the U.S. and Germany. Siklos (2000) presents a very surprising result that the interest rate spread has a significant but negative association with future economic growth in New Zealand at short horizons. This study is based on sample period of the economic reforms in New Zealand i.e. 1985 to 1997.

Models of discrete or binary dependent variables e.g. probability of recession or inflation such as Estrella and Hardouvelis (1991), Lahiri and Wang (1996), Ducker (1997), Estrella and Mishkin (1997a) and Bernard and Gerlach (1998) have performed as well or better than models with continuous variables. However, Chauvet and Potter (2001) find strong evidence of structural instability also in the estimation of the binary probit model.

Usefulness of interest rates and the term spread has also been examined within the context of Vector Autoregressive (VAR) models for output and inflation e.g. Stock and Watson (1989) and Smets and Tsatsaronis (1997).

Thus, this vast literature suggests few conclusions. There is some evidence that the term spread is a candidate for predictor of output growth, particularly, at shorter horizon. However, this relationship may not be stable across time periods, across countries and in different monetary policy regimes. The predictive power of the yield curve is observed to have deteriorated during the last decade. Stock and Watson (2000) point out that the literature reflects the continuation of the ongoing breakdown of predictive relations once considered reliable such as the monetary aggregates in the 1970’s and early 1980’s.
3.3 Reexamining the empirical regularities.

I extend the earlier empirical evidence with data from the recent time period and a larger number of countries.

3.3.1 Methodology

A methodology similar to the one used in most of the studies with continuous dependent variables is adopted. Ex post future real output growth at various horizons is regressed on the difference between current long-term and short-term rate. The regression equation is expressed as

\[ YG_k = \alpha + \kappa_y (L_t - i_t) + \mu_{t+k} \]

where \( YG_k = \frac{1200}{k} (\log Y_{t+k} - \log Y_t) \)

\( YG_k \) is the annualized percentage growth over \( k \) periods in real output and \( (L_t - i_t) \) is the current term spread.

Ordinary Least Square is used for estimation. Ex-post annualized percentage growth of the index of industrial production over 6 to 48 months is regressed on the current term spread. Since the overlapping data points generate moving average serial correlation, the coefficient standard errors are corrected with Newey-West method for \( k-1 \) lags.

Looking at the empirical evidence in the literature, it seems plausible to suppose that output growth and the term spread are stationary time series. Hence OLS estimation appears to be sensible.

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8 This simple framework has an important limitation. As output growth is typically serially correlated, its own past values are themselves useful predictors. An alternative method is to examine the predictive power of the term spread for output growth above and beyond that contained in its lagged values.
3.3.2 Data

The predictive power of the term spread is estimated for Austria, Belgium, Canada, France, Germany, Ireland, Italy, Japan, Netherlands, South Africa, Spain, U.K. and U.S.A. This set of countries represents a wide range of economic structures and policies. The selection of the countries is exclusively based on the availability of data. The long-term interest rate data are not available for many other countries.

The sample period ranges from 1970 to 2000. However, for some of the countries, data are unavailable for the entire period. For the continental European countries the sample period ends in 1998:12, since European economic integration could have given rise to structural breaks in the time series.

Monthly data on the index of industrial production, the CPI, the Treasury bill rate and the government bond rate are used as the measures of output, the price level, the short term rate and the long-term rate respectively. The Money market rate is used instead of the Treasury bill rate if the later is not available. The data series are described in detail in the appendix. All the data are collected from the IFS-CD-ROM.

3.3.3 Empirical results

The empirical evidence on the forecasting ability of the term spread for future output growth is presented in Table 3.1. A glance at Table 3.1 reveals that the term spread has a strong predictive power for future output growth in most of the countries considered.

The strongest evidence of the predictive power is found in Canada, France and the United States. The estimated value of $\kappa^*_y$ is positive and significant at the 1% level over all the time horizons considered. The estimated value decreases as the horizon becomes longer. A

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9 These empirical results should be interpreted with a caveat. The residuals in nearly all the regressions indicate serial correlation of high order. An attempt to whiten these residuals has not been successful even with an ARMA (2, 2) model.
similar result is observed in Austria, Belgium, Germany and Spain, except for the lower level of significance of the estimates over some horizons. Italy, Netherlands, Japan, South Africa and the U.K. show forecasting power of the term spread only at shorter horizons. The estimate of $\kappa_y$ is not significant at any other horizons in Ireland except for six months ahead output growth.

The results presented in Table 3.1 are mostly consistent with the various studies in the literature, including the change of the size of the coefficients over different horizons.

Some authors such as Estrella (1997), Estrella and Mishkin (1997), Smets and Tsatsaronis (1997) have suggested that the relationship between term spread and output growth as well as inflation may not be time-invariant and policy-independent. To investigate this idea further, the full sample period covering three decades is split into three smaller sample periods. Most of the world is observed to have faced inherently different experiences in the decades of the 1970’s, 1980’s and the 1990’s.

Table 3.2 shows the estimation results for shorter sample periods.

The term spread seems to have retained its predictive power for future output growth more or less during all three decades in Austria, France and Germany. However, in Canada, Netherlands and the United States, the term spread largely loses its forecasting ability in the 1990’s. On the other hand, the estimate of $\kappa_y$ is positive and significant in the last decade in Belgium, Ireland and South Africa. In the case of Japan, the term spread seems to contain some information about future output at shorter horizons, except in the decade of 1980’s. The results for the U.K. are in fact puzzling. While in 1970’s and particularly 1980’s, the estimate of $\kappa_y$ is positive and significant, it turns negative and significant at longer horizon in 1990’s. This result is contrary to the widely acknowledged notion of positive relationship between the term structure and output growth. A similar result is observed in Italy in 1980’s but only at shorter horizon.

In short, the predictive power of the term spread varies across countries and over different time periods. No single robust pattern can be extracted from the empirical results except
that the estimated absolute value tends to decrease with forecast horizon. The empirical evidence in Tables 3.2 reinforces the notion proposed in the earlier literature that the observed relationship between the term structure and future output growth is not structural. And yet, any forecasting ability of the term spread is potentially valuable to the policymakers as well as the consumers and producers. This insight provides a strong motivation to investigate the structural sources underlying the predictive power of the term structure.

3.4 Theoretical background.

As noted in section 3.2, during the last two decades, the forecasting power of interest rates and particularly term spreads has been extensively examined. However, the precise mechanism by which interest rate spreads are linked to future movements in real activity and inflation has received relatively less attention. Further, with some exceptions the various explanations provided in the literature are rather informal.

One strand in this literature is based on the Consumption Capital Asset Pricing Model (CCAPM). Harvey (1988) and Hu (1993) attribute the correlation between the term spread and future economic growth to intertemporal consumption smoothing. Consumers maximize their utility subject to the production technology, by allocating consumption between the current and future periods. As a result, the real interest rate is governed by the economy’s output growth. Consumers who rationally forecast recession would increase current savings to boost future income. And hence they would push short rates down and depress longer rates ahead of the slowdown in economic activity. This line of thought suggests a positive relationship between the slope of the real yield curve and economic activity.

Real Business Cycle (RBC) models, as proposed by Long and Plosser (1983), predict a relation between the level of real commodity interest rates and expectations about future real economic growth. Asset prices in these general equilibrium models, such as Kydland and
Prescott (1982), King, Plosser and Rebelo (1988) link the slope of the real term structure to real consumption growth differentials. These consumption growth differentials reflect the marginal rates of substitution between consumptions at different dates as in C-CAPM. In this kind of model the future positive productivity shocks are expected to increase future output, which in turn leads to a higher real interest rates as economic agents substitute current for future consumption. Thus, there is a tendency for the real yield curve to steepen as a consequence of these shocks, preceding economic growth.

However, the models in this strand of literature fail to explain the strong predictive content of the nominal yield curve for real economic activity.

The second strand in the literature emphasizes short-run nominal rigidities and assigns a significant role to monetary policy. Several explanations are suggested for the source of the predictive power of the yield curve for economic activity.

The central bank can affect the short-end of the term structure to a significant degree. However, the long-end is largely determined by the financial market’s expectations of future short rates, the term premium, inflation and economic activity. If these expectations are in any way accurate, then the forward-looking long-term rate and hence the term spread should contain information about future activity.

The yield curve reflects the stance of monetary policy. The term structure, future economic activity and hence inflation are influenced by current monetary policy. According to this school of thought, monetary policy is countercyclical. Following a slowdown in economic activity, the central bank increases the money supply. Short-term interest rates tend to decline. However, long-term interest rates tend to move less than the short rates because monetary easing tends to raise long-term inflation expectations, which may in turn lead investors to expect the central bank to respond in the near future to this increase in inflation. Thus, the result is steepening of the yield curve. The current lower real interest rates encourage economic activity.
Alternatively, the term spread contains information on credit market conditions. Long-term rates reflect supply and demand conditions in the credit markets. If market participants expect future real income to increase, investment opportunities would become more profitable. As a result, the increase in demand for credit would increase long-term rates and hence the term spread, followed by an increase in economic activity and inflation.10

The power of the yield curve is also explained by simple dynamic IS-LM model with a long-term interest rate as in Lowe (1992). Expansionary monetary policy causes the slope of the yield curve to steepen as the liquidity effect of higher real money balances lowers short-term interest rates. It is accompanied by lower real rates and an increase in future economic activity.

Estrella and Mishkin (1997b) point out that from a purely theoretical point of view, the yield curve spread may be related positively or negatively to future real output. Future shifts in the IS curve due to real demand shocks would suggest a positive relationship between term spread and real output. On the other hand, expectations of future monetary tightening could be associated with higher interest rates and consequently lower output, particularly in the short run. This could be thought as future shifts in the LM curve leading to a negative relationship between term spread and real output.

Estrella (1997) presents a theoretical rational expectations model that suggests that the empirical regularities observed in the literature are not structural, but are dependent on monetary policy regime. This structural model is backward-looking and consists of a Phillips cure, an IS curve, a monetary policy reaction function, Fisher’s equation and the expectations hypothesis. Solving the model analytically, Estrella shows that if a strictly inflation targeting monetary policy is adopted; the yield curve does not contain any independent information about future output or inflation.

10Kozicki(1997) points out a less common version of the credit market theory. Long-term yields may rise with a decreased supply of credit possibly due to political uncertainty or decreased credibility of monetary policy. Thus increase in term spread could precede weaker real growth of output.
Smets and Tsatsaronis (1997) use a similar backward-looking structural model to examine the foundations of the predictive content of the yield curve for output growth in Germany and United States. They also include a long-run vertical supply curve along with the other structural equations as in Estrella (1997). They employ a structural VAR to identify and analyze the effects of supply, demand, monetary policy and inflation scare shocks. They conclude that in both the countries monetary policy and demand shocks contribute significantly to the covariance between output growth and the term spread. However, in Germany, the contribution of a positive supply shock is the main reason behind the information content.

Peel and Taylor (1998) propose that the predictive power of the term spread is associated with demand shocks. They examine whether the slope of the yield curve affects real activity through supply or demand side of the economy. They find that the term spread in U.S. and U.K. loses its predictive power for counterfactual cumulative movements in output purged of temporary innovations. On the other hand, purging the output series of permanent innovations does not reduce the forecasting power of the term spread for output growth.

Another study of the indicator properties of the term structure for future inflation and real activity, based on a general equilibrium model is Kotlan (2001). His model includes a backward-looking IS curve, a hybrid Phillips curve, a central bank reaction function, uncovered interest rate parity and the expectations hypothesis. Using model simulations based on the Czech economy, he finds that a stronger monetary policy response to inflation increases the predictive power of the term spread for future inflation while more weight on output stabilization increases the information content for real activity.
3.5 Theoretical predictive power

3.5.1 A structural model

I adopt the framework of New Keynesian macroeconomic model where I add an equation for the term structure of interest rates. It is a dynamic general equilibrium model with money and nominal price rigidities. This model is widely used recently, particularly for monetary policy analysis e.g. Rotenberg and Woodford (1999), McCallum and Nelson (1999), Svensson (1999), Clarida, Gali and Gertler (1999) and King (2000).

Within the model, monetary policy shocks (i.e., nominal shocks) have real effects, much as in the traditional IS-LM framework. A key difference, however, is that the aggregate behavioral equations derive explicitly from optimization by households and firms.

I directly introduce the aggregate equations of the economy. The derivations are presented in the above-mentioned papers.

New Keynesian Phillips curve

\[ \pi_t = \beta E_t \pi_{t+1} + \gamma y_t + s_t \]

IS curve

\[ y_t = E_t y_{t+n} - \delta R_t + d_t \]

Monetary policy rule

\[ i_t = \rho i_{t-1} + \lambda_1 \pi_t + \lambda_2 y_t + z_t \]

Expectations hypothesis augmented with time-varying term premium.

\[ I_t = \frac{1}{n} \sum_{j=0}^{n-1} E_t i_{t+j} + tp_t \]

Fisher equation

\[ I_t = R_t + \frac{1}{n} \sum_{j=1}^{n} E_t \pi_{t+j} \]

where

\[ \pi_t = \text{period t inflation rate measured by percentage change in the price level from t-1 to t} \]

\[ y_t = \text{log of output gap in period t} \]
\( R, i, I \) = long-term real interest rate, short term nominal interest rate, long-term nominal interest rate
\( E_t \) = expectations operator conditional on all information available within the model in period \( t \).
\( n \) = number of time periods.
\( s, d, z, t \) are the supply shock, the demand shock, the monetary policy shock and the time-varying term premium respectively. All the shocks to the system are independent of each other and their behavior can be described by the autoregressive processes.\(^{11}\)

\[ \begin{align*}
6 \quad & s_t = \phi_1 s_{t-1} + \varepsilon_{st}, \quad E(\varepsilon_{st}) = 0, \var(\varepsilon_{st}) = \sigma_s^2 \quad \text{where } |\phi_1| < 1 \\
7 \quad & d_t = \phi_2 d_{t-1} + \varepsilon_{dt}, \quad E(\varepsilon_{dt}) = 0, \var(\varepsilon_{dt}) = \sigma_d^2 \quad \text{where } |\phi_2| < 1 \\
8 \quad & z_t = \phi_3 z_{t-1} + \varepsilon_{zt}, \quad E(\varepsilon_{zt}) = 0, \var(\varepsilon_{zt}) = \sigma_z^2 \quad \text{where } |\phi_3| < 1 \\
9 \quad & tp_t = \phi_4 tp_{t-1} + \varepsilon_{tp}, \quad E(\varepsilon_{tp}) = C, \var(\varepsilon_{tp}) = \sigma_{tp}^2 \quad \text{where } |\phi_4| < 1 \text{ and } C \text{ a non-zero constant.}
\end{align*} \]

The Phillips curve results from staggered nominal price setting. The individual firm’s price setting decision is derived from an explicit optimization problem in the environment of monopolistically competitive firms. Each firm knows that its price may be sticky in the future and hence itrationally considers future marginal costs when setting prices. It is not implausible to assume that real marginal cost is positively related to output gap. Real marginal cost necessarily rises with the level of economic activity if the economy has some fixed factors or higher real wages are necessary to induce workers to supply additional hours.

\(^{11}\) Without loss of generality, the model abstracts from any means of \( \pi, y, R, \) and \( i \). In reality, the means are positive and the mean of \( I \) exceeds that of \( i \).
As assumed by Calvo (1983), each firm has a fixed probability of adjusting price and the timing of firm’s price adjustment is independent of its history. Thus, equation [1] is log-linear approximation about the steady state of the aggregation of individual firms’ pricing decisions.

The exogenous shock to the Phillips curve, called a ‘supply shock’, can be interpreted as a shock to the expected real marginal cost or to markup over marginal cost. Thus, in this sense it would capture cost-push inflation independent of excess demand.

Equation [2] is obtained by log-linearizing the consumption Euler equation that arises from the household’s optimal saving decision. Since the economic agents prefer to smooth consumption, expected higher future consumption (associated with expected higher future output) leads them to increase current consumption and hence current output demand. The interest elasticity in the IS curve, $\delta$ corresponds to the intertemporal elasticity of substitution in consumption.

The 'demand shock' (i.e. the shock to the IS curve) could be interpreted as fiscal policy shifts or preference shocks. An increase in current government purchases relative to future government purchases increases demand for current output for any given expected future output and shifts the IS curve.

The monetary authorities set the short-term nominal interest rate through a Taylor (1993) type policy rule represented in equation [3]. \( \lambda_x \) and \( \lambda_y \) are the authority’s responses to current inflation and output gap, respectively. The policy shock, \( z_t \), could be interpreted as a change in the policy preferences of inflation or output gap targets. \( \rho \) is the policy inertia parameter that implies the interest rate smoothing behavior adopted by the monetary authorities.\(^{12}\)

Equation [4] links the short-term interest rate to the long-term rate with the expectations hypothesis. The traditional expectations hypothesis posits that the long-term rate is a just

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\(^{12}\) There is an extensive literature including Mankiw and Miron (1986), McCallum (1994), Rudebusch (1995) that points out that monetary authorities smooth interest rates. However, Rudebusch (2002) proposes that monetary policy inertia is an illusion which possibly reflects persistent shocks faced by the authorities.
weighted average of future expected short-term rates. However, many studies in the literature such as Fama (1984), Engel, Lilien and Robins (1987), Tzavalis and Wickens (1998) among others have found strong empirical evidence of a time-varying term premium. Therefore it would be more appropriate to augment the expectations hypothesis with a shock capturing the time-varying term premium.\footnote{Goodfrend(1993) and Smets and Tsatsaronis(1997) augment Fisher’s equation with a shock called an ‘inflation scare shock’. The effect in essence would be same i.e. raising the long-term rate more than expected changes in the short rate.}

The conventional Fisher’s equation is described in equation [5]. It relates the nominal interest rate to the sum of the real interest rate and expected future inflation.

