NOTES D'ÉTUDES

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Les Notes d'Études et de Recherche reflètent les idées personnelles de leurs auteurs et n'expriment pas nécessairement la position de la Banque de France.

The information content of the French and German government bond yield curves: Why such differences?

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Abstract

In this paper, we evaluate the information content of the yield curve as regards future interest rates and inflation in France and Germany. An original data set of long-term zero-coupon interest rates for French and German government bonds was constructed for the period 1980-97. Empirical evidence shows that the German yield curve has a significant information content about the future average change in short-term rates and the future path of inflation. The information content of the French yield curve is much more limited and is only relevant for the average change in short-term rates. We show that the difference between the results obtained for both countries mainly stems from lower variability in German risk premia than in French risk premia.

Résumé

Nous évaluons dans ce papier le contenu en information de la pente des taux concernant les taux d'intérêt et l'inflation future en France et en Allemagne. Une base de données contenant les taux zéro-coupon issus des titres publics français et allemands a été construite à cette fin pour la période 1980-97. Nous trouvons que la pente des taux allemande a un contenu en information significatif pour la variation moyenne des taux courts et pour la trajectoire de l'inflation. Le contenu en information de la pente des taux française est beaucoup plus limité et n'est significatif que pour la variation moyenne des taux courts. Nous montrons que la différence entre les résultats obtenus pour les deux pays provient essentiellement de la plus faible variabilité de la prime de risque allemande par rapport à la prime de risque française.

Key words: Term structure of interest rates, Information content.
Classification JEL: E43

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1 Introduction

The yield curve is supposed to reflect investors' expectations about economic variables. For central banks it can be helpful as an indicator of expectations concerning future interest or inflation rates. Most naturally, assuming agents are rational, the slope of the yield curve (the term spread) at a given date may reflect their expectations with regard to future interest rates since, when the expectations hypothesis of the term structure (EH) holds, the 2-year rate today may be viewed as the average of the 1-year rate today and the 1-year rate in a year's time. The spread between the 2-year and 1-year rates today is then equal, except for a constant premium, to the change in the 1-year rate between today and one year from now. Less directly, the slope of the term structure is thought to contain information about the expected path of inflation. This approach is based on the Fisher relation, according to which the expected real rate (defined as the nominal rate minus the expected inflation rate for the period covered by the interest) is constant over time. The spread between the 2-year and 1-year rates today would thus be equal to the difference between the expected inflation rate for the next two years and the expected inflation rate for the next year.

A number of studies have measured the predictive power of the yield curve. Concerning interest rate forecasts themselves, the EH holds for certain types of test or certain pairs of maturities but it is clearly rejected for others.[1] Concerning inflation forecasts, it is broadly apparent that the yield curve does indeed contain some information, but that its predictive content is rather limited.[2] Most studies on the subject have been carried out on US data or on short-term rates. This is hardly surprising: while it is easy to obtain data on short-term rates (interbank rates, Euro-currency rates), the construction of yield curves including long-maturity interest rates is both difficult and costly. This problem is illustrated by Mishkin's two international studies (Mishkin, 1991, and Jorion and Mishkin, 1991): the first, based on 1- to 12-month Euro-currency rates, covered 10 countries while the second, based on 1- to 5-year rates, was able to cover only 4 countries and with data of different origins (from government securities or from Euro-currency markets). Browne and Manasse (1990) also used data from different sources: for Germany, for example, they used interbank market rates for short maturities and government security rates for long maturities.

Some authors made up for the lack of information at the long end of the curve by studying the information content of the spread between 10-year rates and 3-month rates (Hardouvelis, 1994, Estrella and Mishkin, 1995, Gerlach, 1996). Because of its benchmark role in most countries, the 10-year rate is easily available for studies covering long periods. However, using the 10-year rate is not without drawbacks.[3]

With regard to the information content of the yield curve in France, while the short end of the curve has been the subject of some studies, no systematic consider-

[1] See, *e.g.*, Campbell and Shiller (1987, 1988, 1991), Shiller (1990), Fama (1990), Shea (1992), Hardouvelis (1994), Campbell (1995).

