The Information in the Term Structure of German Interest Rates

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Abstract

This paper investigates the informative content of the term structure for German interest rates. Most of the empirical work on this subject has concentrated on tests of the Expectations Hypothesis by using US interest rate data, and the hypothesis has been found to be rejected in the great majority of cases. However, term structure information failures may simply be a reflection of the specific data used and of the particular framework within which the hypothesis has been tested. In fact, in most empirical work the information in the term structure is represented only by some measure of its slope, while an important element, that is a time-varying term premium, is missed from the specification of the models. This paper examines further the information content of the term structure using monthly data for Germany and, following the general equilibrium theory of the term premium, extends the standard framework of the EH by including a measure of the riskless rate volatility in the information set. Our results indicate that the German term structure appears to forecast future short term interest rates surprisingly well, compared with previous studies with US data. Moreover, and in line with previous findings, the slope of the term structure alone does not have predictive power for long term interest rate movements, though the direction suggested by the coefficient estimates is correct. Finally, inclusion of a volatility term represents an improvement in most regressions for the short rate, and significantly improves those for the long rate.

Résumé

Cet article étudie le contenu informatif de la structure à terme des taux d´intéret Allemande. La plupart des recherches empiriques sur cet argument s´est concentrée sur des tests de l´Hypothèse des Expectatives en utilisant des données sur les taux d´intéret pour les Etats Unis, et l´Hypothèse à été refusée dans la plupart des cas. Toutefois, les insuccès des tests sur le contenu informatif des taux d´intéret pourraient dependre des données specifiques utilisées et du contexte particulier où l´hypothèse a été testée. En effect, dans la plupart des travaux empiriques, l´information dans la structure à terme est représentée seulement par une mesure de son inclinaison, tandis que la specification de ces modèles n´a pas un élément important, c´est à dire le prix à risque variable.

Cet article examine aussie le contenu informatif de la structure à terme en utilisant des données mensuelles pour l´Allemagne, et en suivant la théorie de l´équilibre général du prix à risque, cet article-ci développe le contexte standard de la théorie des expectatives en incluent une mesure de la volatilité du taux d´intéret à bref délai dans le set d´information. Nos résultats indiquent que la structure à terme Allemande prévoit les taux d´intéret à bref délai d´une manière surprenante, face à les études précédentes sur les taux d´intéret des Etats Unis. L´inclinaison de la structure à terme toute seule n´a pas du pouvoir de prévision pour les taux d´intéret à long délai, même si la direction suggérée par les estimations des coefficients est correcte. En concluant, l´inclusion de la volatilité représente une amélioration dans la plupart des régressions pour les taux d´intéret à bref délai, et améliore d´une manière significative les régressions pour les taux d´intéret à long délai.

Keywords

Information, interest rate, term structure, term premia, volatility.

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1. INTRODUCTION[i]

Most recent stochastic models of the term structure[ii] do not deal with an issue that has been long debated within the Expectations Theory, i.e. the informative content of the term structure of interest rates.

The relationship between short and long rates has macroeconomic implications in that it is central to monetary transmission mechanism and hence to macroeconomic policy. In fact, while the monetary authority can mainly control short-term rates, the aggregate demand depends essentially on long-term rates, hence the term structure of interest rates plays an important role in the monetary transmission mechanism.

Therefore the analysis of the information content of the term structure establishes a connection between modern theory of finance and economic policy.

Purpose of the present paper is to take a fresh look at the issue in order to discuss and test whether results stemming from stochastic models of the term structure can contribute to a better understanding of the proposed information issue.

A great deal of empirical research on the term structure of interest rates has focused upon the Expectations Hypothesis (EH) that essentially relates long-term yields to actual and expected future short rates. This paper examines whether the slope of the term structure can alone explain future movements on the short rates or whether these can be better explained with the inclusion of a time-varying risk premium. The issue is explored by means of standard regression analysis with monthly data derived from the estimation of the German term structure over the period 1983(12) - 1994(12).

The paper is organised as follows. In section 2 we review the standard regression tests of the EH and in section 3 we examine the role of time-varying term premia and stochastic models. In section 4 we present the data and in section 5 we analyse their properties. In section 6 we use the regression analysis to test the information content of the German term structure, and in section 7 we extend the standard framework by including a measure of the riskless rate volatility in the information set. Section 8 concludes. Notation and definitions are given in the Appendix.

2. THE INFORMATION ISSUE

The information[iii] in the Term Structure (TS) has been empirically analysed by means of linear regression equations: the existing models essentially differ in the choice of the regressors and of the regressand. The former is represented by some measure of the "slope" of term structure, the latter by the information required.

The point is now: what gives information on what? According to the Expectations Hypothesis (EH) framework, long rates are averages of current and expected future short rates. This implies that an upward (downward) sloping TS curve predicts an increase (decrease) in short rates.[iv]

The literature has investigated the informational content of the term structure using different spreads as measures of the term structure thus obtaining different pieces of information, i.e. using different regression equations.

The specification of a linear regression equation consists of the identification of the regressor(s) and of the regressand, which means, in the present context, the source(s) of information and the information obtainable respectively. Plausible regressors are various type of term structure spreads (forward-spot rate differential, long-short rate differential), regressand of interest are: term premia, changes in the spot rate, changes in inflation and changes in the real return. In other words, the term structure of interest rates can be tested both as a predictor of future rates and as a predictor of future inflation. In the present paper only the former case is considered.

2.1 The term structure as a predictor of future interest rates

The current term structure can provide information about the future term structure: the precise content of this statement has been evaluated in a series of papers by Eugene Fama and others. Among them we recall only those that are most directly related to the present discussion: Fama (1984,1990), Fama and Bliss (1987) and Jorion and Mishkin (1990).[v]

The papers are essentially based on estimation of the one or all the following regressions:

$$(1)\ r(T-1,T) - r(t,t+1) = \alpha + \beta[f(t,T-1,T) - r(t,t+1)] + \varepsilon(T)$$

$$(2)\ \ h(t,t+1,T) - r(t,t+1) = \alpha' + \beta'[f(t,T-1,T) - r(t,t+1)] + \varepsilon'(t+1)$$

$$(3)\ r(T-1,T) - r(t,t+1) = \bar{\alpha} + \bar{\beta}[r(t,T) - r(t,t+1)] + \bar{\varepsilon}(T)$$

$$(4)\ \ h(t,t+1,T) - r(t,t+1) = \tilde{\alpha} + \tilde{\beta}[r(t,T) - r(t,t+1)] + \tilde{\varepsilon}\ (t+1)$$

where 1 is the time unit and $T>t$ and the rates are defined in the Appendix.