For simplicity and with little loss in generality, I assume long-term time period as consisting of four short-term time periods i.e. \( n=4 \). So equations [2], [4] and [5] change to

\[ [2'] \quad y_t = E_t y_{t+4} - \delta R_t + d_t \]

\[ [4'] \quad I_t = \frac{1}{4} (i_t + E_t i_{t+1} + E_t i_{t+2} + E_t i_{t+3}) + tp_t \]

and

\[ [5'] \quad I_t = R_t + \frac{1}{4} (E_t \pi_{t+1} + E_t \pi_{t+2} + E_t \pi_{t+3} + E_t \pi_{t+4}) \]

3.5.2 Basic solution to the model

A solution to the model of equations [1], [2'], [3], [4'] and [5'] is an expression for the stationary process that determines the endogenous variables \( \pi_t \) and \( y_t \) in terms of the shocks i.e. \( s_t, d_t, z_t, tp_t \) and the previous period’s short term interest rate. We can obtain a rational expectations bubble-free solution by employing Minimum-State-Variable criterion due to McCallum (1983).
Taking equation [3] forward, I get current and future short term interest rates in terms of inflation, output gap, the previous period’s short-term rate and policy shock. Then I substitute equations [4’] and [5’] and current and future policy rules into equation [2’]. Now, the model can be represented in terms of only $\pi_t$ and $y_t$, their future expectations, the last period short term rate and the four economic shocks.

I guess the solution to be of the form given by equation [10] and equation [11].

\[10\] $\pi_t = r_1i_{t-1} + q_{11}s_t + q_{21}d_t + q_{31}z_t + q_{41}\pi_t$

\[11\] $y_t = r_2i_{t-1} + q_{12}s_t + q_{22}d_t + q_{32}z_t + q_{42}\pi_t$

Taking these equations forward, I get equations for $\pi_{t+1}$, $\pi_{t+2}$ and $\pi_t$, $\pi_{t+1}$, $\pi_{t+2}$ and so on. Using these equations and the Method of Undetermined Coefficients, I then obtain the expressions for $r_j$ and $q_{ij}$ $\forall$ $i$=1 to 4 and $j$=1, 2 in terms of the parameters of the system. Thus, I derive the expressions for all the endogenous variables in the system i.e. $\pi_t$, $y_t$, $i_t$ and $I_t$ in terms of the structural parameters, the last period short-term interest rate and the exogenous shocks.

It is not possible to get closed form solutions for this system of equations. The system is numerically solved by assigning values to the structural parameters. This calibration is discussed in the next section.

Since this system of equations turns out to be non-linear in $r_1$, it has multiple sets of solutions for all the r’s and q’s. Only one of the sets of solutions with real numbers, have signs associated with appropriate economic interpretation. Hence, the other sets of solutions can be eliminated.

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14 McCallum’s Minimum State Variable (MSV) criterion, it is designed to yield a single bubble-free solution by construction. It limits the solutions to linear functions of a minimum set of state variables i.e. predetermined or exogenous determinants of current endogenous variables.
Macroeconomic theory implies that the coefficients of the previous period’s short-term interest rate in the basic solution (i.e. $r_1$ and $r_2$) are negative. An increase in the interest rate is contractionary and hence reduces inflation as well as output. The theory also indicates that $q_{11}$, $q_{21}$, $q_{22}$ are positive whereas $q_{12}$, $q_{31}$, $q_{41}$, $q_{32}$, and $q_{42}$ are negative. $q_{11}$ and $q_{21}$ are the coefficients of supply and demand shocks in the equation for inflation respectively. As the supply shock is modeled as an increase in the real marginal cost, both positive supply and demand shocks increase inflation. The output also increases following a positive demand shock, as reflected in the positive $q_{22}$. Similarly, an increase in marginal cost would put downward pressure on output. A policy shock that raises the short-term nominal interest rate would naturally lower inflation as well as output. The effect of the term premium shock can be explained more easily for output than inflation. Investments and hence economic activity are sensitive to long-term rates. So a higher long-term rate resulting from a higher term premium would lower output. In this case, a higher nominal interest rate given expectations of inflation would mean a higher real interest rate. It is possible to imagine its negative effect on inflation similar to the effect of contractionary monetary policy.

As mentioned earlier, for some reasonable values of the structural parameters, only in one of the sets of solutions $q_{11}$, $q_{21}$ and $q_{22}$ are positive while $r_1$, $r_2$, $q_{12}$, $q_{31}$, $q_{41}$, $q_{32}$, and $q_{42}$ are negative. Thus, this basic solution to the structural model seems to be intuitively sensible.

A caveat to note is that inflation and the output gap in this model are persistent only to the extent that the underlying shocks (i.e. $s_j$, $d_i$, $z$, and $tp_t$) and the current short term interest rate are persistent.\footnote{Ellingsen and Soderstrom (2001) argue that a purely forward-looking model may not lead to long lasting effects of monetary policy. Hence, they adopt a backward-looking dynamic aggregate demand and aggregate supply model to analyze the effects of monetary policy on the term structure.}
3.5.3 Predictive power of the term spread.

Using the basic solution to this rational expectations model, I derive the theoretical predictive power of the term spread for future real activity.

For simplicity, the long-term period is assumed as consisting of four short-term periods. The predictive power of the term spread over short and long horizon is associated with one and four periods ahead forecasting equations, respectively.

The information content in the current slope of the yield curve regarding output growth and at a one period horizon is obtained by estimating equation [12].

\[ (y_{t+k} - y_t) = \alpha + \kappa_y (I_t - i_t) + \mu_{t+k} \quad \text{for } k = 1, 2, 3 \text{ and } 4 \]

The probability limits of the ordinary least squares estimate of \( \kappa_y \) is as following

\[ k_y = \frac{\text{Cov}(y_{t+k} - y_t, I_t - i_t)}{\text{Var}(I_t - i_t)} . \]

Now, I substitute the basic solutions for \( y_{t+k}, y_t, I_t \) and \( i_t \) in the expressions [13] in terms of the last period short-term interest rate, the exogenous shocks and their respective parameters. Then we obtain the covariances and the variance. For simplicity, the shocks are assumed to be uncorrelated with each other. The previous period short-term interest rate is a predetermined exogenous variable. Thus, the probability limit can be expressed as

\[ k_y = \frac{\text{Cov}(y_{t+k} - y_t, I_t - i_t)}{\text{Var}(I_t - i_t)} = \frac{n_1 \sigma_x^2 + n_2 \sigma_d^2 + n_3 \sigma_z^2 + n_4 \sigma_{\eta_0}^2}{d_1 \sigma_x^2 + d_2 \sigma_d^2 + d_3 \sigma_z^2 + d_4 \sigma_{\eta_0}^2} \]

The coefficients of the variances of the shocks depend on the coefficients in the basic solution of the model, the policy parameters (i.e. the responses of the monetary authority to inflation and output gap) and the persistence (i.e. autoregressive parameters) of the shocks. The policy parameters and the persistence of the shocks affect the predictive power of the term spread.
spread directly as well as indirectly through the coefficients the basic solution (i.e. \( r_j \) and \( q_{ij} \) i=1 to 4 and j=1,2). In the next section, I examine the sensitivity of \( k_y \) to the structural parameters and investigate which parameter combinations are consistent with the observed empirical regularities.

3.6 Qualitative analysis: Sensitivity of \( k_y \).

As mentioned earlier, to solve the model and heuristically examine the sensitivity of the value of \( k_y \), we need to assign values for the structural parameters. The subjective discount factor \( \beta \) is set equal to 0.99. For quarterly data, this parameter is essentially indistinguishable from one. Following the earlier literature\(^{16}\), the values assumed in the benchmark model are as following. The output elasticity of inflation, \( \gamma = 0.3 \). The interest rate elasticity of output i.e. \( \delta \) is assumed to be 0.4. The interest rate smoothing parameter in the policy rule \( \rho = 0.8 \). The policy parameters of response to inflation and output gap, \( \lambda_1 = 1.5 \) and \( \lambda_2 = 0.5 \), respectively. The autoregressive parameters of the shocks are assumed as: the supply shock, \( \phi_1 = 0.8 \), the demand shock, \( \phi_2 = 0.8 \), the policy shock, \( \phi_3 = 0.4 \) and time-varying term premium, \( \phi_4 = 0.8 \).\(^{17}\)

At this point, I abstract from assuming any values for the variances of the exogenous shocks and rather focus on their coefficients in the covariance between the term spread and future output growth and the variance of the term spread, in the probability limits of the estimates. Thus, the question addressed here is, for the given variances of the shocks, how does any change in the structural parameters affect the predictive power of the term spread.

Using these assumed values for the structural parameters, I numerically solve the model and get the coefficients in the basic solution (i.e. equations [10] and [11]). Then with these

\(^{16}\) Clarida, Gali and Gertler (2000) and McCallum (2001)

\(^{17}\) The policy shock i.e. a change in the targets would less persistent. The literature, including the previous chapter, indicates a strong evidence of a highly persistent term-premium.
coefficients and the parameters, the probability limit of the ordinary least squares estimate of $\kappa_y$ is calculated. The effect of a change in the parameters on the ordinary least squares estimates is examined by assuming different value for one of the structural parameters and repeating the simulation. All the results are presented in the appendix in Tables A1 to A5. Only the interesting cases are discussed here.

Figure 3.1 represents the contributions of the variances of the four underlying shocks to the covariance between the term spread and output growth over various horizons as well as the variance of the term spread in the benchmark model. In other words, this chart shows the relative size of the coefficients of the variances of the shocks.

For the benchmark model, the coefficients of the variances of supply shock and the term premium shock are positive in the covariance of output growth and the term spread. The relative size of the coefficient of $\sigma_y^2$ increases with the horizon while the contribution of $\sigma_{tp}^2$ is largest at the short horizon. The coefficients of the variances of demand shock and policy shock are negative. The latter is very small and stable over all the horizons. The coefficient of $\sigma_d^2$ decreases with forecast horizon. Not surprisingly, the largest coefficient in the variance of the term spread is the coefficient of the term premium shock.

If the variance of the term premium shock is relatively larger than the variances of the other shocks then the value of the probability limit of $\kappa_y$ tends to decline at longer horizon. This is consistent with the only robust pattern in the empirical evidence of the forecasting ability of the term spread.

Among all the various structural parameters, any change in the policy response parameters and the persistence parameters of the shocks have significant effect on the covariance between the term spread and output growth as well as the variance of the term spread. Figures 3.2 to 3.8 focus on these parameters.
The change in the covariance due to a change in the policy response to inflation is represented in Figure 3.2. This graph shows the results of the simulations with different values of $\lambda_i$ in the benchmark model. An increase in $\lambda_i$ has different effect on the coefficients of the four shocks. The absolute size of the coefficients of $\sigma^2_d$, $\sigma^2_z$ and $\sigma^2_{tp}$ decreases with an increase in $\lambda_i$ while there is an increase in the coefficient of $\sigma^2_s$. Once again the coefficients of $\sigma^2_d$ and $\sigma^2_z$ are negative and the coefficients of $\sigma^2_s$ and $\sigma^2_{tp}$ are positive as in the benchmark model. As a result of an increase in $\lambda_i$, the contributions of all the shocks except the term premium shock tend to increase the covariance between the term spread and output growth.

Hence, once again, if the variance of the term premium shock is relatively larger than the variances of the other shocks, then a stronger policy response to inflation could possibly reduce the probability limit of $\lambda^*_y$.

Any changes in the policy response to the output gap give rise to the similar effects, except for the coefficient of $\sigma^2_s$. Though the coefficient is still positive its value falls with an increase in $\lambda_2$.

Now, I turn to the persistence of the shocks. Figure 3.3 presents the results of the simulations with various autoregressive parameters of the shocks in the benchmark model. A point to note is that any change in the persistence of a shock affects only the coefficient of the variance of that shock itself.

The coefficients of both $\sigma^2_s$ and $\sigma^2_d$ change their sign when the persistence of the shock declines. At low persistence, the coefficient of $\sigma^2_s$ is negative while the coefficient of $\sigma^2_d$ is positive.
Thus, for the given variances of the shocks, a fall in the persistence of the supply shock or an increase in the persistence of the demand shock could heuristically reduce the predictive power of the term spread.

The results appear to be similar for the policy and the term premium shock. A point to note is that a higher persistence of the policy shock is not considered as it does not seem to be plausible. Similarly, following the evidence in the literature, only a highly persistent term premium shock is considered here. A fall in the persistence of the shock increases the absolute size of the coefficient of $\sigma_z^2$ while reducing the absolute value of the coefficient of $\sigma_{tp}^2$. Since the former is negative and the later positive, as in the benchmark model, low persistence of the policy shock as well as the term premium shock reduces the probability limit of $\kappa_y$.

Figure 3.2 and Figure 3.3 illustrate that the forecasting ability of the term spread is sensitive to a change in the policy parameter and a change in the persistence of the shocks, respectively. So, the next evident question to resolve is of the effects of a simultaneous change in the policy parameter and the persistence of the shocks. Figure 3.4 to 3.8 describes these effects for each of the shocks, respectively. All the coefficients for the variance of the each shock move in the same direction over the various forecasting horizons. Hence, for brevity, only the charts for the covariance between one period output growth and the term spread and for the variance of the term spread are included. Similarly, only the effect of a simultaneous change in $\lambda_2$ and $\phi_1$ is presented here since for the other shocks the effects are similar to the ones due to the changes in $\lambda_1$. The complete results are presented in the appendix.

As seen earlier, the coefficient of $\sigma_y^2$ in Figure 3.4 changes its sign from positive to negative as there is a fall in the persistence of the supply shock even when there is a change in the policy response to inflation. The only exception is the coefficient in the covariance between

\[ \text{(18)} \text{ The coefficient of } \sigma_{tp}^2 \text{ increases slightly only in } Y1. \]
the term spread and one-period ahead output growth when the monetary policy response to inflation is one-to-one (i.e. the least strong among the policy responses considered). Further, the stronger the response to inflation, the larger is the absolute value of the coefficient in all the cases. This result also holds true for the variance of the term spread. Thus, an increase in $\lambda_1$, ceteris paribus, tends to reduce the probability limit of $\kappa_y$ at a low persistence of the supply shock.

Figure 3.5 differs from Figure 3.4 only to the extent of the change in the size of coefficients. Unlike the policy response to inflation, the stronger the response to output, the smaller is the absolute value of the coefficient of $\sigma_y^2$ at any level of persistence of the supply shock.

Once again the coefficient of $\sigma_d^2$ in Figure 3.6 changes its sign from negative to positive as there is a fall in the persistence of the demand shock at all the values of $\lambda_1$. Interestingly, the stronger the response to inflation, the larger is the absolute value of the coefficient in the covariance, only at a low level of persistence of the demand shock. Hence, an increase in $\lambda_1$, ceteris paribus, tends to increase the contribution of $\sigma_d^2$ to the probability limit of $\kappa_y$.

The coefficient of the variance of the policy shock is discussed in Figure 3.7. The coefficient of $\sigma_z^2$ is negative in the covariance of output growth and the term spread. A simultaneous fall in $\phi_3$ and an increase in $\lambda_1$ tends to increase the absolute size of this coefficient in both the covariance and the variance of the term spread. Thus, it could possibly reduce the forecasting ability of the term spread if the value of $\sigma_z^2$ is significant relative to the other variances.

Figure 3.8 illustrates an interesting result. A strong policy response to inflation tends to reduce the size of the coefficient of $\sigma_{tp}^2$ in the covariance of output growth and the term spread.
This effect is significant when the term premium is highly persistent. On the other hand, a similar policy response moderately increases the coefficient of $\sigma_{tp}^2$ in the variance of the term spread. Hence, a strong policy response could possibly reduce the predictive power of the term spread through its effect on the contribution of the term premium shock.

The following table presents the results of the simulations in a nutshell.