[2] See, *e.g.*, Fama (1990), Mishkin (1990a, 1990b, 1991), Jorion and Mishkin (1991).

[3] First, the 10 year - 3 month spread should contain information about interest rates or inflation in 10 years' time. Any inference based on this spread implies the loss of the observations from the last 10 years. Moreover, it is not clear that the 10-year rate is the one which contains the most significant information about interest rates or inflation. Yield curves are generally very flat between horizons of 5 and 10 years, while investors are likely to have a much more accurate forecast of inflation over the next 2 to 5 years than over the next 10. So using the 10-year rate, rather than the 5-year rate for example, may therefore introduce additional noise.

ation of the long end has been possible, mainly because of the lack of available data. Studies of the short end of the French yield curve broadly support the EH: using Euro-currency rates, Gerlach and Smets (1997) and Jondeau and Ricart (1996) conclude that in most cases the implications of the EH cannot be rejected. Likewise, Mishkin (1991) states that France is the only one of the countries covered by his study to show strong evidence indicating that the term structure has significant forecasting ability concerning inflation. Browne and Manasse (1990) also obtain rather favourable results with French data for the period 1979-88. Jondeau and Ricart (1998) find little support for the EH using long-term government bond yield curves. Nonetheless, we found no study dealing with the information content of the term structure as regards inflation.

The short end of the German yield curve broadly supports the EH (Kugler, 1990, Gerlach and Smets, 1997, and Jondeau and Ricart, 1996). Hardouvelis (1994) and Gerlach (1996) obtain similar results using the 10-year - 3-month spread. However, the information content of the long-maturity term structure as regards interest rates has not yet been systematically measured. With regard to inflation forecasts, on the other hand, it is possible to distinguish between the results obtained with short rates and those obtained with long rates. Using Euro-currency rates from 1 month to 12 months over the period 1973-86, Mishkin (1991) obtains rather unfavourable results: the coefficient of the yield curve is low (between 0 and 0.5 according to the maturity) and not significantly different from 0. Using long-term rates derived from the Bundesbank dataset over the 1973-89 period, however, Jorion and Mishkin (1991) show that, over the same period, the (4-1)-year and (5-1)-year spreads have a significant information content concerning inflation. This result is confirmed and extended by Gerlach (1995). Using the same data set expanded to cover the period 1968-95, he finds that the intermediate segments of the yield curve are the most informative for forecasting inflation. This is the case, for example, of the (5-1)-year, (6-1)-year and (5-2)-year spreads. Schich (1996) uses zero-coupon yield curves to estimate the information content of the term structure as regards inflation over the period 1972-96. He finds that the three to eight year segment is the most informative.

The first objective of this paper is to measure and compare the information content of the French and German term structures as regards interest rates and inflation, using homogeneous data. For this purpose, we construct end-of-month zero-coupon yield curves for French and German federal government bonds over the period 1980-97. We use the methodology developed by Nelson and Siegel (1987) to extract zero-coupon rates from bond yields-to-maturity. This allows us to estimate zero-coupon rates for a wide array of maturities from 1 to 7 years. Empirical evidence shows that German rates have much greater predictive power for interest rates and inflation than French rates.

Our second objective is to explain the differences between the information contents of the term structures of both countries. We adopt the decomposition of the estimated slope coefficient suggested by Fama (1984) and Hardouvelis (1988). We find that the substantial fluctuations of term premia and real interest rates over time give an explanation for the inability of the French term structure to provide information about the future paths of interest rates and inflation.

The remainder of the paper is organized as follows: Section 2 is devoted to the information content of the term structure as regards interest rates. Section 3 deals with the information content concerning inflation. Section 4 concludes the paper.

2 Yield Curve and Future Interest Rates

2.1 Methodology

Most work on the information content as regards interest rates is based on the expectations hypothesis of the term structure of interest rates, which has been abundantly studied (see the authors quoted in the introduction). Based on the joint assumption of no arbitrage opportunities and rational expectations, the EH states that two investments made at the same date and with the same maturity must have the same expected yield, except for a time- independent premium.