Equation (3) and (4) have been extended in Fama (1990) so to include the spot rate level $r(t,t+1)$ as a regressor.

Fama (1984) estimates regressions (1) and (2) using averages of end-of-month bid and asked prices for one- to six-month U.S. Treasury bills for the 1959-82 period. He finds that while the forward-spot differential has always power as a predictor of future holding term premium, the same is not true as for the future change in the one-month spot rate. In the latter case, the author shows that variation through time of the expected holding term premia contained in the forward rate[vi] obscures the power of the forward rate as a predictor of future spot rates. By means of additional regressions, the author shows that both the expected premia and the expected future spot rate components of the forward rate are time-varying.

The latter assertion is also at the basis of Fama and Bliss (1987) paper, which extends the previous analysis using longer maturity U.S. Treasury bills data, i.e. annual Treasury maturities to five years for the period 1964-85. Main findings are: (i) one-year expected returns for maturities up to 5 years net of the interest rate on a one year bond are time-varying and seem to be directly related to business cycle; (ii) forward rate cannot forecast near-term changes in the spot rate but still have forecast power for changes in the one-year spot rate 2 to 4 years ahead; such a property reflects a mean-reverting tendency of interest rates which is more evident at longer horizons.[vii]

Jorion and Mishkin (1991) also estimate regression (2) but using an international data set made of monthly observations of government bonds of maturity from 1 up to 5 years, from August 1973 to June 1989 for the U.S., Britain, Germany and Switzerland. Unlike Fama and Bliss (1987) they find that "the forward-spot spread has no significant power to forecast changes in U.S. interest rates [...]. One possible explanation for the difference is the shorter sample period used here[...].". The results for the other

countries are not more encouraging and quite consistent across countries, with the exception of Germany and Switzerland that have a significant regression coefficient at the longest 5 years term.

In Fama (1990) the focus shifts on the predictive power of the yield spread, i.e. the difference between the long and the short rate. Since yield spreads for different maturities are highly correlated, the author takes as a common spread the five-year spread and estimates regressions of the type described by equations (3) and (4) using end-of-month U.S. Treasury bond prices from June 1952 to December 1988 for discount bonds with annual maturities from one to five years. The yield-spread can always forecast the expected term premium, which turns out to increase with maturity and to vary through time as emerged in the previous studies. Yet, the yield spread has no power to forecast the one-year spot rate one year ahead and, once again as in earlier papers, its predictive power increases with the forecast horizon. As reported in the next section, Fama explains the latter finding decomposing the nominal rate into a real and an inflation component.

Hence, evidence on the forecast power of the yield spread shows big similarities with evidence on the forecast power of the forward-spot spread. In particular, the time-varying nature of the term premium both in the yield- and in the forward-spot spread seems to obscure the information about expected changes in the spot rate at the near horizon.

Summing up: the term structure (represented either by a forward-spot spread or a yield spread) is a good predictor of expected holding period term premia both at near and at long horizons and a good predictor of expected spot rates only at longer horizons. Time varying term premia play an important role in explaining the poor performance of regressions (1) and (3) over near term horizons. The issue is central to this paper and will be extensively discussed in the next section.

3. THE INFORMATION MISSED AND TIME-VARYING TERM PREMIA

The failures emerging from the tests on the informative content of the term structure have been explained in the literature in many alternative ways. Among them (for a discussion of alternative explanation see Torricelli(1995)), the existence of time-

varying term premia seems to be the most appealing explanation. Yet, time-varying term premia cannot be easily reconciled with the EH. The point is clearly made by Mankiw and Summers (1984): "Note that once it is extended to include a time-varying liquidity premium, the expectations theory becomes almost vacuous. The liquidity premium is a deus ex machina. Without an explicit theory of why there is such a premium and why it varies, it has no function but tautologically to rescue the theory.[...] These results suggest the importance of developing models capable of explaining fluctuating liquidity premiums.[...] Without a satisfactory theory of liquidity premiums, predicting the effect of policies on the shape of the yield curve is almost impossible.".

A couple of years later Mankiw (1986) still writes: "Developing theoretically plausible and empirically testable theories of the term premium should remain high on the research agenda.".

Looking back at the EH literature recalled in the present paper, it is nowadays easy to understand its failure to fully explain the existence and the time pattern of variation in term premia. The EH, in its various versions, is essentially a semideterministic theory in that uncertainty is considered but not appropriately treated. Since the late seventies, stochastic models of the TS based on the no-arbitrage equilibrium assumption have provided a proper treatment of uncertainty.

The still growing stochastic literature on the TS can be broadly split into two main approaches: the Arbitrage Pricing Theory Approach and the General Equilibrium Approach. In a previous paper, Boero and Torricelli (1995), theoretical superiority of the latter has been assessed on the basis of the two following arguments: first, relevant variables, such as the spot interest rate and the interest risk premium, are endogenous, secondly the relationship between the real and the financial side of the economy becomes a clear and important element in understanding the TS.[viii]

The first argument is essential to the present discussion: the general equilibrium models of the TS fill a theoretical gap in that they endogenise risk premia. In fact, not only they imply the existence of risk premia, but also explain their shape and their time pattern of variation in relation to the characteristics of the underlying real economy.

Within this approach, two are the papers that can shed light on the existence and the effects of time-varying risk premia: the Cox, Ingersoll and Ross (1985b) milestone paper and the more recent Longstaff and Schwartz (1992) paper.

Cox, Ingersoll and Ross (1985b) theory of the TS is obtained by specialising Cox, Ingersoll and Ross (1985a) general equilibrium model which gives a complete intertemporal description of a continuous time competitive economy. The CIR model is a single factor model having technology as the only stochastic state variable. Its main characteristics is the endogenous nature of the stochastic process for the equilibrium risk-free rate, which depends on the basic assumptions made about the real economy (e.g. technology, production and the preference structure).

The CIR model not only shows the time-varying nature of the risk premium, but offers also a precise functional form for it. The expected rate of return on a bond derived within the CIR model is given by:

$$(5)\ r(t) + \left(\lambda r(t) \frac{P_r(r,t,T)}{P(r,t,T)} \right)$$

where: λ is the market price for risk and depends on the characteristics of the underlying economy, the subscript stands for partial derivative and the term in parenthesis is the term premium at issue in this paper.

On the latter the authors state: "The factor r is the covariance of changes in the interest rate with percentage changes in optimally invested wealth (the "market portfolio"). Since $P_r < 0$, positive premiums will arise if the covariance is negative." To see this, suppose the covariance is negative, the bond is a bad hedge because has a low value when the marginal utility of wealth is high. Recalling a standard CAPM result, if a financial asset is a bad hedge it has to be priced so to yield a positive premium.