<table>
<thead>
<tr>
<th>Shock</th>
<th>Persistence</th>
<th>Increase in policy parameter</th>
<th>Change in value of coefficient</th>
<th>Contribution to predictive power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply</td>
<td>Low</td>
<td>$\lambda_1$ decrease in n1 increase in d1</td>
<td>Lower $\kappa_y$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\lambda_2$ increase in n1 increase in d1</td>
<td>Higher $\kappa_y$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>$\lambda_1$ Increase in n1 decrease in d1</td>
<td>Higher $\kappa_y$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\lambda_2$ decrease in n1 decrease in d1</td>
<td>Lower $\kappa_y$</td>
<td></td>
</tr>
<tr>
<td>Demand</td>
<td>Low</td>
<td>$\lambda_1$ Increase in n2 increase in d2</td>
<td>Higher $\kappa_y$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\lambda_2$ Increase in n2 increase in d2</td>
<td>Higher $\kappa_y$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>$\lambda_1$ Increase in n2 decrease in d2</td>
<td>Higher $\kappa_y$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\lambda_2$ Increase in n2 increase in d2</td>
<td>Higher $\kappa_y$</td>
<td></td>
</tr>
<tr>
<td>Policy</td>
<td>Low</td>
<td>$\lambda_1$ Increase in n3 increase in d3</td>
<td>Higher $\kappa_y$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\lambda_2$ Increase in n3 increase in d3</td>
<td>Higher $\kappa_y$</td>
<td></td>
</tr>
<tr>
<td>Term premium</td>
<td>High</td>
<td>$\lambda_1$ decrease in n4 increase in d4</td>
<td>Lower $\kappa_y$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\lambda_2$ decrease in n4 increase in d4</td>
<td>Lower $\kappa_y$</td>
<td></td>
</tr>
</tbody>
</table>

where $k_y = \frac{Cov}{Var} = \frac{n_1^* \sigma_s^2 + n_2^* \sigma_d^2 + n_3^* \sigma_z^2 + n_4^* \sigma_{tp}^2}{d_1^* \sigma_s^2 + d_2^* \sigma_d^2 + d_3^* \sigma_z^2 + d_4^* \sigma_{tp}^2}$
3.7 Interpretation and discussion

Several papers in the literature such as Estrella (1997), Estrella and Mishkin (1997), Smets and Tsatsaronis (1997), Estrella, Rodrigues and Schich (2000), Stock and Watson (2000), Kotlan (2001), among others suggest a word of caution in using the term spread as a leading indicator for forecasting real output and change in inflation. They point out that the predictive power of the term spread may be neither time-invariant nor policy-independent. Chauvet and Potter (2001) propose that the predictive power of the yield curve may depend on whether the economy is responding to real or monetary shocks or on the monetary reaction function.

The simulations in the earlier section suggest that the forecasting ability of the term spread does seem to change with a change in the persistence of the underlying economic shocks and the monetary policy preferences. Economic intuition also concurs with this hypothesis.

The most revealing implications of these results is the point that any change in the policy response to output gap or inflation changes the size of the coefficients in the probability limits of $\kappa_i$. The sign of the coefficients and hence the direction of the information content in the term spread depends mainly on the persistence of the underlying economic shocks. The earlier literature seems to have focused mainly on the monetary policy parameters. This paper appears to be the first one to point out the importance of the persistence of the shocks.

Suppose there is a temporary and positive supply shock. As a result, current period output will decrease and current period inflation will increase. Since the shock is not persistent, next period’s output and inflation will not be affected. When we compare current and next period, there will be a positive change in output. Responding to the supply shock, the central bank emphasizing price stability will increase current period short-term interest rate. The long-term interest rate will not rise as much. Hence the current period term spread will decrease. Thus, a fall in the term spread will be associated with future output growth. This would hold even if there is a low persistence in the supply shock. The simulations in the earlier section support this hypothesis. With a small autoregressive parameter on the supply shock, the coefficient on the
variance of the supply shock is negative in the covariance of the term spread and output growth.
In such a scenario, for the given variances of the shocks, the information content in the term
spread for output growth will be lower.

Now, suppose the supply shock is highly persistent. A positive supply shock will reduce
both current and future output while increasing inflation in both the periods, although the
contemporaneous effect is going to be stronger. Hence it will still tend to have positive future
output growth. However, in this scenario, the long-term interest will rise with inflationary
expectations and hence the term spread will increase to some extent. Once again, the
simulations of the model also indicate a higher predictive content of the term spread for future
output growth.

The behavior of the coefficients on the variance of the demand shock also confirm to the
intuition. A demand shock with no persistence will increase both output and inflation in the current
period without affecting future output and inflation. Hence there will a future decrease in output
growth. However, the current term spread will decline following a rise in the short-term interest
rate. This will generate a positive correlation between the change in the term spread and future
output growth. The positive coefficients of the variance of the demand shock in the covariance
strengthen this idea.

The demand shock with a large autoregressive parameter will generate a negative
correlation between the change in the term spread and future output growth. As a result of the
demand shock, output and inflation will increase in the current period more than the increase in
the next period. Hence, there will be a decline in future output growth. However, the term spread
will increase following an increase in the long-term interest rate because of the inflationary
expectations. This negative correlation will tend to reduce the information content in the term
spread.

The effects of a highly persistent supply or demand shocks will be stronger if one of the
assumptions regarding the shocks in this model is relaxed. It is assumed in this model that all the
underlying economic shocks are uncorrelated with one another. However, it is plausible that the term premium shock is correlated with the other economic shocks. If the term premium shock is modeled to be positively correlated with any inflationary shock, then a highly persistent demand or supply shock will significantly increase the term spread.

The effects of the policy shocks on output growth and change in inflation are more indirect. Yet, the negative sign of the coefficients in the model simulations matches the intuition. Any positive policy shock will raise the short-term interest rate and will have a dampening effect on both output and inflation in the current period without much effect on future variables. Thus a future output growth will appear to be positive along with a fall in the current term spread.

A similar intuition is associated with the effects of the term-premium shock. A positive shock will raise the long-term interest rate. A higher interest rate will dampen current output and hence inflation with a weaker effect on future output and inflation. Once again, there will appear to be a positive future output growth along with an increase in the term spread. This intuition concurs with the positive coefficient of the variance of the term-premium shock in the covariance.

A change in the policy response to inflation or output will change only the size of the interest rate movement without changing its direction. Hence such a policy change will only result in a change in the size and not the sign of the correlation between output growth and the term spread.

Thus, the predictive power of the term spread for future output growth could decline with the changes in the structural parameters. In fact for some values of the parameters, particularly at a low persistence of the supply shock, the regression coefficient of the relationship could turn out to be negative.

This hypothesis lends support to the empirical evidence in the section 2. During the last decade, there has been an extensive discussion among the researchers as well as the policymakers on the policy response to inflation versus output deviations. It appears that many
central banks have taken an aggressive stand against inflation. In some of the countries, such as Canada (1991), South Africa (2000), Spain (1994) and U.K. (1992), the monetary authorities have adopted explicit inflation-targeting. Some researchers have proposed the hypothesis that the change in the policy preferences could be the source of the loss in the forecasting ability of the term spread. Based on a forward-looking structural model, this paper supports the idea that the changes in policy preferences tend to affect the size of the information content in the term spread.

Another potential reason for the loss in the predictive power of the term spread, particularly in the U.S., is argued to be the decline in the volatility of the U.S. economy. Kim and Nelson (1999), McConnell and Perez (2000), and Chauvet and Potter (2001) find evidence of a break towards more stability in the economy since 1984. Mankiw (2001) concludes that a larger share of the impressive performance of the U.S. economy during the 1990’s is due to a good luck of an absence of severe economic shocks. The qualitative analysis of the model presented in the earlier section does support this idea. The structural decline in the volatility of GDP would mean lower variances of the exogenous shocks and hence a lower value of $\kappa_y$.

If the variance of the term premium shock is relatively higher than the variances of the other shocks, particularly the supply and the demand shock, then this model could explain the empirical evidence of the forecasting ability of the term spread during the last three decades. A high variance of the term premium shock increases the importance of its contribution to the theoretical value of $\kappa_y$. In this case, the hypothesis of the model concurs with the evidence of the loss of the predictive power of the term spread following a strong policy response to inflation. The hypothesis also corresponds with the only robust pattern in the empirical evidence of the decline of $\kappa_y$ with horizon.

---

Did the stronger policy response to inflation result in the fall in the information content in the term spread? Or is it the decrease in the variances of the supply shock and the demand shock that derive these results? Or was there a change in the persistence of these shocks? This is an empirical question. Further, the answers could be different for different countries.

Some limited empirical support can be found in Siklos (2000). The results suggest that in New Zealand during the period of emphasis on inflation targeting, the interest rate spread has a significant negative effect on future economic growth at short horizon.

3.8 Conclusions

There has been a keen interest in term spreads as leading indicators of economic activity. This interest seems to have evolved, at least partly, due to the deterioration in 1970's and early 1980's of the forecasts of output and inflation based on monetary aggregates. The numerous studies such as Mishkin (1990a, 1990b, 1991), Stock and Watson (1989), Estrella and Hardouvelis (1991), Plosser and Rouwenhorst (1994), to name a few, have found evidence of significant forecasting ability of the term spread for future real activity and inflation. The adage that an inverted yield curve signals a recession and an upward-sloping yield curve precedes an expansion is widely accepted. However, only recently some researchers including Estrella (1997), Estrella and Mishkin (1997b), Smets and Tsatsaronis (1997) have expressed concerns regarding the stability of the relationship between the term spread and future economic activity.

I reach similar conclusions in this paper. The empirical evidence based on a wider set of countries indeed suggests that this relationship varies across countries and across time periods. However, the notable difference between the earlier studies and this paper is the occasional finding of a negative regression coefficient in this empirical relationship. Further, there appears to be a sharp decline in the predictive power of the term spread, particularly for future output growth, in the countries adopting monetary policy with a stronger response to inflation.
To investigate the underlying economic reasons, I explicitly model the information content of the term spread for future output growth based on a forward-looking structural model. The model is then calibrated heuristically by assigning different values to the structural parameters. These simulations suggest that the forecasting ability of the term spread seems to change with a change in the persistence and the variance of the underlying economic shocks and the monetary policy preferences. In fact for some parameter values, the relationship between the term spread and future output growth can even become negative.

The earlier literature, such as Estrella (1997) and Kotlan (2001), has focused mainly on the monetary policy parameters. This paper appears to be the first one to point out the importance of the persistence and the variance of the shocks. The simulations of the model imply that the information content in the term spread depends mainly on the persistence of the underlying economic shocks rather than the policy parameters. The latter appears to affect only the size of the coefficients of the variance of the shocks rather than their sign, in the probability limit of the regression coefficient. Further, the term premium shock seems to have more interesting implications for the forecasting ability of the term spread.

A stronger policy response to inflation together with a fall in the persistence of the supply shock may reduce the information content of the term spread for future output growth. Is this the story behind the observed loss of the forecasting ability of the term spread during the last decade? Or is a decline in the variance of the underlying shocks the reason? Or is the relatively higher variance of the term premium shock the driving force behind these results? This is an empirical issue with lot of research potential.

It would be interesting to verify the economic reasons behind the recent decline in the information content of the term spread. However, it seems to be a daunting exercise. Many of the earlier attempts in the literature to fit a small forward-looking structural model to the data have not been very successful.
3.9 References


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### Table 3.1
Predictive power for output growth: Full sample period

<table>
<thead>
<tr>
<th>Country</th>
<th>$K=6$</th>
<th>12</th>
<th>18</th>
<th>24</th>
<th>30</th>
<th>36</th>
<th>39</th>
<th>42</th>
<th>45</th>
<th>48</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Austria</strong></td>
<td>0.98</td>
<td>0.79 *</td>
<td>0.79**</td>
<td>0.78**</td>
<td>0.77**</td>
<td>0.68**</td>
<td>0.63**</td>
<td>0.56**</td>
<td>0.51**</td>
<td>0.45**</td>
</tr>
<tr>
<td><strong>Belgium</strong></td>
<td>1.13 *</td>
<td>1.03**</td>
<td>0.66 *</td>
<td>0.66**</td>
<td>0.61**</td>
<td>0.60**</td>
<td>0.57**</td>
<td>0.57**</td>
<td>0.51**</td>
<td>0.46**</td>
</tr>
<tr>
<td><strong>Canada</strong></td>
<td>1.93**</td>
<td>1.82**</td>
<td>1.57**</td>
<td>1.28**</td>
<td>1.02**</td>
<td>0.83**</td>
<td>0.74**</td>
<td>0.65**</td>
<td>0.57**</td>
<td>0.50**</td>
</tr>
<tr>
<td><strong>France</strong></td>
<td>1.86**</td>
<td>1.80**</td>
<td>1.29**</td>
<td>0.91**</td>
<td>0.61**</td>
<td>0.52**</td>
<td>0.50**</td>
<td>0.48**</td>
<td>0.45**</td>
<td>0.42**</td>
</tr>
<tr>
<td><strong>Germany</strong></td>
<td>1.27**</td>
<td>1.25**</td>
<td>1.13**</td>
<td>0.93**</td>
<td>0.67**</td>
<td>0.54 *</td>
<td>0.50 *</td>
<td>0.48 *</td>
<td>0.47 *</td>
<td>0.44 *</td>
</tr>
<tr>
<td><strong>Ireland</strong></td>
<td>0.49 *</td>
<td>0.33</td>
<td>0.09</td>
<td>0.02</td>
<td>-0.12</td>
<td>-0.16</td>
<td>-0.1</td>
<td>-0.11</td>
<td>-0.09</td>
<td>-0.14</td>
</tr>
<tr>
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\[ YG_K = \alpha + \kappa (I_T - i_i) + \mu_{i+K} \]

$YG_K$ is the annualized percentage growth of output over $t+k$ periods where $Y$ is measured by index of industrial production, $I_T$ = long-term nominal interest rate measured by the yield on ten year Government bond, $i_i$ = short-term nominal interest rate measured by the yield on three month Treasury Bill and if unavailable, by money market rate, $K$ = time horizon in months

Estimation by OLS with Newey-West standard errors correction for MA serial correlation for k-1 lags

** and * denote significance of 1% and 5% respectively.

Table 3.2
Predictive power for output growth: Smaller sample period.

\[ YG_K = \alpha + \kappa_T (I_T - i_s) + \mu_{T+K} \]

YGK = the annualized percentage growth of output over t+k periods where Y is measured by index of industrial production., \( I_T \) = long-term nominal interest rate measured by the yield on ten year Government bond., \( i_s \) = short-term nominal interest rate measured by the yield on three month Treasury Bill and if unavailable, by money market rate , K=time horizon in months

Estimation by OLS with Newey-West standard errors correction for MA serial correlation for k-1 lags

** and * denote significance of 1% and 5% respectively.

a:- sample endpoint 1998:12 ; b:- sample endpoint 2000:12
Table 3.2 continued

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Predictive power for output growth: Smaller sample period.
Figure 3.1
Coefficient of variances in the benchmark model

\[ Y_1 = \text{Cov}(y_{t+1} - y_t, I_t - i_t); \quad Y_2 = \text{Cov}(y_{t+2} - y_t, I_t - i_t) \]
\[ Y_3 = \text{Cov}(y_{t+3} - y_t, I_t - i_t); \quad Y_4 = \text{Cov}(y_{t+4} - y_t, I_t - i_t) \]
\[ TS = \text{Var}(I_t - i_t) \]

Benchmark structural parameters:
\[ \beta = 0.99; \gamma = 0.3; \delta = 0.4; \rho = 0.8; \lambda_1 = 1.5; \lambda_2 = 0.5; \phi_1 = 0.8; \phi_2 = 0.8; \phi_3 = 0.4; \phi_4 = 0.8 \]

\[ k_y = \frac{\text{Cov}}{\text{Var}} = \frac{n1 \cdot \sigma_y^2 + n2 \cdot \sigma_d^2 + n3 \cdot \sigma_z^2 + n4 \cdot \sigma_{\varphi}^2}{d1 \cdot \sigma_y^2 + d2 \cdot \sigma_d^2 + d3 \cdot \sigma_z^2 + d4 \cdot \sigma_{\varphi}^2} \]
Figure 3.2
Change in covariance due to change in policy response to inflation

\[
Y_1 = \text{Cov}(y_{t+1} - y_t, I_t - i_t); \quad Y_2 = \text{Cov}(y_{t+2} - y_t, I_t - i_t) \\
Y_3 = \text{Cov}(y_{t+3} - y_t, I_t - i_t); \quad Y_4 = \text{Cov}(y_{t+4} - y_t, I_t - i_t) \\
TS = \text{Var}(I_t - i_t)
\]

Structural parameters:
\[
\beta = 0.99; \gamma = 0.3; \delta = 0.4; \rho = 0.8; \lambda_2 = 0.5; \phi_1 = 0.8; \phi_2 = 0.8; \phi_3 = 0.4; \phi_4 = 0.8
\]

\[
k_y = \frac{\text{Cov}}{\text{Var}} = \frac{n_1 \sigma_z^2 + n_2 \sigma_d^2 + n_3 \sigma_c^2 + n_4 \sigma_q^2}{d_1 \sigma_z^2 + d_2 \sigma_d^2 + d_3 \sigma_c^2 + d_4 \sigma_q^2}
\]
Figure 3.3
Change in covariance due to change in persistence of shocks

\[ Y_1 = \text{Cov}(y_{1t+1} - y_t, I_t - i_t) \; ; \; Y_2 = \text{Cov}(y_{2t+1} - y_t, I_t - i_t) \]
\[ Y_3 = \text{Cov}(y_{3t+1} - y_t, I_t - i_t) \; ; \; Y_4 = \text{Cov}(y_{4t+1} - y_t, I_t - i_t) \]