Consider the decomposition of the yield to maturity $i_t^{(n)}$ at t on a n-period zero-coupon bond into two components: the average of expected yields to maturity on successive investments at t, $t+m$, ..., $t+n-m$ in m-period bonds and a rollover term premium, $E_t\theta_t^{(m,n)}$ (Shiller, 1979):[4]

$$i_t^{(n)} = \frac{m}{n} \sum_{k=0}^{\frac{n}{m}-1} E_t i_{t+km}^{(m)} + E_t\theta_t^{(m,n)} \tag{1}$$

where $\frac{n}{m}$ is an integer and E_t denotes the expectation conditional on information available at time t. The EH posits that the term premium may depend on m and n, but it must be time independent, that is $E_t\theta_t^{(m,n)} = \theta^{(m,n)}$, $\forall t$.

Since the mid-1980s, prominent literature has tested the empirical validity of the EH. Several tests have been proposed, but here we consider those studied by Campbell and Shiller (1991) and Hardouvelis (1994), directly derived from equation (1).[5] The first equation is based on the relationship between the expected change in the yield of a long-term bond and the term spread:

$$E_t i_{t+m}^{(n-m)} - i_t^{(n)} = \frac{m}{n-m}\left(i_t^{(n)} - i_t^{(m)}\right) + E_t\varphi_t^{(m,n)}. \tag{2}$$

The LHS of equation (2) can be approximately interpreted as the expected change in the long-term rate. $E_t\varphi_t^{(m,n)} = E_t\theta_{t+m}^{(m,n-m)} - E_t\theta_t^{(m,n)}$ denotes the holding term premium. Note that under constant term premia, the holding term premium is just defined as $\varphi^{(m,n)} = \theta^{(m,n-m)} - \theta^{(m,n)}$. In the following we also define the holding excess return and the rollover excess return as $\theta_t^{(m,n)}$ and $\varphi_t^{(m,n)}$ respectively.

The second equation relates to the expected average change in the short-term rate over n periods and the term spread. It is obtained directly by subtracting the current short-term rate $i_t^{(m)}$ from both sides of equation (1):

$$\frac{m}{n} \sum_{k=1}^{\frac{n}{m}-1} E_t\left(i_{t+km}^{(m)} - i_t^{(m)}\right) = \left(i_t^{(n)} - i_t^{(m)}\right) - E_t\theta_t^{(m,n)}. \tag{3}$$

According to equations (2) and (3), an increase in the term spread must be followed by a rise in both the long rate and the short rate. The initial spread vanishes, however, because the short rate must rise more sharply than the long rate (if $n > 2m$).

[4] m refers to the shorter maturity or investment horizon, n to the longer maturity or investment horizon ($m < n$).

[5] A related approach, developed by Fama (1984), Fama and Bliss (1987) and Hardouvelis (1988), deals with the relation between the expected change in the spot rate and the forward-spot spread. However, as we are more particularly interested in the term spread, we do not consider this approach here.

Tests of the EH based on estimation of equations (2) and (3) require a further assumption regarding expectations. Under the hypothesis of rational expectations, the theoretical equations (2) and (3) can then be rewritten as the following regression equations, denoting $S_t^{(m,n)} = i_t^{(n)} - i_t^{(m)}$ the term spread between the n-period rate and the m-period rate:

$$i_{t+m}^{(n-m)} - i_t^{(n)} = \alpha_1^{(m,n)} + \beta_1^{(m,n)} \frac{m}{n-m} S_t^{(m,n)} + u_{1,t+m}^{(m,n)} \tag{4}$$

$$\frac{m}{n} \sum_{k=1}^{\frac{n}{m}-1} \left(i_{t+km}^{(m)} - i_t^{(m)} \right) = \alpha_2^{(m,n)} + \beta_2^{(m,n)} S_t^{(m,n)} + u_{2,t+n-m}^{(m,n)}. \tag{5}$$

The LHS of equation (5) is sometimes called the rollover spread. Under the EH, the error terms are defined as expectations errors, namely $u_{1,t+m}^{(m,n)} = i_{t+m}^{(n-m)} - E_t i_{t+m}^{(n-m)}$ and ${}_{2,t+n-m}^{(m,n)} = \frac{m}{n} \sum_{k=1}^{\frac{n}{m}-1} \left(i_{t+km}^{(m)} - E_t i_{t+km}^{(m)} \right)$.