Summing up, the CIR model builds up a theory of the TS which is also a theory of time-varying term premia, still missing in the EH literature. In fact, not only their existence is explained, but their characteristics are clarified:

i) the term premium depends on the level of the risk-free interest rate, on the covariance with optimally invested wealth and on the interest rate elasticity of bond prices;

ii) its sign depends only on the covariance of changes in the interest rate with percentage changes in optimally invested wealth.

Yet, the single factor nature of the basic CIR model implies that term premia on different bonds are perfectly correlated. Longstaff and Schwartz (1992) overcome this limitation by extending the CIR general equilibrium model to the case of two state variables. The LS model is thus a two-factor model, the two factors being the short term interest rate, *r(t)* as in CIR, and its volatility *V(t)*, which is also "intuitively appealing since volatility is a key variable in pricing contingent claims".

The instantaneous expected return for a discount bond stemming from LS model is the following:[ix]

(6) $r + \lambda \frac{(\exp(\psi\tau) - 1)B(\tau)}{\psi(\beta - \alpha)}(\alpha r - V)$ where:

λ is as before the market price for risk parameter,[x]

α, β, ψ are parameters describing the dynamics of *r(t)* and *V(t)*,

τ is time to maturity and $B(\tau)$ is a non-linear function of the model parameters and of maturity τ.

As in CIR, the term premium is an increasing function of the riskless rate and its sign is determined by the market price of risk parameter. The novelty here is that the term premia is now a linear function of both the interest rate level and its volatility where the relationship with the latter is indeterminate.

At this stage the question is: how is it possible to reconcile CIR and LS result on time-varying term premia with the models presented in section 1? In other words, how can the general equilibrium theory on time-varying term premia help to explain the inability of the EH to assess the information content of the term structure?

The answer of the present paper relies on a broader use of the word "information" as opposed to that generally made in the literature[xi]. In fact, in regressions (1) to (4) the "information" in the term structure is represented only by some measure of its slope: the information at issue in those equations is only that contained in either the forward-spot or the long-short spread. Yet, the time-varying term premia contained in those spreads obscure the information content of the same.

Thus, the need of adding a time-varying term premium as an explanatory variable in the above-mentioned regressions is apparent. Several studies[xii] have already attempted that, but none has yet done it on the basis of a proper theory of the term premium which allows to have a theoretically consistent interpretation of the results.

Here, on the basis of the general equilibrium models recalled in this section, possible extensions of regressions (1) to (4) are proposed.

The first is based on CIR results: from (5), the term premium to be added to the regression equations could be modelled as the product of the market price for risk and the interest rate elasticity of bond prices[xiii] :

(7) $\Phi(t,T) = \lambda\varepsilon\big(P(r,t,T), r(t)\big)$

where $(P(r,t,T),r(t))$ is the interest rate elasticity of bond prices.

A problem with (7) is its implementation: in the CIR model depends on the covariance between wealth and the state variable and on the preference structure and therefore would require a previous and separate estimation. The real problem here is that the only source of variation in the term premium is again r(t), which plays already a role in the regressions considered in the previous section.

To move a step forward, one has to look at the implications of the LS model. From equation (6), it is possible to write the term premium as follows:

(8) $\Phi(t,T) = \lambda f(T-t)\big(\alpha r(t) - V(t)\big)$

where $f(T-t)$ is a non-linear function of the model parameters and of maturity.

For fixed maturity, the term premium is a linear function of both r(t) and V(t). Unfortunately, as it stands in (8), the term premium cannot be simply added to a linear regression equation. Yet, it suggests that the riskless rate volatility is a further source of information which has to be incorporated into regression equations beside the riskless rate or the yield spread. Two points still have to be discussed: how to incorporate it and what measure of volatility to take.

As for the first, if the theory has to be testable the simplest way to preserve linearity is to incorporate volatility by means of a second regressor in equations (1) to (4) of the type: $+\gamma V(t)$ where the sign of γ is, according to the LS model, indeterminate and depends essentially on the length of the maturity. The consideration of the volatility

term could explain some of the empirical regularities which are at odds with the EH. In fact, even if the term structure were flat (i.e. the first regressor equal to zero), volatility could still account for future spread or premia.

The second point is what is volatility. Theoretically, in LS paper, it is the instantaneous variance of changes in the riskless rate and for its estimation the GARCH framework is suggested. It is thus clear that the point is more an empirical one. In this paper we measure volatility by a moving average of absolute changes in the short rate, over a predetermined number of observations. This measure has been used in previous studies, but this choice is arbitrary and alternative proxies for a time varying risk premium could be adopted.

Summing up, the two mentioned stochastic models of the term structure provide a few interesting hints for future research on the information content of the term structure. At this stage, the issue is mainly an empirical one: in fact, the opportunity to introduce volatility (or other regressors explaining time-varying term premia) has to be confirmed by the data. In the analysis below we present the first stages of our empirical study of the German term structure.

4. ESTIMATION OF THE TERM STRUCTURE

The empirical results of this study are based on time series drawn from estimated term structure curves.[xiv] We have estimated 134 monthly term structures of interest rates based on German government bond data, covering the time period from November 1983 to December 1994. The data are provided by the Karlsruher Kapitalmarkt Datenbank (KKMDB) and refer to the 15th of each month.

The estimation precedure followed the non-linear regression approach suggested by Chambers, Carleton and Waldman (CCW) (1984). The basic idea of CCW is to approximate the term structure of interest rates using a polynomial of an arbitrary degree. Formally for a fixed estimation date t the following equation holds:

$$(9)\ r(t,T) = \sum_{J=1}^{l} a_j (T-t)^{j-1}$$

The discount function $B_t(T)$ according to (9) is an exponential polynomial:

$$(10)\ B_t(T) = \exp(-\sum_{j=1}^{l} a_j T^j)$$

Based on this assumptions a statistical model to estimate the parameters of the discount function from the observed coupon bond prices is:

$$(11) \qquad B_0(k_s, T) = \sum_{i=1}^{n-1}\left[k_s \exp(-\sum_{j=1}^{l} a_j t_i^j) \right] + (100 + k_s)\exp(-\sum_{j=1}^{l} a_j t_n^j) + \varepsilon_s,$$

where $k_s (s = 1,...,m)$ denotes the coupon payment of the s th coupon bond, $t_i, (i = 1,...,n)$ denotes the time measured in years from the estimation date to the relevant coupon payment date.

Based on (11) the parameters $a_j, (j = 1,...,l)$ can be estimated using a non-linear regression approach.