Benchmark structural parameters:
\[ \beta = 0.99; \gamma = 0.3; \delta = 0.4; \rho = 0.8; \lambda_1 = 1.5; \lambda_2 = 0.5; \phi_1 = 0.8; \phi_2 = 0.8; \phi_3 = 0.4; \phi_4 = 0.8 \]

\[ k_y = \frac{\text{Cov}}{\text{Var}} = \frac{n1 \sigma_s^2 + n2 \sigma_d^2 + n3 \sigma_z^2 + n4 \sigma_{\epsilon p}^2}{d1 \sigma_s^2 + d2 \sigma_d^2 + d3 \sigma_z^2 + d4 \sigma_{\epsilon p}^2} \]
Change in covariance due to change in persistence of shocks
Figure 3.4
Persistence of supply shock and policy response to inflation

\[ Y_1 = \text{Cov}(y_{mt} - y_t, I_t - i_t) \]

\[ TS = \text{Var}(I_t - i_t) \]

Structural parameters:
\[ \beta = 0.99; \gamma = 0.3; \delta = 0.4; \rho = 0.8; \lambda_1 = 1.5; \lambda_2 = 0.5; \phi_2 = 0.8; \phi_3 = 0.4; \phi_4 = 0.8 \]

\[
k_y = \frac{\text{Cov}}{\text{Var}} = \frac{n_1 \sigma_y^2 + n_2 \sigma_d^2 + n_3 \sigma_z^2 + n_4 \sigma_q^2}{d_1 \sigma_y^2 + d_2 \sigma_d^2 + d_3 \sigma_z^2 + d_4 \sigma_q^2}
\]
Figure 3.5
Persistence of supply shock and policy response to output

\[ Y_1 = \text{Cov}(y_{t+1}, y_t, I_t - i_t) \]
\[ TS = \text{Var}(I_t - i_t) \]

Structural parameters:
\[ \beta = 0.99; \gamma = 0.3; \delta = 0.4; \rho = 0.8; \lambda_1 = 1.5; \lambda_2 = 0.5; \phi_2 = 0.8; \phi_3 = 0.4; \phi_4 = 0.8 \]

\[ k_y = \frac{\text{Cov}}{\text{Var}} = \frac{n1*\sigma_y^2 + n2*\sigma_d^2 + n3*\sigma_z^2 + n4*\sigma_{\eta_y}^2}{d1*\sigma_y^2 + d2*\sigma_d^2 + d3*\sigma_z^2 + d4*\sigma_{\eta_y}^2} \]
Figure 3.6
Persistence of demand shock and policy response to inflation

\[ Y_1 = \text{Cov}(y_{t+1} - y_t, I_t - i_t) \]
\[ TS = \text{Var}(I_t - i_t) \]

Structural parameters:
\[ \beta = 0.99; \gamma = 0.3; \delta = 0.4; \rho = 0.8; \lambda_1 = 1.5; \lambda_2 = 0.5; \phi_1 = 0.8; \phi_3 = 0.4; \phi_4 = 0.8 \]

\[
 k_y = \frac{\text{Cov}}{\text{Var}} = \frac{n_1 \sigma_d^2 + n_2 \sigma_d^2 + n_3 \sigma_z^2 + n_4 \sigma_{\nu}^2}{d_1 \sigma_d^2 + d_2 \sigma_d^2 + d_3 \sigma_z^2 + d_4 \sigma_{\nu}^2}
\]
Figure 3.7
Persistence of policy shock and policy response to inflation

\[ Y_1 = \text{Cov}(y_{t+1} - y_t, I_t - i_t) \]
\[ TS = \text{Var}(I_t - i_t) \]

Structural parameters:
\[ \beta = 0.99; \gamma = 0.3; \delta = 0.4; \rho = 0.8; \lambda_1 = 1.5; \lambda_2 = 0.5; \phi_1 = 0.8; \phi_2 = 0.8; \phi_3 = 0.8 \]

\[ k_y = \frac{\text{Cov}}{\text{Var}} = \frac{n1 \cdot \sigma_i^2 + n2 \cdot \sigma_d^2 + n3 \cdot \sigma_z^2 + n4 \cdot \sigma_{\phi}^2}{d1 \cdot \sigma_i^2 + d2 \cdot \sigma_d^2 + d3 \cdot \sigma_z^2 + d4 \cdot \sigma_{\phi}^2} \]
Figure 3.8
Persistence of term premium shock and policy response to inflation

\[ Y_1 = \text{Cov}(y_{t+1} - y_t, I_t - i_t) \]
\[ \text{TS} = \text{Var}(I_t - i_t) \]

Benchmark structural parameters:
\[ \beta = 0.99; \gamma = 0.3; \delta = 0.4; \rho = 0.8; \lambda_1 = 1.5; \lambda_2 = 0.5; \phi_1 = 0.8; \phi_2 = 0.8; \phi_3 = 0.4; \phi_4 = 0.8 \]

\[ k_y = \frac{\text{Cov}}{\text{Var}} = \frac{n_1 \sigma_s^2 + n_2 \sigma_d^2 + n_3 \sigma_z^2 + n_4 \sigma_{qp}^2}{d_1 \sigma_s^2 + d_2 \sigma_d^2 + d_3 \sigma_z^2 + d_4 \sigma_{qp}^2} \]
Table 3.3
Theoretical predictive power: Covariance of one period output growth.

\[ k_{y_{t+1}} = \frac{Cov(y_{t+1} - y_t, I_t - i_t)}{Var(I_t - i_t)} = \frac{n_1 \sigma_z^2 + n_2 \sigma_d^2 + n_3 \sigma_s^2 + n_4 \sigma_{sp}^2}{d_1 \sigma_z^2 + d_2 \sigma_d^2 + d_3 \sigma_s^2 + d_4 \sigma_{sp}^2} \]

Using the structural parameters, with the Method of Undetermined Coefficients I get the basic solution to the system i.e. the parameters for equations [10] and [11]. Then using these parameters, I calculate the coefficients of the variances of supply, demand, monetary policy and term premium shocks in the theoretical regression coefficient. In each subsequent case, the value of one of the structural parameters is changed. Benchmark structural parameters:
\[ \beta = 0.99; \gamma = 0.3; \delta = 0.4; \rho = 0.8; \lambda_1 = 1.5; \lambda_2 = 0.5; \phi_1 = 0.8; \phi_2 = 0.8; \phi_3 = 0.4; \phi_4 = 0.8 \]
Baseline structural parameters
\[ \beta = 0.99; \gamma = 0.3; \delta = 0.4; \rho = 0.8; \lambda_1 = 1.5; \lambda_2 = 0.5; \phi_1 = \phi_2 = \phi_3 = \phi_4 = 0 \]
Table 3.4
Theoretical predictive power: Covariance of two period output growth.

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<tr>
<td>$\phi_4 = 0.4$</td>
<td>0.291</td>
<td>-0.317</td>
<td>-0.018</td>
<td>0.362</td>
</tr>
<tr>
<td>$\gamma = 0.05$</td>
<td>1.332</td>
<td>-0.322</td>
<td>-0.015</td>
<td>0.477</td>
</tr>
<tr>
<td>$\gamma = 1.22$</td>
<td>0.028</td>
<td>-0.160</td>
<td>-0.012</td>
<td>0.336</td>
</tr>
<tr>
<td>$\delta = 1.0$</td>
<td>0.132</td>
<td>-0.076</td>
<td>-0.035</td>
<td>0.842</td>
</tr>
<tr>
<td>$\rho = 0.4$</td>
<td>0.015</td>
<td>-0.010</td>
<td>-0.047</td>
<td>0.406</td>
</tr>
</tbody>
</table>

Using the structural parameters, with the Method of Undetermined Coefficients I get the basic solution to the system i.e. the parameters for equations [10] and [11]. Then using these parameters, I calculate the coefficients of the variances of supply, demand, monetary policy and term premium shocks in the theoretical regression coefficient. In each subsequent case, the value of one of the structural parameters is changed. Benchmark structural parameters:

$\beta = 0.99; \gamma = 0.3; \delta = 0.4; \rho = 0.8; \lambda_1 = 1.5; \lambda_2 = 0.5; \phi_1 = 0.8; \phi_2 = 0.8; \phi_3 = 0.4; \phi_4 = 0.8$

Baseline structural parameters:

$\beta = 0.99; \gamma = 0.3; \delta = 0.4; \rho = 0.8; \lambda_1 = 1.5; \lambda_2 = 0.5; \phi_1 = \phi_2 = \phi_3 = \phi_4 = 0$
### Table 3.5
Theoretical predictive power: Covariance of three period output growth.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>n1</th>
<th>n2</th>
<th>n3</th>
<th>n4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>-0.115</td>
<td>0.279</td>
<td>-0.051</td>
<td>0.388</td>
</tr>
<tr>
<td>Benchmark</td>
<td>0.547</td>
<td>-0.383</td>
<td>-0.024</td>
<td>0.503</td>
</tr>
<tr>
<td>( \lambda_1 = 2.0 )</td>
<td>0.699</td>
<td>-0.352</td>
<td>-0.023</td>
<td>0.471</td>
</tr>
<tr>
<td>( \lambda_1 = 1.0 )</td>
<td>0.317</td>
<td>-0.417</td>
<td>-0.026</td>
<td>0.547</td>
</tr>
<tr>
<td>( \lambda_2 = 1.0 )</td>
<td>0.410</td>
<td>-0.337</td>
<td>-0.023</td>
<td>0.457</td>
</tr>
<tr>
<td>( \lambda_2 = 0 )</td>
<td>0.742</td>
<td>-0.428</td>
<td>-0.025</td>
<td>0.566</td>
</tr>
<tr>
<td>( \lambda_1 = 2.0, \lambda_2 = 1.0 )</td>
<td>0.556</td>
<td>-0.309</td>
<td>-0.021</td>
<td>0.434</td>
</tr>
<tr>
<td>( \lambda_1 = \lambda_2 = 1.0 )</td>
<td>0.197</td>
<td>-0.368</td>
<td>-0.025</td>
<td>0.487</td>
</tr>
<tr>
<td>( \lambda_1 = 1.0, \lambda_2 = 0 )</td>
<td>0.521</td>
<td>-0.459</td>
<td>-0.025</td>
<td>0.637</td>
</tr>
<tr>
<td>( \phi_1 = 0.4 )</td>
<td>-0.128</td>
<td>-0.383</td>
<td>-0.024</td>
<td>0.503</td>
</tr>
<tr>
<td>( \phi_1 = 0.2 )</td>
<td>-0.134</td>
<td>-0.383</td>
<td>-0.024</td>
<td>0.503</td>
</tr>
<tr>
<td>( \phi_2 = 0.4 )</td>
<td>0.547</td>
<td>0.137</td>
<td>-0.024</td>
<td>0.503</td>
</tr>
<tr>
<td>( \phi_2 = 0.2 )</td>
<td>0.547</td>
<td>0.219</td>
<td>-0.024</td>
<td>0.503</td>
</tr>
<tr>
<td>( \phi_3 = 0.2 )</td>
<td>0.547</td>
<td>-0.383</td>
<td>-0.041</td>
<td>0.503</td>
</tr>
<tr>
<td>( \phi_4 = 0.2 )</td>
<td>0.547</td>
<td>-0.383</td>
<td>-0.024</td>
<td>0.384</td>
</tr>
<tr>
<td>( \gamma = 0.05 )</td>
<td>2.759</td>
<td>-0.406</td>
<td>-0.022</td>
<td>0.601</td>
</tr>
<tr>
<td>( \gamma = 1.22 )</td>
<td>0.048</td>
<td>-0.182</td>
<td>-0.015</td>
<td>0.381</td>
</tr>
<tr>
<td>( \delta = 1.0 )</td>
<td>0.251</td>
<td>-0.087</td>
<td>-0.044</td>
<td>0.967</td>
</tr>
<tr>
<td>( \rho = 0.4 )</td>
<td>0.024</td>
<td>-0.012</td>
<td>-0.058</td>
<td>0.500</td>
</tr>
</tbody>
</table>

Using the structural parameters, with the Method of Undetermined Coefficients I get the basic solution to the system i.e. the parameters for equations [10] and [11]. Then using these parameters, I calculate the coefficients of the variances of supply, demand, monetary policy and term premium shocks in the theoretical regression coefficient. In each subsequent case, the value of one of the structural parameters is changed.

**Benchmark structural parameters:**
- \( \beta = 0.99; \gamma = 0.3; \delta = 0.4; \rho = 0.8; \lambda_1 = 1.5; \lambda_2 = 0.5; \phi_1 = 0.8; \phi_2 = 0.8; \phi_3 = 0.4; \phi_4 = 0.8 \)

**Baseline structural parameters:**
- \( \beta = 0.99; \gamma = 0.3; \delta = 0.4; \rho = 0.8; \lambda_1 = 1.5; \lambda_2 = 0.5; \phi_1 = \phi_2 = \phi_3 = \phi_4 = 0 \)
Table 3.6
Theoretical predictive power: Covariance of four period output growth.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>n1</th>
<th>n2</th>
<th>n3</th>
<th>n4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>-0.127</td>
<td>0.274</td>
<td>-0.056</td>
<td>0.381</td>
</tr>
<tr>
<td>Benchmark</td>
<td>0.802</td>
<td>-0.421</td>
<td>-0.028</td>
<td>0.553</td>
</tr>
<tr>
<td>$\lambda_1 = 2.0$</td>
<td>0.987</td>
<td>-0.384</td>
<td>-0.026</td>
<td>0.514</td>
</tr>
<tr>
<td>$\lambda_1 = 1.0$</td>
<td>0.513</td>
<td>-0.462</td>
<td>-0.030</td>
<td>0.606</td>
</tr>
<tr>
<td>$\lambda_2 = 1.0$</td>
<td>0.616</td>
<td>-0.366</td>
<td>-0.027</td>
<td>0.497</td>
</tr>
<tr>
<td>$\lambda_2 = 0$</td>
<td>1.060</td>
<td>-0.477</td>
<td>-0.029</td>
<td>0.630</td>
</tr>
<tr>
<td>$\lambda_1 = 2.0, \lambda_2 = 1.0$</td>
<td>0.795</td>
<td>-0.335</td>
<td>-0.025</td>
<td>0.469</td>
</tr>
<tr>
<td>$\lambda_1 = \lambda_2 = 1.0$</td>
<td>0.350</td>
<td>-0.403</td>
<td>-0.029</td>
<td>0.533</td>
</tr>
<tr>
<td>$\lambda_1 = 1.0, \lambda_2 = 0$</td>
<td>0.780</td>
<td>-0.517</td>
<td>-0.030</td>
<td>0.717</td>
</tr>
<tr>
<td>$\phi_1 = 0.4$</td>
<td>-0.154</td>
<td>-0.421</td>
<td>-0.028</td>
<td>0.553</td>
</tr>
<tr>
<td>$\phi_1 = 0.2$</td>
<td>-0.152</td>
<td>-0.421</td>
<td>-0.028</td>
<td>0.553</td>
</tr>
<tr>
<td>$\phi_2 = 0.4$</td>
<td>0.802</td>
<td>0.138</td>
<td>-0.028</td>
<td>0.553</td>
</tr>
<tr>
<td>$\phi_2 = 0.2$</td>
<td>0.802</td>
<td>0.215</td>
<td>-0.028</td>
<td>0.553</td>
</tr>
<tr>
<td>$\phi_3 = 0.2$</td>
<td>0.802</td>
<td>-0.421</td>
<td>-0.046</td>
<td>0.553</td>
</tr>
<tr>
<td>$\phi_4 = 0.4$</td>
<td>0.802</td>
<td>-0.421</td>
<td>-0.028</td>
<td>0.358</td>
</tr>
<tr>
<td>$\gamma = 0.05$</td>
<td>4.275</td>
<td>-0.461</td>
<td>-0.026</td>
<td>0.653</td>
</tr>
<tr>
<td>$\gamma = 1.22$</td>
<td>0.065</td>
<td>-0.191</td>
<td>-0.017</td>
<td>0.402</td>
</tr>
<tr>
<td>$\delta = 1.0$</td>
<td>0.362</td>
<td>-0.092</td>
<td>-0.049</td>
<td>1.025</td>
</tr>
<tr>
<td>$\rho = 0.4$</td>
<td>0.032</td>
<td>-0.014</td>
<td>-0.064</td>
<td>0.568</td>
</tr>
</tbody>
</table>

\[
k_{y4} = \frac{\text{Cov}(y_{t+4} - y_t, I_t - i_t)}{\text{Var}(I_t - i_t)} = \frac{n1*\sigma^2 + n2*\sigma^2_d + n3*\sigma^2 + n4\sigma^2_p}{d1*\sigma^2 + d2*\sigma^2_d + d3*\sigma^2 + d4\sigma^2_p}
\]

Using the structural parameters, with the Method of Undetermined Coefficients I get the basic solution to the system i.e. the parameters for equations [10] and [11]. Then using these parameters, I calculate the coefficients of the variances of supply, demand, monetary policy and term premium shocks in the theoretical regression coefficient. In each subsequent case, the value of one of the structural parameters is changed.