In empirical work, the EH implies that $\beta_i^{(m,n)} = 1, = 1, 2$, and that the term premia $E_t \varphi_t^{(m,n)}$ and ${}_t\theta_t^{(m,n)}$ are constant over time, that is $\alpha_1^{(m,n)} = E_t \varphi_t^{(m,n)}$ and $\alpha_2^{(m,n)} = E_t \theta_t^{(m,n)}$, $\forall t$. But assessing the predictive power of the term structure leads us to focus on the significance of the parameter $\beta_i^{(m,n)}$. Indeed, the spread will be said to contain information about interest rates if the hypothesis $\beta_i^{(m,n)} = 0$ can be rejected. It is worth noting that, under the EH, the term spread contains information about some special combinations of future interest rates, namely the change in the yield of a long-term bond and the average change in the short-term rate over a long period of time.

2.2 Empirical evidence

2.2.1 Data

The data relating to French government securities come from the "Cote Officielle" for the last working day of the month over the period 1980-97. The quoted prices of German government bonds were provided by the Bundesbank. We extract the 1-year to 10-year zero-coupon rates by interpolating a zero-coupon yield curve for each month using the Nelson and Siegel (1987) methodology. See the Appendix for details concerning this methodology.

German long-term rate data usually cover a longer period of time (from 1972), but we concentrate on the 1980-97 period in order to remain consistent with French data, for which we were unable to obtain earlier relevant data (particularly because of a lack of government issues during the 70s). Note that before 1980, the number of issues with low residual maturity (typically below 2 years) is very small. French and German interest rates for different maturities are shown in graphs 1 and 2 respectively. Graphs 3 and 4 display the term spreads, the changes in long-term rate and the average changes in short-term rates for $(1, 2)$, $(2, 4)$ and $(3, 6)$ maturities. The reason why we choose these maturity pairs is that for $n = 2m$ the RHS variables in (4) and (5) are the same.

Table 1 reports unconditional sample means and standard deviations for the term spread, the m-year change in long-term rates and the average change in short-term rates and holding and rollover excess returns over the period 1981-97. All data are measured in annualized percentage points.

Over the period under review, we obtain quite similar patterns with French and German yield curves: the term structure rises rapidly with maturity, from 0.1 when $n = 2$ years to 0.7 when $n = 7$ years. The m-year changes in the long-term rate $\left(i_{t+1}^{(n-1)} - i_t^{(n)}\right)$ are all negative; this indicates that the higher yields offered by long bonds are accompanied by capital gains. Note however that changes in the long-term rate are globally stable for the French rate whatever the maturity, whereas they increase for the German market, implying smaller capital gains in Germany over the period. Holding excess returns are negative as well, at about 0.7 in France and 0.5 in Germany. As far as average changes in short-term rate are concerned, they are negative and decrease with maturity in both countries. The decrease is much stronger in France (from -0.3 to -1.6) than in Germany (from -0.2 to -0.6). Similarly rollover excess returns are positive and increase with maturity.

This pattern can be understood in the light of equations (2) and (3). The m-year change in the long-term rate can be broken down into the following two components: the term spread $\left(i_t^{(n)} - i_t^{(1)}\right) / (n-1)$ and the holding excess return $\varphi_t^{(1,n)}$. The first term is almost constant whatever the maturity, at about 0.1. This implies that the direct effect of the term structure on the long-term rate is rather limited. In fact, the long-term rate typically changes with the maturity as does the holding excess return . The negativeness of the holding excess return is rather surprising, since the intuition behind the EH is that the risky asset should yield a higher return than the risk-free asset. However, it is worth noting that the excess return combines the term premium and the expectation error. It may well be that a large part of the decrease in interest rates during the first half of the 1980s was not expected by market participants.