For the given data different degrees of the polynomial were employed. In order to assess the goodness of fit of the estimated parameters we used the mean absolute deviation (MAD). The price deviation ε_s is the difference in DM of the observed market price of bond s and its present value calculated with the estimated rates. The Mean absolute deviation is then defined as follows:

$$(12) \qquad MAD = \frac{1}{m}\sum_{s=1}^{m} abs(\varepsilon_s)$$

As mentioned above we estimated the parameters for different degrees of the exponential polynomial. However, we eventually decided in favour of an exponential polynomial of degree 8. Exponential polynomials of degree less then 8 turned out to yield heavily worse MAD, whereas no significant enhancement of the goodness of fit could be achieved when we used exponential polynomials of higher degrees.

For the performed term structure estimation we obtained an overall MAD of DM 0.190 which has to be considered an excellent result.[xv] We have also calculated the MAD for each year. The best fit is for 1989 with an MAD of DM 0.113 the worst fit turns out to be for 1985 with MAD of DM 0.369. Further analysis shows that overall 75% of the absolute deviations are less than DM 0.228.[xvi]

The regressions below use monthly observations of interest rates derived from the estimation of the German term structure. The short rates considered are the one-day and the one-month rates. The long rates are the one- to five-year rates. The evolution of the

term structure of interest rates over time is presented in Figures 1a and 1b. Figure 1a shows the time period from November 1983 to June 1989, Figure 1b covers the time period from July 1989 to December 1994. As can be better seen from the Figure 2, German interest rates were at a relatively high level at the beginning of the time period under consideration. German rates were heavily influenced by high rates in the U.S. due to the so called deficit spending policy of the Reagan administration. However, interest rates in Germany declined to a very low level in the mid-eighties . The next period of high interest rates was mainly caused by fears of inflation resulting from the monetary union of East and West Germany and their later unification. As a result interest rates increased sharply by the end of 1989, but were still at a moderate level (about 6%-7%). The DM was introduced in East Germany in the middle of 1990. This resulted in further inflation and caused interest rates to increase again. Especially rates for short maturities were extremely high. After rates peaked in October 1993 a constant decrease of interest rates could be observed.

All rates move mostly in the same direction. In particular, the short (one day rate and one month rate) resulted almost equivalent, so that in the present paper we decided to use only the one day rate. Fig.2 shows the evolution of the one-day rate and the 5 year rates for the period November 83 December 94.

The time the short rates are lower than the 5 years rate until 1990, implying an upward sloping term structure, while from the end of 1990 to the begining of 1994 the term structure was downward sloping.

5. PRELIMINARY ANALYSIS OF THE DATA

The estimated models

The following empirical study is based on regressions of the type described by equation (3) but extended to examine the information content of the term structure for both short and long rates. The data set consists of monthly observations of interest rates derived from the estimation of the term structure described in the previous section.

First, we study the usefulness of the spreads between long and short rates as indicators of future changes in both short and long rates. So we estimate the following regressions:

(13) $r_{t+h} - r_t = \alpha + \gamma (R_t - r_t) + u_{t+h}$

(14) $R_{t+h} - R_t = \alpha + \gamma (R_t - r_t) + u_{t+h}$

where r is the short rate, R the long rate and h the forecast periods (months).

Second, we add a second regressor, the volatility of the short rate, as a proxy for a time-varying risk premium, to see whether more information can be extracted from the term structure by including this variable. The regressions used for this second purpose are the following:

(15) $r_{t+h} - r_t = \alpha + \gamma (R_t - r_t) + \delta \, VOL_t + u_{t+h}$

(16) $R_{t+h} - R_t = \alpha + \gamma (R_t - r_t) + \delta \, VOL_t + u_{t+h}$

As we will see later, the volatility has been approximated by a moving average of absolute changes in the short rate, computed over six periods (MA6). This measure will clearly be a crude proxy of the true volatility, but it will be related to it, and it has been used in other studies (see Simon, 1989).

Most series exhibit a structural break during the German Unification period. However, the empirical analysis below is not affected by this regime shift as much as we would expect, perhaps because the breaks cancell across linear combinations of the variables (see the concept of *co-breaking* series recently introduced by Hendry and Clements (1995)). This point requires further examination.

Unit root tests

Estimation of regressions of the type described by equations (13) - (16) requires that the variables are stationary. So we first checked for the presence of a unit root by applying Augmented Dickey-Fuller (ADF) tests. The ADF test accounts for temporally dependent and heterogeneously distributed errors by including lagged innovations sequences in the fitted regression.

The results of the tests not reported here (see Boero-Madjlessi.Torricelli, 1995), suggest that changes in the short interest rate are stationary for forecast horizons of one- to 16-months, but they indicate the presence of a unit root for longer horizons. Changes in the long rate are stationary for forecast horizons of one- to nine-months and become non-stationary for longer horizons. Finally, the tests suggests that all spreads and the

volatility term are stationary. These results are important for determining which variables should be considered in the regression analysis performed below.

6. TESTS OF THE INFORMATION IN THE GERMAN TERM STRUCTURE

The results presented below are derived from estimates of equations (13) and (14). First we address the question whether current spreads contain information for future changes in the short rate. Then we address the same issue for changes in the long rate.

6.1 Predicting short term rates

The forecasting equations relate used for this analysis relate changes in the short term interest rate h periods (months) ahead to the current spread between long term (R=1,2,3,and 5 years) and short term (r=1-day) interest rates. The regressions are similar to those used in Fama(1990). To obtain meaningful results, all the variables in a regression should be stationary or cointegrated. According to the unit root tests in the previous section, all spreads are stationary, while changes in the short rate are stationary for forecast periods up to 16 months, and become non stationary over longer periods. So the estimated equations in Table 1 are specified for changes in the short rates from 3- to 12-months ahead, with the spreads of the yield on a one, two, three and five-year bond over the one-day spot rate. These are called in table 1 SP1-0, SP2-0, SP3-0 and SP5-0, respectively. We do not report results with SP4-0 as they were very similar to those with SP5-0. Due to overlapping data, the equations are estimated by OLS with corrections based on Newey-West (1987) for a moving average of order h-1, where h is the forecasting horizon (in months), and for conditional heteroscedasticity. Several findings are of interest.

First, our results indicate that the German term structure, in the period 1983-1994, appears to forecast future interest rates surprisingly well. The results reveal that the parameter estimates for γ, the coefficient of the slope of the term structure always contain significant predictive power for future changes in short-term rates at the 1 percent level, with R^2 ranging from 0.15 to 0.48. We note that these R^2s are much higher than those obtained with data for the US term structure. For example, Fama (1990) in table 1 reports R^2=0.00 for interest rate changes one-year ahead, and R^2=0.24 for forecast horizon extended to 5 years. This finding is in line with recent evidence in

Hardouvelis (1994), where using different data (not from the estimation of the term structure) and methodology notes that the US term structure seems to predict interest rates less well than the term structure for the other G-7 countries.