Benchmark structural parameters:
$\beta = 0.99, \gamma = 0.3; \delta = 0.4; \rho = 0.8; \lambda_1 = 1.5; \lambda_2 = 0.5; \phi_1 = 0.8; \phi_2 = 0.8; \phi_3 = 0.4; \phi_4 = 0.8$

Baseline structural parameters
$\beta = 0.99, \gamma = 0.3; \delta = 0.4; \rho = 0.8; \lambda_1 = 1.5; \lambda_2 = 0.5; \phi_1 = \phi_2 = \phi_3 = \phi_4 = 0$
Using the structural parameters, with the Method of Undetermined Coefficients I get the basic solution to the system i.e. the parameters for equations [11] and [12]. Then using these parameters, I calculate the coefficients of the variances of supply, demand, monetary policy and term premium shocks in the theoretical regression coefficient. In each subsequent case, the value of one of the structural parameters is changed.

**Benchmark structural parameters:**
- $\beta = 0.99; \gamma = 0.3; \delta = 0.4; \rho = 0.8; \lambda_1 = 1.5; \lambda_2 = 0.5; \phi_1 = 0.8; \phi_2 = 0.8; \phi_3 = 0.4; \phi_4 = 0.8$

**Baseline structural parameters**
- $\beta = 0.99; \gamma = 0.3; \delta = 0.4; \rho = 0.8; \lambda_1 = 1.5; \lambda_2 = 0.5; \phi_1 = \phi_2 = \phi_3 = \phi_4 = 0$

### Table 3.7
**Theoretical predictive power: Variance of term spread**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>$d1$</th>
<th>$d2$</th>
<th>$d3$</th>
<th>$d4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0.263</td>
<td>0.106</td>
<td>0.117</td>
<td>1.277</td>
</tr>
<tr>
<td>Benchmark</td>
<td><strong>0.671</strong></td>
<td><strong>0.204</strong></td>
<td><strong>0.016</strong></td>
<td><strong>2.208</strong></td>
</tr>
<tr>
<td>$\lambda_1 = 2.0$</td>
<td>0.674</td>
<td>0.198</td>
<td>0.017</td>
<td>2.216</td>
</tr>
<tr>
<td>$\lambda_1 = 1.0$</td>
<td>0.630</td>
<td>0.205</td>
<td>0.014</td>
<td>2.207</td>
</tr>
<tr>
<td>$\lambda_2 = 1.0$</td>
<td>0.562</td>
<td>0.193</td>
<td>0.018</td>
<td>2.223</td>
</tr>
<tr>
<td>$\lambda_2 = 0$</td>
<td>0.784</td>
<td>0.203</td>
<td>0.013</td>
<td>2.210</td>
</tr>
<tr>
<td>$\lambda_1 = 2.0, \lambda_2 = 1.0$</td>
<td>0.561</td>
<td>0.182</td>
<td>0.018</td>
<td>2.238</td>
</tr>
<tr>
<td>$\lambda_1 = \lambda_2 = 1.0$</td>
<td>0.535</td>
<td>0.202</td>
<td>0.017</td>
<td>2.211</td>
</tr>
<tr>
<td>$\lambda_1 = 1.0, \lambda_2 = 0$</td>
<td>0.720</td>
<td>0.186</td>
<td>0.010</td>
<td>2.233</td>
</tr>
<tr>
<td>$\phi_1 = 0.4$</td>
<td>0.108</td>
<td>0.204</td>
<td>0.016</td>
<td>2.208</td>
</tr>
<tr>
<td>$\phi_1 = 0.2$</td>
<td>0.213</td>
<td>0.204</td>
<td>0.016</td>
<td>2.208</td>
</tr>
<tr>
<td>$\phi_2 = 0.4$</td>
<td>0.671</td>
<td>0.027</td>
<td>0.016</td>
<td>2.208</td>
</tr>
<tr>
<td>$\phi_2 = 0.2$</td>
<td>0.671</td>
<td>0.068</td>
<td>0.016</td>
<td>2.208</td>
</tr>
<tr>
<td>$\phi_3 = 0.2$</td>
<td>0.671</td>
<td>0.204</td>
<td>0.059</td>
<td>2.208</td>
</tr>
<tr>
<td>$\phi_4 = 0.4$</td>
<td>0.671</td>
<td>0.204</td>
<td>0.016</td>
<td>1.339</td>
</tr>
<tr>
<td>$\gamma = 0.05$</td>
<td>5.181</td>
<td>0.165</td>
<td>0.008</td>
<td>2.263</td>
</tr>
<tr>
<td>$\gamma = 1.22$</td>
<td>0.023</td>
<td>0.087</td>
<td>0.014</td>
<td>2.398</td>
</tr>
<tr>
<td>$\delta = 1.0$</td>
<td>0.086</td>
<td>0.019</td>
<td>0.017</td>
<td>2.338</td>
</tr>
<tr>
<td>$\rho = 0.4$</td>
<td>0.001</td>
<td>0.000</td>
<td>0.104</td>
<td>2.757</td>
</tr>
</tbody>
</table>

Using the structural parameters, with the Method of Undetermined Coefficients I get the basic solution to the system i.e. the parameters for equations [11] and [12]. Then using these parameters, I calculate the coefficients of the variances of supply, demand, monetary policy and term premium shocks in the theoretical regression coefficient. In each subsequent case, the value of one of the structural parameters is changed.

**Benchmark structural parameters:**
- $\beta = 0.99; \gamma = 0.3; \delta = 0.4; \rho = 0.8; \lambda_1 = 1.5; \lambda_2 = 0.5; \phi_1 = 0.8; \phi_2 = 0.8; \phi_3 = 0.4; \phi_4 = 0.8$

**Baseline structural parameters**
- $\beta = 0.99; \gamma = 0.3; \delta = 0.4; \rho = 0.8; \lambda_1 = 1.5; \lambda_2 = 0.5; \phi_1 = \phi_2 = \phi_3 = \phi_4 = 0$
### 3.12 Data appendix

<table>
<thead>
<tr>
<th>Country</th>
<th>Sample</th>
<th>Data Description</th>
</tr>
</thead>
</table>

All the data from the IFS-CD-ROM June 2001.
4.1 Introduction

New Keynesian optimizing model has been recently on the forefront of the macroeconomic literature. It is widely applied, particularly, in the monetary policy analysis by Rotemberg and Woodford (1997, 1999), McCallum and Nelson (1999a, 1999b), King and Wolman (1999), Clarida, Gali and Gertler (1998, 1999) among many others. The Keynesian assumption of sticky price along with behavioral equations based on the micro-foundations and rational expectations are very appealing. However, most of these models incorporate the short term real interest rate in the aggregate demand equation or the IS curve.

The short term nominal interest rate is widely acknowledged as an instrument of monetary policy. The policy stance is reflected in the long term interest rate through the term structure of market interest rates. And this long term market rate crucially influences investment and consumption decisions. Thus, the interest rate channel of the monetary transmission works via the term structure. However, the New Keynesian models proposed in the literature largely abstract from the term structure relationship.

Term structure models are based on the two strands in the literature. The Expectations Hypothesis of Term Structure (EHTS) relates the long term interest rate to current and expected future short term rates.
The models in the other strand are based on the general equilibrium framework of the Consumption-Capital Asset Pricing Model (C-CAPM) and Asset Pricing Theory (APT). These models relate asset prices and interest rates to the first and second moments of the state variables of the economy.

This paper seeks to integrate New Keynesian model and the model of the term structure with a time-varying term premium endogenous to the model. This is a more plausible description of the economy compared to the earlier models. In this model, output responds to an interest rate that includes a time varying term premium, which in turn is associated with economic agents’ expectations about the future economic variables. Thus, aggregate demand reacts not only to monetary policy actions but also expectations of the future state of the economy.

New Keynesian models are often used in monetary policy analysis to give recommendations regarding optimal monetary policy. Hence it is important that such models portray a better understanding of the economy.

I find evidence that the output response to the long term interest is larger than its response to short term rates. Further, output is sensitive to the unobservable term premium contained in the long term interest rate as well as to the expected average of short rates. Drawing support from this evidence, I propose a structural model within the New Keynesian framework. This model consists of a New Keynesian Phillips curve (NKPC), an IS curve, a monetary policy reaction function and the expectations hypothesis augmented with a time varying term premium. I model this term premium as a function of the conditional volatility of output and inflation.

Estimation of the model obtains a limited success. Except for the NKPC, the results from the estimation of the IS curve, policy function and the modified Expectations Hypothesis support the model. As claimed in the literature, the failure of NKPC could be attributed to the lack of appropriate measure of the driving variable. Economic uncertainties, particularly output volatility, are important sources of the time varying term premium. Interestingly, the empirical results imply a plausible value of the coefficient of relative risk aversion.
On the whole, the estimation results along with the theoretical underpinnings offer a large potential of this model for policy analysis.

The paper is organized as follow. Section 4.2 briefly discusses the development of New Keynesian models in the literature. The dynamics of output and the interest rate associated with output decisions are examined in the section 4.3. Section 4.4 presents a small structural model of the economy. A model of the time varying term premium based on the underlying economic variables is developed in section 4.5. This structural model is estimated in Section 4.6. The last section presents concluding remarks.

4.2 Related literature

In last few years New Keynesian or monetary business cycle models have attracted much attention in the macroeconomic literature. These models are essentially an amalgamation of the dynamic general equilibrium models and Keynesian models of sticky price and nominal rigidities.

King and Wolman (1996), Rotemberg and Woodford (1997), McCallum and Nelson (1999a, 1999b) developed small structural models that incorporate explicit rational expectations, optimizing behavior and frictions that allow monetary policy to have real effects.

These models are built on the earlier work by Taylor (1980), Calvo (1983) and Fischer (1997) among others that emphasized staggered nominal wage and price setting by forward looking consumers and firms. Quadratic adjustment cost was proposed to be another motivation for sticky prices by Rotemberg (1982). The aggregation of the price setting decisions of the individual firms gives rise to the inflation dynamics called the ‘New Keynesian Phillips curve’.

The aggregate demand in the economy described by the IS curve is based on the individual household’s optimal saving decisions and the market clearing conditions.
The third building block of these simple models is the monetary policy rule similar in the spirit to rule proposed by Taylor (1993). Svensson (1996), Bernanke and Woodford (1997) and Clarida, Gali and Gertler (1998) among others, derive policy rules for a central bank with quadratic loss function in inflation and output deviations from their targets.

Thus, a baseline New Keynesian model consists of three equations.

\[
\begin{align*}
\pi_t &= \beta E_t \pi_{t+1} + \gamma y_t \\
\gamma_t &= E_{t+1} \pi_{t+1} - \delta(i_t - E\pi_{t+1}) \\
\lambda_t &= \rho r_{t-1} + \lambda_1 \pi_t + \lambda_2 y_t
\end{align*}
\]

where \( \pi_t \) is the inflation rate between period t-1 and t, \( y_t \) is the output gap and \( r_t \) is the short term nominal interest rate, which is the policy instrument.

Despite its theoretical appeal, this model has not met significant empirical success\(^{20}\). There is no consensus on the empirical validity of the purely forward looking New Keynesian Phillip's curve. Rotemberg and Woodford (1997) argue that allowing a serially correlated error term permits the model with pure rational expectations to fit the US data well over the post-1979 period. On the other hand, Fuhrer and Moor (1995a) among many others argue that purely forward looking NKPC does not fit the post-war U.S. data.

Fuhrer and Moor (1995a), Fuhrer (1997) and Roberts (1997, 2001) show that a modified model with lagged inflation fits the U.S data better than a fully rational expectations model. Since then many researchers have adopted a hybrid version of NKPC

\[
\pi_t = \beta E_t \pi_{t+1} + (1-\beta)\pi_{t-1} + \gamma y_t
\]

\(^{20}\) Estrella and Fuhrer (2002) illustrate the 'jump variable' behavior or a lack of inertia of the rational expectations models that generate dynamic inconsistencies with the data.
The motivation behind the hybrid approach is largely empirical though a few justifications have been put forward for the additional lags of inflation not implied by the standard theory. Fuhrer and Moor (1995a) appeal to the relative wage hypothesis while Roberts (2001) appeals to 'rule of thumb' price setting by a section of the economy or the so called 'less-than rational expectations'.

However, even the hybrid Phillip's curve has met with rather limited empirical success. The estimated coefficients of the driving variable in the NKPC (i.e. the output gap) have been insignificant or have had the wrong sign. Sbordone (1999), Gertler and Gali (1999) and Gertler, Gali and Lopez-Salido (2000) assign the empirical failure of the NKPC to the use of detrended GDP as a proxy for output gap. They offer empirical support for forward looking behavior in the NKPC based on marginal labor cost rather than the output gap.

Compared to the much discussed NKPC, New Keynesian IS curve has received less attention in the literature. In the simple model of Rotemberg and Woodford (1997), aggregate demand is based on the model of optimizing household behavior. However, output persistence is not present in this IS curve with full rational expectations. Fuhrer (2000) enhances the model of consumer behavior with habit formation process that adds significant inertia to consumption dynamics. Oliner, Rudebusch and Sichel (1995, 1996) generate inertia in investment Euler equation by adding adjustment cost and time-to-build lags to the model. Based on these approaches, McCallum and Nelson (1999), Fuhrer (2000) and Fuhrer and Rudebusch (2002) adopt hybrid models of aggregate demand similar to the hybrid NKPC.

\[ y_t = \mu E_{t+1} y_{t+1} + \left(1 - \mu \right) y_{t-1} - \delta \left( i_t - E\pi_{t+1} \right) \]

Taylor (1993) inspired the discussion of interest rate rules for monetary policy actions. He proposed a feedback rule where the policy responds to the deviation of current inflation from its target and the output gap. Fuhrer and Moor (1995a), Rotemberg and Woodford (1997) and McCallum and Nelson (1998) among others followed similar policy rules which also incorporate
partial adjustment or interest rate smoothing behavior\textsuperscript{21}. Clarida, Gali and Gertler (1998, 2000) formulate a forward-looking rule. Under this rule policy responds to expected inflation rather than current or lagged inflation. Inflation targeting, price level targeting and nominal GDP targeting are some other alternative policy rules proposed in the literature\textsuperscript{22}.

4.3 The IS curve and output Euler equation

The IS curve in a baseline New Keynesian model is derived from log-linearizing the consumption Euler equation that arises from household’s optimal saving decisions. As individuals prefer to smooth consumption, expectations of higher future consumption (associated with higher expected output) leads them to increase current consumption and hence current output demand. The intertemporal substitution of consumption results in the negative effect of the real interest rate on consumption and output.

However, Cogley and Nason (1995), Estrella and Fuhrer (1998) and Fuhrer (2000) among others find that IS curve based on a simple Euler equation has difficulty in fitting the data. The model requires some adjustment process to match the output persistence present in the data.

Fuhrer (2000) augments the model of consumer behavior with habit formation process, in which consumers’ utility depends partly on current consumption relative to past consumption. This builds an inertial response of consumption.

The “putty-clay” model and irreversibility of investment generate inertial response of output other than consumption. Oliner, Rudebusch and Sichel (1995) point out unreliable assumptions underlying typical investment Euler equations. Based on the “putty-putty’
technology, these simple equations do not distinguish between already-installed capital and capital still to be purchased. These equations expect the capital-output ratio for the entire capital stock to adjust to a change in relative prices or interest rates. However, the “putty-clay” model would not allow firms to alter capital intensity of their existing production facilities. The typical investment Euler equation also assumes investment to be fully reversible. Pindyck (1991) and others have shown that with irreversibility, investment spending adjusts sluggishly to price changes.

These assumptions also make output, particularly consumption durables and investment, sensitive to long term interest rate rather than short term interest rate.

4.3.1 Interest rate sensitivity of the output

Yet many of the New Keynesian models in the literature, with a few exceptions such as Fuhrer and Moor(1995b) and Fuhrer and Rudebusch (2002), incorporate a one period interest rate in their specification of the IS curve.

Table 4.1 examines the sensitivity of output gap to the long term interest rate. The nominal and the real components of real interest rates of different terms to maturity are included in the typical specification of the IS curve.

For the empirical specification of the aggregate demand, I add three leads and lags to the hybrid IS curve. To incorporate the sluggish adjustment of investment and demand for consumer durables to changes in interest rate, lagged values of interest rate variables are used.

\[ y_t = \alpha_y + \mu_1 \frac{1}{3} \sum_{k=1}^{3} y_{t+k} + \mu_2 \frac{1}{3} \sum_{k=1}^{3} y_{t-k} - \delta_1 (i_{t-1} - \Pi_{t-1}) - \delta_2 i_{t-n}^n + \delta_3 \Pi_{t-n}^n + d_t \]

where \( y_t \) is the output gap, \( i_t^n \) is the interest rate associated with an n period asset, \( \Pi_t^n \) is the expected annualized inflation over n periods and \( d_t \) is the disturbance to the IS curve.
The sample period for estimation is 1983:1 to 2002:12. The log of the index industrial production detrended with a quadratic trend is used as my measure of the output gap. Consumer Price Index is used to compute inflation. Six month, one year, two year and three year Treasury constant maturity rates are used as long term nominal interest rates.