The average change in the short-term rate can be explained by two opposite effects: a rising term spread, which is approximately the same in both countries; and a rising rollover excess return (which has a negative effect on the change in the short-term rate). The decrease in the short-term rate is much larger for France (from -0.3 for $n = 2$ to -1.6 for $n = 7$) than for Germany (from -0.2 for $n = 2$ to -0.6 for $n = 7$). As previously, the difference between both countries is due to the difference between rollover excess returns.[6]

2.2.2 Econometric results

The estimates of equations (4) and (5) are shown in table 2, for m varying from 1 to 3 years and for n varying from $m + 1$ to 7 years. As we use overlapping data, we face a problem concerning the serial correlation of error terms, even if we assume that expectations errors $\left(i_{t+1}^{(m)} - E_t i_{t+1}^{(m)}\right)$ are serially uncorrelated. More precisely, the error term $u_{1,t+m}^{(m,n)}$ in (4) displays a $(12m - 1)$ moving-average component, whereas the error term $u_{2,t+n-m}^{(m,n)}$ in (5) displays a $(12n - 12m - 1)$ moving-average component (Mishkin, 1988). Following the approach initiated by Hansen and Hodrick (1980), we compute standard errors that are heteroscedasticity-consistent and robust to MA errors of order $(m - 1)$ and $(n - m - 1)$ respectively. These asymptotic standard errors are computed as follows: they are adjusted by the Hansen and Hodrick (1980) correction, allowing the presence of a moving average in the error process, and by the White (1980) correction, taking account of possible heteroscedasticity; lastly, the

[6] We obtain a negative holding excess return and a positive and rising rollover excess return. This is consistent with the relation established in section 2.1, according to which $\varphi_t^{(m,n)} = \theta_{t+m}^{(m,n-m)} - \theta_t^{(m,n)}$.

covariance matrix of residuals is adjusted as suggested by Newey and West (1987) in order to ensure that it is semi-positive. Such standard errors are asymptotically valid, but they can be biased in small samples (Richardson and Stock, 1989, and Hodrick, 1992). The bias problem can be serious especially when the degree of overlapping is large. To deal with this problem, we adopt a bootstrapping strategy, in addition to the asymptotic standard errors. This strategy was proposed by Mishkin (1990b) to obtain empirical critical values taking account of the statistical properties of residuals. Interest rate spreads, changes in interest rate and the monthly inflation rate are separately modelled using autoregressive processes. The order of the AR is determined using the BIC criterion. 1000 artificial samples are then simulated using these AR models (the dimension of the series corresponds to the number of observations in the series) by means of bootstrapping. These simulations are performed using error terms generated by the empirical law of motion of residuals of the previous AR models. The error terms are reshuffled, ensuring that any correlation between error terms of the different series is eliminated. The paths of spreads, changes in interest rates and inflation are then independent by construction. Regressions (4), (5), (10) and (11) corresponding to tables 2 and 5 are carried out for each artificial sample. Finally, the empirical p-values are defined as the proportion of artificial samples in which the estimated $\beta_i^{(m,n)}$ is larger than the $\beta_i^{(m,n)}$ obtained from the original data (see Mishkin, 1990b, for further details on estimating critical values).

The p-values associated with the test $\beta_i^{(m,n)} = 0$ are then computed in two ways: the first one is simply based on the t-stat evaluated with the asymptotic standard errors; the second one is based on the bootstrapping strategy.

The estimates are clearly different for both countries. For French rates, we obtain a puzzle similar to the one highlighted by Campbell and Shiller (1991): the estimates of $\beta_1^{(m,n)}$ in (4) are systematically negative (and even significantly different from 0 for some pairs of maturities, when $n = 2$ or 3). Conversely, the estimates of $\beta_2^{(m,n)}$ in (5) are generally positive for spreads vis-à-vis the 1-year rate, but less than 1. For some maturity pairs, we obtain an information content as regards interest rates with estimates significantly greater than 0. That is the case for $m = 1$ and $n = 5$ and 6, for significance levels of 9.4% and 6.1% respectively. When bootstrapping empirical values are used, estimates of $\beta_i^{(m,n)}$ are never significant. Even in these cases, the corrected R^2s are less than 0.08.