Second, Table 1 shows that, for a common spread, the coefficient estimate γ and the predictive power of the regressions increase with the forecast horizon. For example, when the one-year spread (SP1-0) is used as the regressor, for short forecast horizons (3 to 6 months) the coefficient estimates are less than one, and become greater than one as the forecast horizon is extended (10 to 12 months). Similarly, the R^2 values increase from 0.27 (3-months ahead) to 0.47 (12-months ahead). The finding that the forecast power increases with the forecast horizon is in line with the evidence for the US in Fama (1984, 1990), Fama and Bliss (1987), Campbell and Shiller (1987), Hardouvelis (1988) and Mishkin (1988). These studies, however, report much lower R^2s than those we obtained for Germany.

Third, our results suggest that the one-year spread contains more information for changes in the short rate over periods closer to one year; in the same way and in accordance with equation (3), we would expect a 2-year spread to be more informative for changes in the short rate over a period of two years. However, we could not investigate this issue further, using this simple regression framework, due to the non stationary properties of changes in the short rate over periods longer than one year. These results are interesting as they indicate that the choice of the spread to include in the regressions matters. This is in contrast with previous findings for the US (see Fama 1990), where a common spread (five-year spread) could be used in all regressions as different spreads were very highly correlated and shared nearly identical time-series properties. Our results suggest a common pattern within each forecast horizon considered: the most informative spread is the one-year over one-day rate (SP1-0), and the values of both γ and R^2 decrease with the length of the maturity spread.

To summarize this section, overall, the results for the German term structure are surprisingly good, compared with previous findings for US data. In most cases the "slope" of the term structure has a fair degree of explanatory power for the change in short rates, when the appropriate spread is used, with R^2 of 0.27 and above. These results are even more satisfactory, given the simplicity of these regressions: so far we are

restricting ourselves to extract information about future changes of short interest rates using only knowledge at time t of the "slope" of the term structure. Surely the spread is not the only predictor for changes in the short rate. Highly significant diagnostic tests can be considered evidence for omitted variables. Moreover, a plot of recursive estimates of the γ coefficient in Figure 10 reveals some instability and suggests that the equations should be better specified. In section 7 we make use of an additional variable, specifically the volatility of the short term interest rate, to see if we can extract more information from the term structure beyond that contained in the slope. Before we do that we repeat the analysis above for long term rates.

6.2 Predicting long-term interest rates

An extensive literature, mostly on US data, documents that the term structure is a good predictor for variations in the short-term interest rate, but not for the long term (see Mankiw, 1986, Campbell and Shiller, 1991, Hardouvelis, 1994, and Grande, 1994, for an application to the Italian Treasury Bill market). A general finding of these studies is that if the slope of the term structure forecasts changes in the long rate at all, the sign of the coefficient estimate is negative, that is the spread predicts changes in the long rate in the direction opposite to that predicted by the Expectations Hypothesis. In this section we test the information content of the German term structure by regressing changes in the long-term interest rate on the slope of the term structure. Table 2 reports the results. The long term rate R_t is the five-year rate, the short rate r_t is the one-day rate. The analysis is conducted for 1- to 9-months forecast periods only, as according to the unit root tests, changes of the long-term interest rate over periods longer than 9 months show non-stationarity. Several findings are of interest.

First, in line with previous studies where different data and methodologies have been used, in these regressions which have the change in the long rate as the dependent variable, the results are overall negative, suggesting that there is no predictive power in the slope of the term structure for long-rate movements. The coefficient estimates of the spread are not significantly different from zero, and the R^2 are very low.

Second, although the predictive power of the regressions is poor, it is interesting to note that while previous studies with data for the US report a negative sign for the coefficient γ, indicating that the spread predicts the wrong direction in future changes of

the long rate, the direction emerged in our estimates for Germany is correct, according to the expectations hypothesis. However, due to the poor specification of the model, we cannot interpret these results further.

7. THE INFORMATION CONTENT OF VOLATILITY

In this section we extend the framework presented in section 6, used in standard tests of the Expectations Hypothesis, by including a measure of the riskless rate volatility in the information set, as a proxy for a time-varying risk premium. The results presented below are derived from estimates of equations (15) and (16), which are inspired by the Longstaff and Schwartz (1992) model, as discussed in section 3. As this analysis is quite new, it can only be viewed as an early experiment.

First, we address the issue whether a volatility term, proxy for a time-varying risk premium, can help extracting more information from the term structure for future changes in the short rate. Then, we see whether inclusion of a time-varying risk premium can improve the forecast performance of the regressions for the long rate.

7.1 Does volatility add information for the short-term interest rate?

In table 3 we extend the standard framework presented in section 6 by including a measure of the riskless rate volatility in the information set, as a proxy for a time-varying risk premium. The risk premium is proxied by a moving average of absolute one-day interest rate changes over the previous six months. A similar measure has been used in previous empirical analyses of the term structure (see Simon, 1989, for example), but of course the choice is arbitrary, and comparisons with other measures should be explored in future research. A number of results are of interest.

First, the coefficient estimates of γ remain significant at the 1 per cent level in all cases.

Second, the coefficient estimate δ of the volatility term is significantly different from zero in ten cases out of sixteen. Overall, however the contribution of the short rate volatility in terms of R^2 is marginal. Thus, most of the information in the term structure for movements in the short rate is contained in the spread.

Third, despite the marginal increase in the predictive power, diagnostic tests suggest that these extended regressions represent an improvement in some cases. Moreover,

recursive estimates of the showed a remarkable improvement in terms of stability in the extended regressions. Indeed, both coefficients γ and δ are surprisingly stable, and seem not to be affected by the structural break observed in most series around the German Unification period. A more thorough analysis of the impact of regime shifts in the estimated models is currently under investigation.

Finally a note on the negative sign of the volatility term. Although this sign is in line with previous studies which have used similar proxies (see Simon, 1989), according to the theoretical model of Longstaff and Schwartz (1992) the sign of volatility is indeterminate. So, as our approach is inspired by the LS model, we are inclined to believe that the finding of a negative sign is specific to the particular operational measure used for the short rate volatility, and to the data and period considered. As a preliminary check, not reported here, we conducted the analysis for different subperiods, and with the standard deviation of the short rate as an alternative measure for volatility. The results were not very robust in terms of both the sign and the significance of the estimated coefficient of the volatility term. These depend on the forecast periods considered, the set of interest rates and spreads selected, and the proxy used for the volatility term. The choice of the volatility measures is in fact entirely arbitrary, and it is not clear what is the best measure to use. Comparisons with other indices should be further explored.