The parameters of equation [2.3] are estimated with GMM. The instrument set includes a constant, time trend, 3 lags each of the output gap, inflation and the short term nominal rate.

Table 4.1 shows that both the nominal and real parts of the long term real interest rate have significant effect on the output. The output gap appears not be sensitive to one period interest rate in the presence of a longer term interest rate, except when the term of maturity of the latter is three years. This result supports the inclusion of a long term interest rate in the aggregate demand equation rather than a short term rate.

Further, the estimate of $\mu_t$ by and large increases with the term of the interest rate. Fuhrer and Rudebusch (2002) note that there can be a close relationship between the importance of forward-looking output expectations and the term of the interest rate.

4.3.2 Expectations hypothesis

The relationship between the short term and long term rate is described by the Expectations hypothesis. The pure expectations theory posits that expectations of the future course of short term interest rate are the sole determinant of the long term interest rate. This hypothesis is traditionally expressed as

$$[4.1] \quad i_t^n = \frac{1}{n} \sum_{k=0}^{n-1} E_t i_{t+k}^1 + \tau^n$$

where $i_t^n$ and $i_t^1$ are interest rates associated with $n$ and one period assets, respectively. $\tau^n$ is a constant term premium on a $n$ period asset.
However, many studies in the literature such as Fama (1984), Engel, Lilien and Robins (1987), Lee and Tse (1991) and Tzavalis and Wickens (1998) among others have found strong empirical evidence of a time-varying term premium. In fact, the empirical failure of expectations hypothesis has been interpreted by many studies as being caused by time varying term premium. Hence a modified Expectations hypothesis is expressed as

\[
[4.2] \quad i^n_t = \frac{1}{n} \sum_{k=0}^{n-1} E_t [i^1_{t+k}] + t\Lambda^n_t
\]

where \( t\Lambda^n_t \) denotes a time-varying term premium.

Thus, the response of output to long term interest rate includes a composite response to current and expected future short term rates and a response to the term premium. The theories of term structure based on the C-CAPM model propose that this term premium could be related to expected variance of consumption. Consequently, the term premium may hold information about the private sector’s expectations of the future path of the economy.

Both Fuhrer and Moor (1995b) and Fuhrer and Rudebusch (2002) incorporate long term interest rate in their IS curve in terms of short term rate. Fuhrer and Rudebusch (2002) approximate the long term interest rate by expected sum of future short term rates like the pure Expectations hypothesis. Fuhrer and Moor (1995b) set the yield to maturity on a hypothetical long-term real bond equal to the expected real return on Treasury bills forecast by a Vector autoregression for inflation, Treasury bill rate and output. Hence in both these models and their estimation, the output response to a time varying term premium could be possibly absent.

In Table 4.2 and Table 4.3 I examine the sensitivity of output response to the expected sum of short term interest rates and a residual term premium respectively. Since the term premium is unobservable, residuals of the least square regression of the long term interest rate

\[\text{If both the expected sum of short term interest rates and a residual term premium are included in the same regression, then the coefficient estimates of both these variables loose their statistical significance. The linear relationship between these regressors is interpreted as the reason behind such a result. Hence their explanatory power for output is examined in two different regressions.}\]
on the sum of current and expected future short rates over the term of the long term rate. Under
the assumption of rational expectations, the expected future rates are replaced by the realized
interest rates\(^{24}\).

Table 4.2 presents the parameter estimates of the following equation.

\[
y_t = \alpha_y + \mu_1 \frac{1}{3} \sum_{k=1}^{3} y_{t+k} + \mu_2 \frac{1}{3} \sum_{k=1}^{3} y_{t-k} - \delta_1 \left( i_{t-1} - \Pi_{t-1} \right) - \delta_2 \frac{1}{n} \sum_{k=0}^{n/3-1} \Pi_{t+3k} + \delta_3 \Pi_{t-n} + d_t
\]

The estimation in Table 4.3 replaces the expected sum of future short rates by the term
premium contained in the long term rate.

\[
y_t = \alpha_y + \mu_1 \frac{1}{3} \sum_{k=1}^{3} y_{t+k} + \mu_2 \frac{1}{3} \sum_{k=1}^{3} y_{t-k} - \delta_1 \left( i_{t-1} - \Pi_{t-1} \right) - \delta_2 t \Pi_{t-n} + \delta_3 \Pi_{t-n} + d_t
\]

A comparison of Table 4.2 and Table 4.3 reveals that the output response to both the
expected sum of short rates and the term premium is significant though the sensitivity to the latter
is larger. The coefficient estimates of \( \delta_2 \) in Table 4.2 range from 0.05 to 0.15 while the range in
Table 4.3 is 0.08 to 0.34. This indicates that the term premium and the information it contains
about the future state of the economy might have a greater effect on output than the effect of the
expected path of monetary policy actions.

The assumption that output responds to the real interest rate rather than the nominal
interest rate is reflected in the results in Table 4.2. The coefficient estimates of the expected
inflation are greater than the coefficient estimates of the average of the short term nominal
interest rates in the IS curve.

An interesting point to note is that the coefficient of the expected sum of future short rates
by and large increases with the term to maturity while at the same time the coefficient of the term

\(^{24}\) As a result, a forecast error could be possibly included in the term premium.

\[ I_t - \frac{1}{n} \sum_{k=0}^{n-1} i_{t+k} = t \Pi_{t-n} + \eta_t = TP_{t-n} \]
premium decreases. A possible explanation to this observation could be found in Kessel (1965). He points out that the fraction of the term premium (which is called as nonpecuniary return) to the total return from securities decreases with the term to maturity. On the other hand, the fraction of the return from the expected changes in interest rate (pecuniary return) to the total return from securities increases with the term to maturity.

In short, along with the expected path of the short term interest rate, the term premium has significant effect on the output demand.

Surprisingly, New Keynesian models in the literature have overlooked term premium and the term structure of interest rates. It is widely acknowledged that the monetary authorities control the short term nominal interest rate as a policy instrument. The monetary policy stance is reflected in the long term interest rate through the term structure of market interest rates. And this long term market rate crucially influences investment and consumption decisions. Thus, the interest rate channel of the monetary transmission works via the term structure.

Drawing from the empirical evidence in this section, the next two sections present a New Keynesian model that incorporates the term structure of interest rates and an endogenous term premium.

4.4 The structural model

This model describes an economy that consists of three sectors i.e. households, firms and the central bank. The aggregate macroeconomic relations are set within the New Keynesian framework. Following the previous literature, this model also exhibits endogenous persistence in output and inflation. The distinguishing characteristics of this model is that it integrates a time

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25 Estrella (1997), Smets and Tsatsaronis (1997), Bernanke, Gertler and Watson (1997) and Kotlan (2001) are some of the models that include term structure but they do not incorporate either structural equations or time varying term premium.
varying term premium derived from the household optimization decision into the New Keynesian
description of the economy.

The economy is characterized by four equation and the laws of motion of their
disturbances. I directly introduce the aggregate equations. Their derivations are available in the
literature.\(^{26}\)

NKPC describes the aggregate supply relation. Inspired by Fuhrer (1997) and Roberts
(2001), I replace the single lag and lead of inflation by a three period average of inflation in the
hybrid NKPC. One justification for this modification is that some prices are set for a quarter at a
time implying concern for inflation several periods ahead.

\[
\pi_t = \beta_1 \left[ \frac{1}{3} \sum_{k=1}^{3} E_{t+k} \pi_{t+k} \right] + \beta_2 \left[ \frac{1}{3} \sum_{k=1}^{3} \pi_{t-k} \right] + \gamma r_t + s_t \quad ^{27}
\]

\(s_t\) represents a supply shock. It is interpreted as a shock to the expected real marginal
cost or to markup over marginal cost. Thus, in this sense it captures cost-push inflation
independent of excess demand. The supply shock is characterized as autoregressive with
heteroscedastic innovations.

\[
s_t = \phi s_{t-1} + e_{st}, \quad \text{where } e_{s,t} \sim N\left(0, \sigma_{s,t}^2\right); \quad \sigma_{s,t}^2 = a_s + b_s e_{s,t-1}^2 \quad \text{and} \quad |\phi| < 1
\]

Aggregate demand in the economy is expressed by the hybrid IS curve. Similar to the
aggregate supply equation, I replace the single lead and lag of the output gap by a three period
average. This modification could be justified by the sluggish adjustment of investment based on

\(^{26}\) Yun (1996), McCallum and Nelson (1997), Rotemberg and Woodford (1997)

\(^{27}\) Following Sbordone (1999), Gertler and Gali (1999) et la. I also consider NKPC specification with marginal cost as its
driving variable.
the adjustment cost and time-to-build lags. With the same concerns, I also incorporate a one period delay in the effect of the real interest rate on the output gap.\textsuperscript{28, 29}

\begin{equation}
[2.6] \quad y_t = \mu_1 \left[ \frac{1}{3} \sum_{k=1}^{3} E_t y_{t+k} \right] + \mu_2 \left[ \frac{1}{3} \sum_{k=1}^{3} y_{t-k} \right] - \delta \left( i_{t-1}^n - \frac{1}{n} \sum_{k=1}^{n} E_{t-1} \pi_{t+k-1} \right) + d_t
\end{equation}

The demand shock\textsuperscript{' }denoted by \( d_t \), could be interpreted as fiscal policy shifts or preference shocks. An increase in current government purchases relative to future government purchases increases demand for current output for any given expected future output and shifts the IS curve. The description of this shock process is similar to the supply shock.

\begin{equation}
[5.2] \quad d_t = \phi_d d_{t-1} + \varepsilon_{dt}, \quad \text{where} \quad \varepsilon_{d,t} \sim N\left(0, \sigma_{d,t}^2\right); \quad \sigma_{d,t}^2 = a_d + b_d \varepsilon_{d,d-1}^2 \quad \text{and} \quad |\phi_d| < 1
\end{equation}

The monetary authorities respond to current inflation and the output gap through an interest rate rule. This reaction function also exhibits partial adjustment of the short-term nominal interest rate used as the policy instrument.

\begin{equation}
[3.2] \quad r_t = \rho r_{t-1} + \lambda_\pi \pi_t + \lambda_y y_t + z_t
\end{equation}

The policy shock \( z_t \) could be interpreted as a change in the policy preferences over inflation and the output gap. Unlike the supply and demand shocks\textsuperscript{30}, the innovations to the policy shock are assumed to have a constant variance over time.

\begin{equation}
[5.3] \quad z_t = \phi_z z_{t-1} + \varepsilon_{zt}, \quad \text{where} \quad \varepsilon_{z,t} \sim N\left(0, \sigma_{z,t}^2\right) \quad \text{and} \quad |\phi_z| < 1
\end{equation}

\textsuperscript{28} Much of the available evidence suggests a time lag in the effect of a shift in interest rates on output. Svensson (1997a, 1997b), Ball (1997) and Fuhrer and Rudebusch (2001) include the delayed response of the output gap to the real interest rate in their specification.

\textsuperscript{29} The real interest rate is an unobserved variable based on the celebrated Fisher equation.

\textsuperscript{30} Supply shocks, demand shocks and policy shocks are assumed to be uncorrelated with each other.
The modified expectations hypothesis expressed as equation [4.2] in the earlier section links the short-term market interest rate\(^{31}\) to the long-term market rate. This equation augments the traditional expectations hypothesis with a shock capturing the time-varying term premium.

\[ [4.2] \quad i_t^n = \frac{1}{n} \sum_{k=0}^{n-1} E_t i_{t+k}^1 + tp_t^n \]

The short term nominal interest rate is controlled by the monetary authorities. At the same time the long term interest rate evolves according to the private sector’s expectation of the future path of the monetary policy and the economy. The expected sum of future short rates contains information about the former while the term premium is based on the expected course of the economic variables.

In the next section, the term premium is modeled as a function of the volatility of inflation and output gap. For the sake of completeness of this section and to close the structural model of the economy, I introduce the description of the term premium relationship.

\[ [5.4] \quad tp_t^n = \phi_p tp_{t-1}^n + \nu E_t \sigma_{s,t+1}^2 + \nu d E_t \sigma_{d,t+1}^2 + \epsilon_{\phi,t} \quad \text{where} \quad |\phi_p| < 1 \]

\[ \epsilon_{\phi,t} \sim N(0, \sigma_{\phi,t}^2) \quad \text{where} \quad C \text{ is a non-zero constant and} \quad \sigma_{\phi,t}^2 = a_{\phi} + b_{\phi} \epsilon_{\phi,t-1}^2 \]

The term premium is characterized as persistent with heteroscedastic innovations. This description together with its correlation with the conditional variances of supply and demand shocks imparts the time varying nature of the term premium.\(^{32}\)

\(^{31}\) Even though \( r_t \) and \( i_t^1 \) are highly correlated and move together, they are not exactly same. To incorporate this stylized fact in the structural model, we need to identify the formal relationship between \( r_t \) and \( i_t^1 \). Consequently, we need to add a banking sector to model the response of banks’ asset management and the market interest rate \( i_t^1 \) for a one period bond to the policy instrument \( r_t \). This complicated modeling is left for further research.

\(^{32}\) Previous literature finds strong empirical evidence of a time-varying term premium.
4.5 Time varying term premium

Various economic theories proposed in the literature\textsuperscript{33} have different implications for the term premium. The expectations theory traditionally assumes a constant term premium. However, there is a strong empirical evidence of a time varying term premium. Engel, Lilien and Robins (1987), Lee and Tse (1991), Kwon (1992), Oh (1994), Lee (1995), Hejazi, Lai and Yang (2000) and Castillo and Fillion (2002) employ various models of conditional heteroscedasticity to model the time varying term premium observed in the data.

According to the Intertemporal Capital Asset Pricing model of Merton (1983), risk premia\textsuperscript{34} are the prices of risk built into assets priced according to their hedging capabilities against the uncertainties related to the state variables in the economy. As these uncertainties change over time, the prices of risk related to the state variables and hence the risk premia vary over time. Lee (1995) models time varying term premia based on the second moments of macroeconomic state variables such as output and money supply.

This model is inspired by the intertemporal general equilibrium asset pricing model used by Lee (1995).\textsuperscript{35} He develops a cash-in-advance model in which the representative household maximizes the discounted expected value of a time separable intertemporal utility function. The utility function is assumed to be of CRRA type.

\[
U(C_{t+k}) = \frac{C_{t+k}^{1-\alpha}}{1-\alpha} \text{ where } \alpha = \text{coefficient of risk aversion.}
\]

The dynamic Lagrangean and the first order conditions of this consumption optimization problem could be found in Lee (1995).

\textsuperscript{33} Hicksian liquidity preference theory (1946), preferred habitat hypothesis of Modigliani and Sutch (1966), market segmentation hypothesis by Culbertson (1957), Consumption-Capital Asset Pricing Model of Cox, Ingersoll and Ross (1985) and Campbell (1986)

\textsuperscript{34} The term premium could be interpreted as the risk premium required for buying a long term asset (or lending for a long period) rather than rolling over a short term asset.

\textsuperscript{35} Campbell (1986) adopts a similar model of representative agent’s utility maximization. In his model, consumption is assumed to be lognormally distributed, resulting in a constant term premium.
Form these first order conditions; we get the typical asset pricing equation for a n-period discount bond.

\[ P_{t}^{t+n} = e^{-nI(t,t+n)} = E_t \left[ \frac{U'(C_{t+n})}{U'(C_t)P_{t+n}} \beta \right] \]

where \( P_t \) is the price of one unit of consumption good at time \( t \), \( C_t \) is per capita consumption at time \( t \), \( P_{t}^{t+n} \) is the time \( t \) price of one unit of discount bond which pays $1 at time \( t+n \), \( I(t+m,t+n), n > m \) is the continuously compounded yield-to-maturity of the \( n-m \) period discount bonds at time \( t+m \).