For German rates on the contrary, the predictive power of the term structure is much greater: the estimates of $\beta_1^{(m,n)}$ in (4) are always positive and significantly greater than 0 for $m = 2$ and 3; however, they are never significant for bootstrapping empirical values. Moreover, the estimates of $\beta_2^{(m,n)}$ in (5) are always positive (and often greater than 1) and generally significantly greater than 0, even with bootstrapping p-values. The corrected R^2s are rather large, ranging from 0.1 for the $(1, 2)$ combination to 0.7 for the $(1, 7)$ combination.

As far as forecasting interest rates is concerned, the main conclusions are as follows: French term spreads have a rather weak information content and only for short-term rates. German spreads contain significant information for the m-period change in the long-term rate as well as the change in the short-term rate. For both countries, the information content is stronger for forecasting the average change in short-term rates than the change in long-term rates, and for spreads vis-à-vis a longer rate ($m = 2$ or 3 years) than vis-à-vis a shorter rate ($m = 1$ year).

2.2.3 Interpretation

As in previous studies (Fama, 1984, Mankiw and Miron, 1986, Hardouvelis, 1988 and 1994), we interpret these econometric results by assuming that the term premium may be time-varying. In this case, the probability limits of the estimated slope coefficients $\beta_i^{(m,n)}$ in (4) and (5) are given respectively by:

$$\text{plim } \beta_i^{(m,n)} = \frac{1 + \rho_i^{(m,n)} q_i^{(m,n)}}{1 + \left(q_i^{(m,n)}\right)^2 + 2\rho_i^{(m,n)} q_i^{(m,n)}}, \; i = 1, 2 \tag{6}$$

where

$$\begin{aligned}
\rho_1^{(m,n)} &= \text{corr}\left(E_t i_{t+m}^{(n-m)} - i_t^{(n)}, E_t \varphi_t^{(m,n)}\right) \\
\rho_2^{(m,n)} &= \text{corr}\left(\frac{m}{n}\sum_{k=1}^{\frac{n}{m}-1}\left(E_t i_{t+km}^{(m)} - i_t^{(m)}\right), E_t \theta_t^{(m,n)}\right) \\
q_1^{(m,n)} &= \frac{\sigma\left(E_t \varphi_t^{(m,n)}\right)}{\sigma\left(E_t i_{t+m}^{(n-m)} - i_t^{(n)}\right)} \\
q_2^{(m,n)} &= \frac{\sigma\left(E_t \theta_t^{(m,n)}\right)}{\sigma\left(\frac{m}{n}\sum_{k=1}^{\frac{n}{m}-1}\left(E_t i_{t+km}^{(m)} - i_t^{(m)}\right)\right)}
\end{aligned}$$

where $\sigma^2(x)$ denotes the variance of x and $\text{corr}(x, y)$ the correlation between x and y. Under the EH, the variances of the term premia are null, and we obviously obtain that the probability limits of $\beta_i^{(m,n)}$ are unity. Conversely, the presence of time-varying term premia implies plim $\beta_i^{(m,n)} \neq 1$. The sign and the size of the bias depend on two components: the correlation between the expected change in interest rates and the risk premium $\left(\rho_i^{(m,n)}\right)$ and the ratio of the variability of the risk premium with respect to the expected change in interest rates $\left(q_i^{(m,n)}\right)$. Figure 1 shows the relationship between plim $\beta_i^{(m,n)} \neq 1$ and $q_i^{(m,n)}$ for different values of $\rho_i^{(m,n)}$.

We note that for a large negative $\rho_i^{(m,n)}$, the probability limit of $\beta_i^{(m,n)}$ is very sensitive to the value of $q_i^{(m,n)}$. Indeed, when $q_i^{(m,n)}$ is close to but less than 1, we obtain a parameter $\beta_i^{(m,n)}$ greater than 1; conversely, for a ratio $q_i^{(m,n)}$ close to but larger than 1, we obtain a negative $\beta_i^{(m,n)}$.