7.2 Does volatility add information for the long-term interest rate?

In table 4 we extend the regressions presented in section 6.2 for the long-term interest rate, by including a time-varying risk premium term. To facilitate the comparison, we also report the results from table 2. The proxy used for volatility is the same as in section 7.1, that is a moving average of absolute one-day interest rate changes over the previous six months. The results presented below show that, with the inclusion of the volatility term, the forecasting regressions for changes in the long rate significantly improve. In particular, the coefficient estimate γ now becomes significant at the 5 and 1 percent levels with a coefficient which is more than twice the value obtained without the volatility term. The coefficient estimate of δ is also significantly different from zero, and there is a fair improvement in terms of the R^2.

Moreover, a recursive estimate of the coefficient has revealed that, with the inclusion of the volatility term, the coefficient estimate of γ becomes stable, and that the value of the coefficient is positive for most of the sample period. Thus, our results suggest that the direction indicated by the spread for future changes in the long rate is correct, according to the Expectations Hypothesis, in contrast with previous studies with U.S. data.

To conclude, our analysis suggests that these extended regressions represent an improvement with respect to simple regressions which use only knowledge at time t of the slope of the term structure. However, there is still some information missed about future changes of interest rates. In particular, dynamics are excluded from these regressions, and ways to improve the specification of these models are under study. One possibility is to adopt an error correction specification which combines the long-run information in the term structure with short-run dynamics. Another possibility is to use the conditional variances estimated from GARCH models, rather than a moving average term as a proxy for interest rate volatility.

8. CONCLUSIONS

Previous studies have recognised the failure of the Expectations Hypothesis to properly detect the information content of the term structure. In the present paper, we have proposed an explanation for such a failure based on the existence of time-varying term premia and we have tested it for the case of Germany.

The issue is reexamined in the light of the most recent stochastic models, which essentially confirm the existence of time-varying term premia. In order to combine the latter with the information analysis, an explicit theory for the time-varying term premia is needed. Such a theory is found only within general equilibrium stochastic models of the term structure. To this end, Cox, Ingersoll and Ross (1985) and Longstaff and Schwartz (1992) models are examined and their implications about term premia considered. Among other things, term premia turn out to be proportional not only to the level of the riskless rate, but also to its volatility.

Hence, the theory suggests the need for a broader use of the expression "information in the term structure" which, in our opinion, implies consideration of a second regressor

in equations (1) to (4). According to the general equilibrium theory of the term premium, a sensible explanatory variable is volatility.

The empirical analysis performed here is quite preliminary and can be viewed as an early experiment. However, several results are of interest. First, our results indicate that the German term structure appears to forecast future short term interest rates surprisingly well, compared with previous studies with US data.[xvii] Second, and in line with previous findings, the slope of the term structure alone does not have predictive power for long term interest rate movements, though the direction suggested by the coefficient estimates is correct. Third, inclusion of a volatility term represents an improvement in most regressions for the short rate, and significantly improves those for the long rate. The empirical results improve in terms of the statistical significance of the coefficients, their stability, and the predictive power of the regressions.

Although these results seem overall interesting, the regressions used for the test of the information content of the term structure are very simple, and so there are many directions this study can take to improve the predictive power of the models and better understand the nature of the series.

In particular dynamics are excluded from the analysis. One way to improve the specification of the models is to adopt an error correction (or equilibrium correction) specification which combines the long-run information in the term structure with short-run dynamics. Moreover, further research is needed to establish whether a more significant contribution to the forecasting power of the term structure can be obtained with alternative measures of volatility. One possibility is to use the conditional variances estimated from GARCH models. Finally, the series used in this study contain a regime shift due to the German unification; once account is taken of the structural break, the results may improve significantly. The points just made represent current and future research work.

APPENDIX: Notation and definitions

The literature on the term structure of interest rates is unfortunately characterised by a cumbersome notation, which is furthermore far from being uniform among contributors. In the present appendix Shiller(1990) is adopted.

Let:

- t be time with $t \le T$

  $p(t,T)$ be the price at t of a pure discount bond maturing at T, whose principal is 1

- $m = T - t$ be the term or time to maturity of the bond

then $r(t,T)$, the yield to maturity or spot interest rate of the pure discount bond maturing at T, whose principal is 1, is given by:

$$r(t,T) = -\ln(p(t,T)) / (T-t).$$

$r(t,T)$ is the short rate if the term m is small, the long rate if m is big.

The forward rate at time t applying to the time interval t' to T is given by:

$$f(t,t',T) = -\ln(p(t,T) / p(t,t')) / (T-t') \quad \text{with } t<t'<T$$

or alternatively:

$$f(t,t',T) = \frac{(T-t)r(t,T) - (T-t')r(t,t')}{T-t'}$$

The holding period return from t to t' on a bond maturing at T is given by:

$$h(t,t',T) = \frac{(T-t)r(t,T) - (T-t')r(t',T)}{t'-t}$$

Having defined relevant returns, it is now possible to define the term premia that play a role in the analysis of the informative content of the term structure.

The forward term premium is defined as the difference between the forward rate and the corresponding future spot rate, i.e.:

$$\Phi_f(t,t',T) = f(t,t',T) - E_t r(t',T) \quad \text{with } t<t'<T$$

and E_t is the rational expectation operator.

The holding period term premium is defined as the difference between conditional expected holding period yield and the corresponding spot rate, i.e.:

$$\Phi_h(t,t',T) = E_t h(t,t',T) - r(t,t') \quad \text{with } t<t'<T$$

The rollover term premium is defined as the difference between bond maturing at time t' and conditional expected holding period return from rolling over m-period bonds, i.e.:

$$\Phi_r(t,t',m) = r(t,t') - E_t h(t,t',t+m) \quad \text{with } t<t+m<t'$$

In the early literature, e.g. Hicks (1946) and Keynes (1936), the forward and the rolling over premia were referred to as "risk premium" or "liquidity premium". The holding period term premium is the theory of finance "excess return".

See Shiller (1990), for the relationships between the various types of premia.

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[i] An earlier version of this paper can be found in Boero, Madjlessi and Torricelli (1995).

[ii] For a survey on the literature, see: Boero and Torricelli (1994, 1995), Vetzal (1994).

[iii] The information we address in this paper is only information on monetary variables (interest rates, inflation) and not on real variables. Yet, the term structure can be used as an indicator and predictor of real economic activity: among others see Estrella and Hardouvelis (1991).