Multiplying both sides by \( \frac{P_t}{P_{t-n}} \) gives us

\[ \frac{P_t}{P_{t-n}} P_{t}^{t+n} = e^{-nI(t,t+n)} \frac{P_t}{P_{t-n}} = E_t \left[ \frac{C_{t+n}^{-\alpha} P_t}{P_{t-n}} \frac{P_{t+n}}{P_t} \right] \]

In equilibrium, abstracting from investment and a government sector, \( C_t = Y_t \), implying

\[ \frac{P_t}{P_{t-n}} P_{t}^{t+n} = e^{-nI(t,t+n)} \frac{P_t}{P_{t-n}} = E_t \left[ \frac{Y_t^{\alpha} P_t}{Y_{t+n}^{\alpha} \frac{P_{t+n}}{P_t}} \right] \]
If we expand the terms in brackets to second order terms in a Taylor series about zero and take natural logs of the resulting equation and denote \( \log \bar{y}_t \) by \( y_t \),

\[
\frac{1}{n} \log \frac{P_{t-n}}{P_t} \text{ by } \pi_t ^{36}
\]

\[ -nI(t,t+n) + n\pi_t = n \log \beta + \alpha(y_t - E_{y_{t+n}}) + \left( \pi_t - E\pi_{t+n} \right) \]

\[ + \frac{\alpha^2}{2} \text{Var}_t(y_{t+n}) + \frac{1}{2} \text{Var}_t(\pi_{t+n}) + \alpha \text{Cov}_t(y_{t+n}, \pi_{t+n}) \]

[7.1]

With the same approximation,

\[ E_t[-(n-1)I(t+1,t+n) + n\pi_{t+1}] \approx (n-1) \log \beta + \alpha(E_t y_{t+1} - E_{y_{t+1}}) + (E_t \pi_{t+1} - E\pi_{t+n}) \]

\[ + \frac{\alpha^2}{2} \text{Var}_t(y_{t+1}) + \frac{\alpha^2}{2} \text{Var}_t(\pi_{t+1}) + \frac{1}{2} \text{Var}_t(\pi_{t+n}) \]

\[ + \alpha \text{Cov}_t(y_{t+1}, y_{t+n}) - \text{Cov}_t(\pi_{t+1}, \pi_{t+n}) + \alpha \text{Cov}_t(y_{t+n}, \pi_{t+n}) \]

\[ + \alpha \text{Cov}_t(y_{t+1}, \pi_{t+n}) - \alpha \text{Cov}_t(y_{t+n}, \pi_{t+n}) \]

[7.2]

The holding period premium on a n-period bond held for one period is defined as the expected value of the excess return over a one period bond. It is the difference between the rate of return on holding a n-period bond for one period and the return on a one period bond.

\[ E_t[H(t,t+1,t+n)] \equiv E_t[nI(t,t+n) - (n-1)I(t+1,t+n) - I(t,t+1)] \]

---

36 To be precise, \( \log \frac{P_{t-n}}{P_t} = \pi_{t-n,t} \). The subscript t-n is suppressed for the sake of brevity.

37 There are some higher order terms which are of second order and hence close to zero.

38 If \( y_{t+n} \) and \( \pi_{t+n} \) have lognormal distribution conditional on information at time t, [7.1] becomes as exact relation without higher order terms. However, in that case the term premium is constant over time.
Substituting the expressions for \( nI(t, t + n), I(t, t + 1) \) and \( E[H(t, t + 1, t + n)] \) we have

\[ [8.2] \]

\[
E[H(t, t + 1, t + n)] = \frac{\alpha^2}{2} Var_t(y_{t+1}) + \frac{1}{2} Var_t(\pi_{t+1}) - \alpha^2 Cov_t(y_{t+1}, y_{t+n}) - Cov_t(\pi_{t+1}, \pi_{t+n}) \]

\[
+ 2\alpha Cov_t(y_{t+1}, \pi_{t+1}) - \alpha Cov_t(y_{t+n}, \pi_{t+1}) \]

The term premium in the Expectations hypothesis\(^{40}\) can be approximated by the expected value of the sum of one period holding period premia over the maturity of the long term asset.

\[ [9.1] \]

\[
tp_n = \sum_{j=0}^{n-2} E[H_{t+j}^{n-j}] \]

As a result, we can represent the term premium as a function of the variance –covariance of the macroeconomic variables.

For \( n=2 \)

\[ [9.2] \]

\[
 tp_2 = \frac{\alpha^2}{2} Var_t(y_{t+1}) + \frac{1}{2} Var_t(\pi_{t+1}) - \alpha^2 Cov_t(y_{t+1}, y_{t+2}) - Cov_t(\pi_{t+1}, \pi_{t+2}) \]

\[
+ 2\alpha Cov_t(y_{t+2}, \pi_{t+2}) - \alpha Cov_t(y_{t+2}, \pi_{t+1}) \]

\(^{39}\) Left hand side expression also includes a term =

\[
- n\pi_{t-n,t} + E[\sum_{j=0}^{n-1} \pi_{t-1,t} (L)^j - \pi_{t-1,t} (L)] = 0 \]

\(^{40}\) It is also known as rolling term premium because it is the expected excess return on holding a \( n \)-period bond relative to rolling over a one-period bond. Another name for it is liquidity premium, indicating a premium required to give up liquidity by buying a long term asset over a short term asset.

\(^{41}\) Usually the Jensen’s law terms such as \( Var_t(\pi_{t+1}) \) are small relative to the risk terms associated with \( \alpha \) and are thus often neglected.
Using the macroeconomic relations of output and inflation described in the earlier section,

\[
[9.3] \quad Var_t(y_{t+1}) = E_t(y_{t+1} - E_t y_{t+1})^2 = E_t \epsilon_{t, t+1}^2 = \sigma_{y, t+1}^2
\]

\[
Var_t(\pi_{t+1}) = E_t(\pi_{t+1} - E_t \pi_{t+1})^2 = E_t \epsilon_{t, t+1}^2 = \sigma_{\pi, t+1}^2
\]

Since the innovations to output and inflation are uncorrelated to each other and their own lags, all the covariance terms are equal to zero. Effectively, the term premium is a function of the variance of output and inflation.

\[
[9.4] \quad tp_t^2 = \vartheta_d \sigma_{y, t+1}^2 + \vartheta_s \sigma_{\pi, t+1}^2 \quad \text{where} \quad \vartheta_d, \vartheta_s > 0
\]

Thus, the term premium varies proportionally with the variance of innovations to output and inflation. Further, the response of the term premium to the variance of output innovations is associated with the coefficient of risk aversion. The term premium is proportional to the square of the coefficient of relative risk aversion in the utility function. This indicates that an effect of the risk aversion behavior is of second order if the coefficient is close to zero but it is of first order important for a large value of the coefficient.

An increase in the variance of output or inflation indicates an increase in economic volatility. Greater uncertainty about the future tends to increase (decrease) demand for short (long) term assets as risk adverse consumers prefer liquidity. As a result, economic uncertainty should have a positive effect on the term premium. At the same time, with a higher risk aversion, the consumers require a larger term premium.

A point to note here is that Lee (1995), Hejazi, Lai and Yang (2000) and Castillo and Fillion (2002) use univariate time series to characterize macroeconomic variables such as output, money supply, inflation and exchange rate. The inflation and output dynamics in this model are based on the theoretical framework.
4.6 Estimation of the structural model

4.6.1 Methodology

A keen focus on New Keynesian theory in the last few years has led to numerous attempts of estimating these models. Interestingly, just like the theoretical framework, there is a lack of consensus in the literature regarding the estimation methods employed for these models.


More recent studies such as Rudd and Whelan (2001), Fuhrer and Rudebusch (2002), Linde (2002) and Jondeau and Bihan (2003) examine the conflict that is observed in the literature between the estimation procedures and the empirical results of maximum likelihood (ML) and GMM. ML estimates are noted to undervalue the forward looking behavior in these models while GMM tend to overestimate it. GMM is noted to have a small sample bias.

As an econometric procedure, full information techniques such as FIML appear to be superior to alternative limited information techniques. However, they have a risk of contaminating all the parameter estimates even if a single equation in the model is miss-specified. Further, FIML has an additional high computational cost.

---

42 A complete characterization of the rational expectations solution to this model is left for future work. A Minimum State Variable (McCallum 1983) solution could be conjectured as a system of two economic variables.

\[
\pi_t = r_1 \pi_{t-1} + r_{21} y_{t-1} + r_{31} i_{t-2} + q_{11} s_t + q_{21} d_t + q_{31} z_{t-1} + q_{41} e_{s,t}^2 + q_{41} e_{d,t}^2 \\
y_t = r_{12} \pi_{t-1} + r_{22} y_{t-1} + r_{32} i_{t-2} + q_{12} s_t + q_{22} d_t + q_{32} z_{t-1} + q_{42} e_{s,t}^2 + q_{42} e_{d,t}^2
\]

where all the r’s and q’s are functions of the structural parameters.

Hence, at this stage, I choose to use GMM to estimate the structural model presented in section 4.4, FIML estimation of the model is deferred for future work. A two step estimation procedure is employed. In the first step, the four macroeconomic relations in the model i.e. equations [1.3], [2.6], [3.2] and [4.2] are separately estimated by GMM, allowing for a constant term. The residuals obtained from each of these regressions are then used as respective shocks in the second step. The Autoregressive Conditional Heteroscedasticity (ARCH) process of each of the supply, demand, policy and the term premium shocks is estimated using maximum likelihood (ML) method.

In any instrumental variables estimation, the choice of the instruments is very important. The instruments should be correlated with the regressors but orthogonal to the forecast errors. Since the model incorporates economic shocks specified to be AR(1) in nature, lags 2 to 4 of the independent variables are used while excluding lag 1 from the instruments. Instrument set also includes a constant and a linear time trend.

The long term interest rate is believed to contain a time varying term premium, which in turn, is modeled as correlated with the output innovations. Hence, in the estimation of the IS curve, lags of the short term interest rates rather than the long term rate are used as instruments.

4.6.2 Data

I estimate the model with monthly data for the U.S. The sample period is 1983:1 to 2002:12, in order to avoid the structural breaks observed in the date before 1983.\textsuperscript{44} The index of Industrial Production, Consumers’ Price Index and Aggregate Weekly Hours Index for the private non-farm payroll are used as the measures of the output, price level and labor costs respectively. The Federal Funds rate is used as the policy instrument while 3 month, 6 month, 1 year, 2 year

\textsuperscript{44} Much of the evidence in the monetary policy literature suggests a structural break in U.S. time series data in 1979 known as Volker-Greenspan era. Further, a regime change in the Federal Reserve’s operating procedures is observed between 1979 and 1982.
and 3 year Treasury constant maturity rates are used for the market interest rates. All the data are obtained from the FRED databank at the Federal Reserve Bank at St. Louis.

The variables for inflation and marginal costs are computed as annualized logarithmic change in the price level and labor costs, respectively. The measure of the output gap is computed by detrending the log of output with a deterministic quadratic trend.

4.6.3 Empirical results

Table 4.4 presents estimation of the first step i.e. equations describing the macroeconomic relationships while Table 4.5 exhibits the results of the ARCH estimation in the second step.

Similar to the previous literature, estimating NKPC meets with only limited success. There is a strong evidence of the forward looking behavior as the coefficient of the expected inflation is highly significant and close to 1. Backward looking price setting is not found to be significant. A Wald test for the sum of the coefficients of the expected and lagged inflation to be unity is not rejected. However, the estimate of the coefficient of the driving variable i.e. the output gap is also not different from zero though positive as expected. A very low adjusted $R^2$ also indicates a poor fit for the regression.

The parameter estimates of NKPC with marginal labor cost as the driving variable (in Table 4.5) are qualitatively similar to the estimates in which the output gap is used as the measure of the economic activity.45

The estimates of the IS curve appear to support the model. Unlike the evidence found by Fuhrer and Rudebusch (2002), the estimate of the interest rate elasticity is significantly different from zero and with the correct sign. The expected output gap as well as its lags is highly

45 Gali and Gertler (1999) estimate a positive and significant coefficient of the marginal cost in NKPC. They use labor income share as a measure of the marginal cost.
significant. At the same time, the sum of their coefficients is rejected by Wald test to be 1. R² close to 1 indicates good fit of the regression.

The policy rule estimates are similar to the ones in the literature. The rule seems to capture the behavior of the Fed successfully. It indicates a partial adjustment of the policy instrument. The estimates imply a stronger response to inflation and a weaker response to the output gap compared to the policy response estimated in the literature earlier.46

The estimation of the term structure required an addition of an AR(1) term, to take into account large serial correlation in the residuals. This is reflected in a large and highly significant coefficient of the AR term. The hypothesis that the coefficient of the expected sum of future short rates is equal to one is not rejected. Thus, results support the expectations hypothesis augmented by a time varying term premium.

The null hypothesis of the absence of an ARCH effect in the error term of NKPC, the IS curve and the term structure is rejected by the data. Thus, the conditional variances of the supply shocks, demand shocks and the term premium seem to vary over time.

However, the ARCH estimation for supply shocks presents contradictory results. Neither the lag of the supply shock nor the lag of its squared innovations is significantly different from zero. This result could be attributed to the fact that the estimate of NKPC itself is not very successful.

ARCH model seems to fit demand shocks well. At the same time, the innovations to the policy shock are found to be homoscedastic.

In agreement with the previous literature, the results of this estimation also imply that the term premium varies over time. The term premium exhibits strong ARCH effects. The conditional variance of the innovations to output has significant explanatory power for the term premium. An increase in the variance of output and hence economic uncertainty appears to increase the term

46 Clarida, Gali and Gertler (1998)
premium significantly. On the other hand, the conditional variance of the inflation innovations does not seem to explain the term premium. This result is in fact in line with the theory as it suggests little role for the variance of inflation innovations.47

The parameter for the response of the term premium to output innovations is associated with the coefficient of relative risk aversion in the model. The coefficient estimate of this parameter is 31 in the model with output gap while 33 in the model with marginal cost. Both these estimates would imply value of the coefficient of relative risk aversion to be approximately 8. This value is considered to be plausible among the various values considered by Mehra and Prescott (1985).

4.7 Conclusions

New Keynesian models integrate the Keynesian assumption of sticky prices with the optimizing behavior and rational expectations of general equilibrium theory. Despite being theoretically appealing, the pure forward looking first generation models do not find empirical support. The second generation models within this framework introduce endogenous persistence to inflation and output through assumptions such as less than fully rational expectations, forward looking price setting by only a section of the economy, habit formation in consumption, adjustment costs and sluggish adjustment of investment.

However, this rich development of New Keynesian models has abstracted from the term structure relationship. These models include either the short term interest rate or the expected sum of short rates in some cases. This approach ignores the effect of the term premium on the aggregate demand and in turn the economy as a whole.

Empirical evidence in this paper suggests that the output gap is sensitive to the unobserved term premium contained in the long term rate as well as the expected sum of future

47 The theory suggests the coefficient of the variance of inflation innovations to be 0.5. This restriction is not rejected by the data
short rates. The response of output gap to the interest rate increases with the term to maturity of the latter. Further, the term premium seems to have a greater effect on output than the effect of the expected future short term rates.

Thus, the empirical evidence presented in this paper indicates that ignoring the term structure and term premium could possibly leave out some important features of the workings of the economy.

Therefore, this paper attempts to fill this gap in the literature by integrating the New Keynesian model with a model of term structure in which the term premium varies endogenously over time. Based on the Consumption Capital Asset Pricing model, the term premium is modeled as a function of the expected conditional volatilities of the innovations to inflation and output. A distinguishing feature of this model is that the inflation and output dynamics are based on the theoretical framework rather than the univariate time series assumed in the literature.

This approach to modeling these macroeconomic relations results in a more plausible description of the economy compared to earlier models. In this model, output responds to an interest rate that includes a time varying term premium, which in turn is associated with economic agents’ expectations about the future economic variables. Thus, aggregate demand reacts not only to monetary policy actions but also to the expectations of the future state of the economy.

Estimation of the model obtains a limited success. Except for NKPC, the results from the estimation of the IS curve, policy function and the modified expectations hypothesis support the model. As claimed in the literature, the failure of NKPC could be attributed to the lack of appropriate measure of the driving variable. The parameter estimates of the IS curve reveal the importance of forward looking behavior as well as backward looking behavior. The interest rate semi elasticity is found to be significant. The estimated policy reaction function is in agreement with the literature.

The estimation results support the expectations hypothesis augmented by a time varying term premium. The strong presence of the latter is reflected in a large and highly significant
coefficient estimate of the autoregressive term in the equation. The hypothesis that the coefficient of the expected sum of future short rates is equal to one is not rejected.

The ARCH model of conditional volatility of the innovations to demand shocks and the term premium appears to fit the data well. It fails with the supply shock even though a null hypothesis of no ARCH effect is rejected. This contradictory result could be attributed to the poor fit of NKPC itself.

Similar to the previous literature, this paper also finds that economic uncertainties are important sources of time varying term premium. The conditional variance of the innovations to output has highly significant explanatory power for the term premium. In line with the theory, the conditional variance of the inflation innovations does not seem to explain the term premium.

These optimistic estimation results along with the strong theoretical framework offer a large potential for this model for future research.

The relationship between the monetary policy rate and the term structure could be addressed by a model in a similar vein to Ellingsen and Soderstrom (2001). They argue that the nature of the information asymmetry between the central bank and the economic agents about supply and demand shocks can generate different comovements in the policy rate and the long term rate. The possibility that the central bank has private information could change household behavior in the asset market.

Another avenue for further research is to employ the model in this paper for the optimal monetary policy analysis similar to Rotemberg and Woodford (1997, 1999), Clarida, Gali and Gertler (1999) and McCallum and Nelson (1998) among others. The introduction of an endogenous term premium could potentially affect monetary transmission and consequently alter the nature of the optimal policy.
4.8 References


Castillo, D. C. and J. F. Fillion (2002) "Term Premium Determinants of Three-Month Forward Interest Rates", 


## 4.9 Tables

**IS curve:**

\[ y_t = \alpha_y + \mu_1 \frac{1}{3} \sum_{k=1}^{3} y_{t+k} + \mu_2 \frac{1}{3} \sum_{k=1}^{3} y_{t-k} - \delta_1 \left( i_{t-1}^1 - \Pi_{t-1}^1 \right) - \delta_2 i_{t-n}^n + \delta_3 \Pi_{t-n}^n + d_t \]

**Instruments:**

\[ y_{t-2}, y_{t-3}, y_{t-4}, i_{t-2}, i_{t-3}, i_{t-4}, \pi_{t-2}, \pi_{t-3}, \pi_{t-4} \]

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**Table 4.1**

Interest rate in the IS curve

Estimated by GMM. Standard errors in the bracket.

Sample period – 1983:1 to 2002:12

\( n \) = maturity of the long term rate in months

\( \pi \) = annualized change in CPI over one month, \( y \) = quadratic detrended output, \( \Pi^n \) = expected annualized change in CPI over \( n \) months, \( i^n \) = Treasury constant maturity \( n \) months rate.

a: A constant and a linear trend also included in the instrument set.

***, ** and * at 1%, 5% and 10% significance level respectively
IS curve: -

\[ y_t = \alpha_y + \mu_1 \frac{1}{3} \sum_{k=1}^{3} y_{t+k} + \mu_2 \frac{1}{3} \sum_{k=1}^{3} y_{t-k} - \delta_1 (\Pi_{t-1}^{1} - \Pi_{t-1}^{1}) - \frac{\delta_2}{n} \sum_{k=1}^{n-1} \frac{i}{t+k} + \delta_3 \Pi_{t-n} + d_t \]

Instruments\(^a\): \(y_{t-2}, y_{t-3}, y_{t-4}, i_{t-2}^{1}, i_{t-3}^{1}, i_{t-4}^{1}, \pi_{t-2}, \pi_{t-3}, \pi_{t-4}\)

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Table 4.2
Short term rate in the IS curve

Estimated by GMM. Standard errors in the bracket.
Sample period – 1983:1 to 2002:12
\(n\) = maturity of the long term rate in months
\(\pi\) = annualized change in CPI over one month, \(y\) = quadratic detrended output, \(\Pi^{\pi}\) = expected annualized change in CPI over \(m\) months, \(i^n\) = Treasury constant maturity \(n\) months rate, \(\alpha\): A constant and a linear trend also included in the instrument set.
\(***\), ** and * at 1%, 5% and 10% significance level respectively.
IS curve:-

\[ y_t = \alpha_y + \mu_1 \sum_{k=1}^{3} y_{t+k} + \mu_2 \sum_{k=1}^{3} y_{t-k} - \delta_1 (i_{t-1} - \Pi_{t-1}^1) - \delta_2 t p_{t-n}^n + \delta_3 \Pi_{t-n}^n + d_t \]

instruments\(^a\): \(y_{t-2}, y_{t-3}, y_{t-4}, i_{t-2}^1, i_{t-3}^1, i_{t-4}^1, \pi_{t-2}, \pi_{t-3}, \pi_{t-4}\)

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Table 4.3
Term premium in the IS curve

Estimated by GMM. Standard errors in the bracket.
Sample period – 1983:1 to 2002:12
\(n\) = maturity of the long term rate in months
\(\pi\) = annualized change in CPI over one month, \(y\) = quadratic detrended output, \(\Pi^n\) = expected annualized change in CPI over \(n\) months, \(tp^n\) = residual term premium for a \(n\)-period asset
\(^a\): A constant and a linear trend also included in the instrument set.
***, ** and * at 1%, 5% and 10% significance level respectively.
Phillip's curve:

\[ \pi_t = \alpha_\pi + \beta_1 \frac{1}{3} \sum_{k=1}^{3} \pi_{t+k} + \beta_2 \frac{1}{3} \sum_{k=1}^{3} \pi_{t-k} + \gamma y_t + s_t \]

instruments\(^a\): \(\pi_{t-2}, \pi_{t-3}, \pi_{t-4}, y_{t-2}, y_{t-3}, y_{t-4}\)

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<th>(\gamma)</th>
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IS curve:

\[ y_t = \alpha_y + \mu_1 \frac{1}{3} \sum_{k=1}^{3} y_{t+k} + \mu_2 \frac{1}{3} \sum_{k=1}^{3} y_{t-k} - \delta(t_{t-12} - \Pi_{t-12}^{12}) + d_t \]

instruments\(^a\): \(y_{t-2}, y_{t-3}, y_{t-4}, i_{t-2}^3, i_{t-3}^3, i_{t-4}^3, \Pi_{t-2}, \Pi_{t-3}, \Pi_{t-4}\)

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Table 4.4
Estimation of the Structural model

Each equation estimated separately by GMM. Standard errors in the bracket.
Sample period – 1983:1 to 2002:12
\(\pi\)=annualized change in CPI over one month, \(y\)=quadratic detrended output, \(\Pi\)=change in CPI over twelve months, \(i^3\)=Treasury constant maturity 3 months rate, \(I\)=Treasury constant maturity 12 month rate.
a:- A constant and a linear trend also included in the instrument set.
***, ** and * at 1%, 5% and 10% significance level respectively.
Table 4.4-continued

Policy rule:-

\[ i_t = \alpha_i + \rho i_{t-1} + \lambda_\pi \pi_t + \lambda_y y_t + z_t \]

instruments\(^a\): \( i_{t-2}, i_{t-3}, i_{t-4}, \pi_{t-2}, \pi_{t-3}, \pi_{t-4}, y_{t-2}, y_{t-3}, y_{t-4} \)

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Term structure of interest rates :-

\[ I_t = \alpha_I + \theta \frac{1}{4} \sum_{k=0}^{3} i_{t+3k}^3 + \xi \left( I_{t-12} - \theta \frac{1}{4} \sum_{k=0}^{3} I_{t+3k-4} \right) + \nu_{12} \]

instruments\(^a\): \( i_{t-2}, i_{t-3}, i_{t-4}, i_{t-2}, i_{t-3}, i_{t-4}, I_{t-2}, I_{t-3}, I_{t-4} \)

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Estimation of the Structural model

Each equation estimated separately by GMM. Standard errors in the bracket.
Sample period – 1983:1 to 2002:12
\( \pi \) = annualized change in CPI over one month, \( y \) = quadratic detrended output, \( i^1 \) = federal funds rate, \( i^3 \) = Treasury constant maturity 3 months rate, \( I \) = Treasury constant maturity 12 month rate.
\( a \): A constant and a linear trend also included in the instrument set.
***, ** and * at 1%, 5% and 10% significance level respectively.
Phillip’s curve:-

\[ \pi_t = \alpha_{\pi} + \beta_1 \frac{1}{3} \sum_{k=1}^{3} \pi_{t-k} + \gamma mc_t + \beta_2 \frac{1}{3} \sum_{k=1}^{3} \pi_{t-k} + s_t \]

instruments\( ^a \): \( \pi_{t-2}, \pi_{t-3}, \pi_{t-4}, mc_{t-2}, mc_{t-3}, mc_{t-4} \)

<table>
<thead>
<tr>
<th></th>
<th>( \alpha_{\pi} )</th>
<th>( \beta_1 )</th>
<th>( \beta_2 )</th>
<th>( \gamma )</th>
<th>Wald test ( \beta_1 + \beta_2 = 1 )</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.006</td>
<td>0.600**</td>
<td>0.163</td>
<td>0.074</td>
<td>0.95</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.28)</td>
<td>(0.12)</td>
<td>(0.08)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.5
Phillips curve with marginal cost

Estimation by GMM. Standard errors in the bracket.
Sample period – 1983:1 to 2002:12
\( \pi \) = annualized change in CPI over one month, \( mc \) = annualized change in average weekly hours index over one month,
a:- A constant and a linear trend also included in the instrument set.
***, ** and * at 1%, 5% and 10% significance level respectively.
### Table 4.6

Estimation of economic shocks

Supply shock:
\[ s_t = \alpha_s + \phi_s s_{t-1} + \varepsilon_{s,t} ; \sigma_{s,t}^2 = a_s + b_s \varepsilon_{s,t-1}^2 \]

<table>
<thead>
<tr>
<th></th>
<th>( \sigma_{s,t}^2 )</th>
<th>( \alpha_s )</th>
<th>( \phi_s )</th>
<th>( a_s )</th>
<th>( b_s )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11.69***</td>
<td>0.0007</td>
<td>0.1082</td>
<td>0.0003***</td>
<td>0.279</td>
</tr>
</tbody>
</table>

Demand shock:
\[ d_t = \alpha_d + \phi_d d_{t-1} + \varepsilon_{d,t} ; \sigma_{d,t}^2 = a_d + b_d \varepsilon_{d,t-1}^2 \]

<table>
<thead>
<tr>
<th></th>
<th>( \sigma_{d,t}^2 )</th>
<th>( \alpha_d )</th>
<th>( \phi_d )</th>
<th>( a_d )</th>
<th>( b_d )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9.87***</td>
<td>-1.23e-04</td>
<td>0.3182***</td>
<td>9.59e-06***</td>
<td>0.3124**</td>
</tr>
</tbody>
</table>

Policy shock:
\[ z_t = \alpha_z + \phi_z z_{t-1} + \varepsilon_{z,t} ; \sigma_{z,t}^2 = a_z + b_z \varepsilon_{z,t-1}^2 \]

<table>
<thead>
<tr>
<th></th>
<th>( \sigma_{z,t}^2 )</th>
<th>( \alpha_z )</th>
<th>( \phi_z )</th>
<th>( a_z )</th>
<th>( b_z )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.01</td>
<td>-7.56e-06</td>
<td>0.2287***</td>
<td>1.07e-05***</td>
<td>0.0142</td>
</tr>
</tbody>
</table>

Term premium:
\[ t\text{p}_t^n = \alpha_{\text{tp}} + \phi_{\text{tp}} t\text{p}_{t-1} + \vartheta_{\text{tp}} \sigma_{\text{tp},t}^2 + \vartheta_d \sigma_{\text{tp},t+1}^2 + \varepsilon_{\text{tp},t} ; \sigma_{\text{tp},t}^2 = a_{\text{tp}} + b_{\text{tp}} \varepsilon_{\text{tp},t-1}^2 \]

<table>
<thead>
<tr>
<th></th>
<th>( \sigma_{\text{tp},t}^2 )</th>
<th>( \alpha_{\text{tp}} )</th>
<th>( \phi_{\text{tp}} )</th>
<th>( \vartheta_{\text{tp}} )</th>
<th>( \vartheta_d )</th>
<th>( a_{\text{tp}} )</th>
<th>( b_{\text{tp}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12.13**</td>
<td>-0.0002</td>
<td>0.337***</td>
<td>-0.4027</td>
<td>30.9807**</td>
<td>3.26e-06***</td>
<td>0.427***</td>
</tr>
</tbody>
</table>


ARCH test: \( \varepsilon_t^2 \) regressed on \( \varepsilon_{t-1}^2 \) for each economic shock. Null hypothesis: homoscedasticity. ***, ** and * at 1%, 5% and 10% significance level respectively.
Supply shock:
\[ s_t = \alpha_s + \phi_s s_{t-1} + \epsilon_{s,t} ; \sigma^2_{s,t} = a_s + b_s \epsilon^2_{s,t-1} \]

<table>
<thead>
<tr>
<th>( \sigma^2_{s,t} = \sigma^2_s )</th>
<th>( \alpha_s )</th>
<th>( \phi_s )</th>
<th>( a_s )</th>
<th>( b_s )</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.97***</td>
<td>0.0004</td>
<td>0.0512</td>
<td>0.0004**</td>
<td>0.1618*</td>
</tr>
<tr>
<td>(0.00)</td>
<td>(0.08)</td>
<td>(0.00)</td>
<td>(0.10)</td>
<td></td>
</tr>
</tbody>
</table>

Term premium:
\[ t_p = \alpha_{tp} + \phi_{tp} t_{p,t-1} + \psi^2_{t} \sigma^2_{\epsilon,t+1} + \psi_{d} \sigma^2_{\epsilon_d,t+1} + \epsilon_{tp,t} ; \sigma^2_{tp,t} = a_{tp} + b_{tp} \epsilon^2_{tp,t-1} \]

<table>
<thead>
<tr>
<th>( \sigma^2_{tp,t} = \sigma^2_{tp} )</th>
<th>( \alpha_{tp} )</th>
<th>( \phi_{tp} )</th>
<th>( \psi_{t} )</th>
<th>( \psi_{d} )</th>
<th>( a_{tp} )</th>
<th>( b_{tp} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.13**</td>
<td>0.0002</td>
<td>0.3339***</td>
<td>-1.4592</td>
<td>32.9550**</td>
<td>3.26e-06***</td>
<td>0.4194***</td>
</tr>
<tr>
<td>(0.00)</td>
<td>(0.05)</td>
<td>(1.32)</td>
<td>(14.48)</td>
<td>(5.4e-07)</td>
<td>(0.14)</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.7
Estimation of economic shocks with marginal cost
(Estimates of demand shocks and policy shocks same as in Table 4.6)

Residuals from the structural model used as dependent variables.
Sample period – 1983:1 to 2002:12
ARCH test: \( \epsilon^2_t \) regressed on \( \epsilon^2_{t-1} \) for each economic shock. Null hypothesis:- homoscedasticity.
***, ** and * at 1%, 5% and 10% significance level respectively.
CHAPTER 5

CONCLUSIONS

This dissertation contributes to the study of the term structure of interest rates by addressing some of the gaps in this literature.

Chapter 2 examines the expectations hypothesis in the newly developed financial markets. Unlike the industrialized economies, the expectations hypothesis finds some empirical evidence in these newly developed financial markets. This disparity could be attributed to the inherent differences in economic characteristics and particularly monetary policy actions.

Further, contrary to the simple expectations theory, the empirical evidence also suggests the presence of a highly persistent time varying term premium in all the financial markets.

Chapter 3 investigates the so called ‘forecasting ability’ of term spreads for future output growth. The empirical evidence based on a wider set of countries compared to the previous literature, indeed suggests that the relationship between term spread and future output growth varies across countries and across time periods. The calibrations of a structural model suggest that the information content of term spreads changes with a change in the persistence and the variance of the underlying economic shocks and in the monetary policy preferences. Consequently, this analysis casts doubts on the reliability of term spreads in forecasting future economic variables.

On a different note, Chapter 4 presents a model that integrates New Keynesian model and the model of term structure based on the Intertemporal Asset Pricing Model (I-CAPM). This
model provides a more plausible description of the economy which is essential, particularly for analysis and formulations of economic policies.

In this model, the output responds to the interest rate that includes a time varying term premium, which, in turn is associated with economic agents' expectations about the future economic variables. Thus, aggregate demand reacts not only to the monetary policy actions but also the expectations of future state of the economy. The empirical results give confidence in future research in this direction.

Chapter 2 employed single equation technique to examine empirical evidence of the expectations hypothesis. This exercise could be extended with system estimation. All the interest rates, and hence, term spread are correlated with each other. Thus, cross equation correlations potentially contain additional information that could be used with system estimation.

On the theoretical side, a structural model similar to the one adopted in chapter 3, could be simulated to resolve the puzzles about the expectations hypothesis. A time-varying term premium or the interest rate smoothing behavior of the monetary authorities, are the reasons proposed in the literature for the empirical failure of this hypothesis in the industrialized countries. The simulations of the model adopted in this paper could verify the reasons behind the empirical failure of the expectations hypothesis.

Another appealing question is the effect of financial innovations on the term spread and its predictive power. Is the break down of the relationship between the term spread and future economic activity similar to the one earlier observed based on the monetary aggregates? Explaining these issues might help us in the quest for reliable leading indicators of the economy.

The hypothesis in this paper indicates that the term premium has a significant effect on the forecasting power of the term spread. This insight leads to questions such as, is the term premium the source of the predictive power of the term spread? Can the term premium replace
the term spread as a leading indicator? Some papers in the literature have examined these issues. Yet, there is a wide scope for further theoretical as well as empirical research.

A more involved extension of the model in chapter 4 that would bring it closer to the real economy is to model the relationship between the short term interest rate used as the monetary policy instrument and the market rate on a short term asset. This rich development of the model would need to introduce a banking sector with its asset and liability management in response to the policy rate.

On a different note, the relationship between the monetary policy rate and the term structure could be addressed by a model in a similar vein to Ellingsen and Soderstrom (2001). They argue that the nature of information asymmetry between the central bank and the economic agents about supply and demand shocks can generate different comovements in the policy rate and the long term rate. The possibility that the central bank has private information could change household behavior in the asset market.

Another avenue for further research is to employ the model in this paper for the optimal monetary policy analysis similar to Rotemberg and Woodford (1997, 1999) Clarida, Gali and Gertler (1999) and McCallum and Nelson (1998) among others. The introduction of an endogenous term premium could potentially affect the monetary transmission and consequently alter the nature of the optimal policy.
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