[iv] For a discussion of various versions of the EH in relation to the information issue, see Torricelli (1995).

[v] The empirical literature considered in this section uses data drawn from estimated term structure curves which can be considered as returns on pure discount bonds. In the next sections, some reference is made also to papers based on yield data. By yield data we mean the term structure of the internal rate of return on coupon bonds, which is not a correct measure of the term structure of interest rates.

[vi] In two previous papers, Fama (1976a,b), the author shows that the forward rate f(t,T-1,T) can be decomposed in three parts: (i) the expected value of the future spot rate, E[r(T-1,T)], (ii) the expected holding premium in the one month return on a bond of maturity T, (iii) current and expected changes in future expected holding premia. Precisely the latter two components obscure the relationship between f(t,T-1,T) and E[r(T-1,T)]

[vii] For an illustration of this finding, see Fama and Bliss (1897) page 690.

[viii] For a complete comparative evaluation of the two approaches, both at a theoretical and at an empirical level, the interested reader is referred to the original article.

[ix] Details about the model and the variables involved in (6) are to be found in the original paper. Here only results concerning the term premium are discussed.

[x] In LS model as well can be interpreted in terms of covariance between optimally invested wealth and the state variable: see Longstaff and Schwartz (1992) page 1263.

[xi] For example, Mishkin (1990) writes: "...we are restricting ourselves to extracting information about the future path of inflation using only our knowledge of the slope of the term structure."

[xii] Among others: Shiller, Campbell and Schoenholtz (1983), Engle, Lilien and Robins (1987), Simon (1989).

[xiii] Since the regression equations proposed in section 2 are in discrete time, also the term premia proposed in this section should be added in their discrete time version.

[xiv] Other studies use Bundesbank bond yield data (e.g. Gerlach, 1995). The Bundesbank provides the term stucture of internal rate of returns of default-free bonds, which coincides with the term structure of interest rates only if the latter is flat. Since the aim of the present paper is to detect the informative content of the term structure of interest rates, we think it is important to use time series drawn from properly estimated term structure curves.

[xv] Bühler, Uhrig, Walter and Weber (1995) in a recent study fit a cubic spline to a discrete term structure estimated with a quadratic programming approach. They report an MAD for 1993 of DM 0.114.

[xvi] Further details on the estimation of the term structure are available upon request to the interested reader.

[xvii] A possible intuitive interpretation of such a difference can be the following. German term premia are relatively small and constant, compared with U.S., so that most of the information about future short rates is given by the yield spread. This would also explain why volatility does not add much information.

Table 1
Estimated regression: $r_{t+h} - r_t = \alpha + \gamma (R_t - r_t) + u_{t+h}$

h periods ahead (months)	Spread	γ	R^2	LM(12)	FF(1)	N(2)	H(1)	sample No. obs.
3	SP1-0	0.57***	0.27	***	0.73	0.16	0.79	84.2-94.12
3	SP2-0	0.50***	0.26	***	0.35	*	0.55	131
3	SP3-0	0.41***	0.21	***	*	*	0.17	131
3	SP5-0	0.28***	0.15	***	**	*	0.21	131
6	SP1-0	0.96***	0.44	***	0.80	0.15	0.50	84.5-94.12
6	SP2-0	0.85***	0.43	***	0.85	***	0.55	128
6	SP3-0	0.71***	0.37	***	0.45	**	0.22	128
6	SP5-0	0.50***	0.28	***	0.16	*	0.17	128
10	SP1-0	1.25***	0.48	***	0.24	0.77	***	84.9-94.12
10	SP2-0	1.10***	0.45	***	0.11	0.22	***	124
10	SP3-0	0.95***	0.42	***	0.12	0.28	***	124
10	SP5-0	0.71***	0.36	***	0.35	0.41	***	124
12	SP1-0	1.41***	0.47	***	0.21	0.58	**	84.11-94.12
12	SP2-0	1.27***	0.46	***	*	*	***	122
12	SP3-0	1.10***	0.42	***	*	0.16	***	122
12	SP5-0	0.84***	0.39	***	0.13	0.29	***	122

***, **, and * indicate statistical significance at the 1%, ** 5% and * 10% levels, respectively.
LM(p) is the Lagrange multiplier test for pth-order serial correlation
FF(1) is the Ramsey-RESET test for functional form misspecification
N(2) is the Bera-Jarque test for normality
H(1) is the White test for heteroscedasticity

Table 2
Estimated regression: $R_{t+h} - R_t = \alpha + \gamma (R_t - r_t) + u_{t+h}$
R = 5-year interest rate
r= one-day interest rate

h months ahead	Spread	γ	R^2	sample	no. obs.
1	SP5-0	0.02	0.01	83.12-94.14	133
3	SP5-0	0.07	0.03	84.2-94.12	131
6	SP5-0	0.15	0.06	84.5-94.12	128
9	SP5-0	0.21	0.07	84.8-94.12	125

Table 3
Estimated regression: $r_{t+h} - r_t = \alpha + \gamma (R_t - r_t) + \delta \, VOL_t + u_{t+h}$

h periods ahead (months)	Spread	γ	δ	R^2	LM(12)	FF(1)	N(2)	H(1)	sample No. obs.
3	SP1-0	0.62***	-0.71	0.29	***	0.51	0.34	0.65	84.8-94.12
3	SP2-0	0.62***	-1.16**	0.31	***	0.32	0.18	0.63	125
3	SP3-0	0.57***	-1.47***	0.28	***	0.39	0..16	0.51	125
3	SP5-0	0.44***	-1.64***	0.23	***	0.59	0.24	0.49	125
6	SP1-0	1.01***	-0.84	0.44	***	0.54	*	0.63	84.11-94.12
6	SP2-0	1.03***	-1.69***	0.47	***	0.55	***	0.81	122
6	SP3-0	0.98***	-2.37***	0.46	***	0.92	***	0.92	122
6	SP5-0	0.78***	-2.78***	0.39	***	0.59	***	0.57	122
10	SP1-0	1.28***	-0.19	0.48	***	0.32	0.81	**	85.3-94.12
10	SP2-0	1.27***	-1.23*	0.47	***	0.45	0.16	***	118
10	SP3-0	1.22***	-2.13***	0.47	***	0.54	0.12	***	118
10	SP5-0	1.01***	-2.78***	0.43	***	0.53	0.25	***	118
12	SP1-0	1.37***	0.73	0.46	***	*	0.53	**	85.5-94.12
12	SP2-0	1.34***	-0.34	0.44	***	0.14	*	**	116
12	SP3-0	1.27***	-1.23	0.42	***	0.16	**	**	116
12	SP5-0	1.04***	-1.91*	0.39	***	0.19	0.14	***	116

***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. LM(p) is the Lagrange multiplier test for pth-order serial correlation; FF(1) is the Ramsey-RESET test for functional form misspecification; N(2) is the Bera-Jarque test for normality; H(1) is the White test for heteroscedasticity.

Table 4

Estimated regression: $R_{t+h} - R_t = \alpha + \gamma (R_t - r_t) + \delta VOL_t + u_{t+h}$

R = 5-year interest rate

r = one-day interest rate

h months ahead	Spread	γ	δ	R^2	sample	no. obs.
1	SP5-0	0.02		0.01	83.12-94.12	133
		0.04**	-0.29**	0.03	84.6-94.12	127
3	SP5-0	0.07		0.03	84.2-94.12	131
		0.17**	-0.94***	0.11	84.8-94.12	125
6	SP5-0	0.15		0.06	84.5-94.12	128
		0.33***	-1.62***	0.16	84.11-94.12	122
9	SP5-0	0.21		0.07	84.8-94.12	125
		0.43**	-1.73*	0.17	85.3-94.12	118

*** and ** indicate statistical significance at the 1% and 5% levels, respectively.
VOL= volatility of the short term interest rate proxied by a moving average of absolute one-period changes over the previous six months

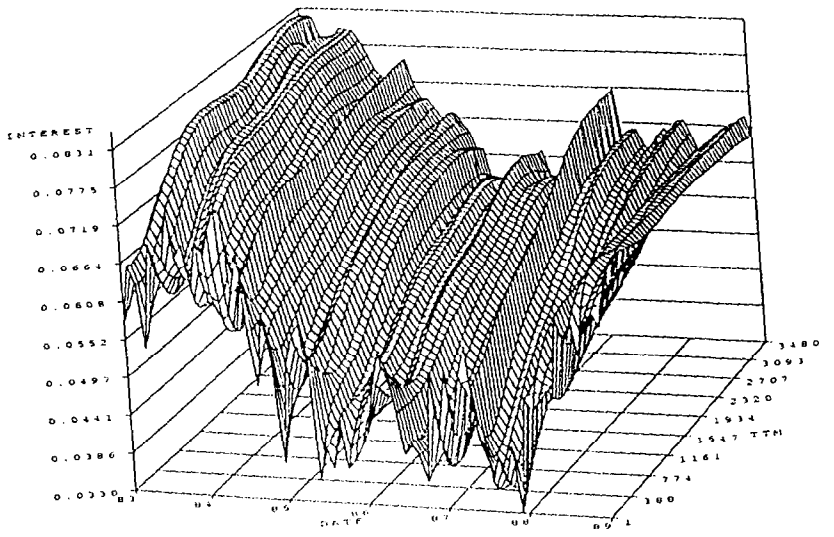


Figure 1a: The term structure of German interest rates: 1/1983 - 6/1989

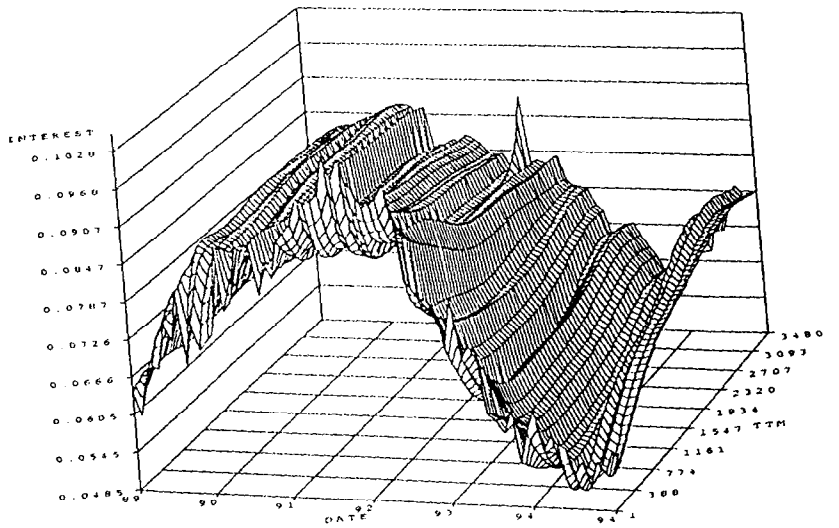
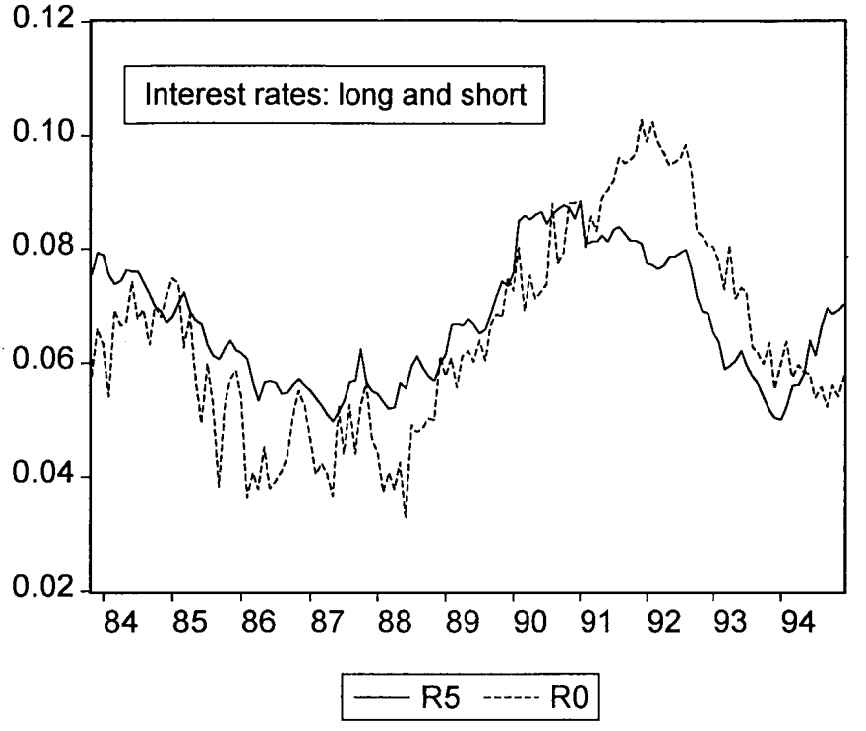


Figure 1b: The term structure of German interest rates: 1/1989 - 6/1994

Figure 2


Interest rates: long and short
0.12
0.10
0.08
0.06
0.04
0.02
84
85
86
87
88
89
90
91
92
93
94
R5
R0