The expected terms in relation (6) are estimated using their observed counterparts on 12 lags of the term spread and 12 lags of the change in the short-term rate as regressors, as in:

$$y_t^{(m,n)} = \mu + \sum_{j=1}^{12} \delta_{1j} S_{t-j}^{(m,n)} + \sum_{j=1}^{12} \delta_{2j} \Delta r_{t-j}^{(m)} + v_t^{(m,n)} \tag{7}$$

where $y_t^{(m,n)}$ denotes respectively $\left(i_{t+m}^{(n-m)} - i_t^{(n)}\right)$, $\frac{m}{n}\sum_{k=1}^{\frac{n}{m}-1}\left(i_{t+km}^{(m)} - i_t^{(m)}\right)$, $\varphi_t^{(m,n)}$ and $\theta_t^{(m,n)}$. The values of $q_i^{(m,n)}$, $\rho_i^{(m,n)}$ and plim $\beta_i^{(m,n)}$ are then obtained from relation (6). We define the standard deviation of the estimated expected change in the interest rate, $\sigma_{\Delta r}$, and the standard deviation of the estimated risk premium, σ_{er}. These standard deviations and the corrected R^2s of relation (7) are reported in Table 3.

The decomposition of $\beta_i^{(m,n)}$ is helpful in interpreting our results. Two points are interesting to consider: the differences between the change in the long-term rate equation and the change in the short-term rate equation; and the differences between French and German results.

First we consider French interest rates. We obtain a negative $\beta_1^{(m,n)}$ but generally a positive $\beta_2^{(m,n)}$. When we compute the corresponding decomposition given by equation (6), we find the following patterns: for the change in long-term rate equation, the correlation between the holding term premium and the expected change in the long-term rate is close to -1. Figure 1 shows that, for large $\rho_1^{(m,n)}$, an estimated $q_1^{(m,n)}$ greater than 1 can lead to a negative $\beta_1^{(m,n)}$. Now, for each maturity pair, we obtain a ratio $q_1^{(m,n)}$ between 1.1 and 1.6, giving a negative estimate $\tilde{\beta}_1^{(m,n)}$. Concerning the change in short-term rate equation, the correlations are much smaller. For instance, they are between -0.3 and 0.7 for $m = 1$. Therefore, as $q_2^{(m,n)}$ is generally fairly close to 1, we find an estimate of $\tilde{\beta}_2^{(m,n)}$ of between -0.7 and 0.2.

With German data, the pattern for $\beta_1^{(m,n)}$ is rather different than with French data. As previously, we find a correlation $\rho_1^{(m,n)}$ close to -1. But now the ratio $q_1^{(m,n)}$ is less than 1. This makes it possible to obtain an estimate of $\tilde{\beta}_1^{(m,n)}$ greater than 1. Such a difference with French interest rates can be explained by the standard deviation of equation (7). Indeed, the standard deviation of the estimated expected change in the long-term rate $E_t\left(i_{t+m}^{(m)} - i_t^{(m)}\right)$, denoted $\sigma_{\Delta r}$, is greater than the standard deviation of the estimated holding term premium $E_t\varphi_t^{(m,n)}$, denoted σ_{er}. This is just the contrary with French data. In other words, the small $q_1^{(m,n)}$ ratio obtained in Germany stems from the low variability of the estimated holding term premium as compared to the estimated expected change in the long-term rate (since the change in the rate and the excess return have basically the same standard deviation) especially for $m = 2$ and 3. Conversely, the large $q_1^{(m,n)}$ in France stems from the greater variability of the estimated holding term premium.

Concerning the German short-term rate change equation, the correlations are clearly negative and close to -1 for $n = 2$ and 3. Moreover, the ratio $q_2^{(m,n)}$ is small (around 0.6), giving an estimate of $\tilde{\beta}_2^{(m,n)}$ greater than 1. Once again, this finding is largely explained by the low variability of the rollover term premium.

To sum up, the greater information content obtained for the German term structure compared to the French term structure mainly results from the low variability of German risk premia or, alternatively, from the better forecasting performance of the German interest rate change equations. The great variability of the French term premia can be mainly explained by the events of the 1980-85 period. The decrease in interest rates was initiated by the short-term rate, which implies that long-term rates did not react as predicted by the EH. The rejection of the EH can have two sources: market participants essentially did not anticipate this major change in nominal rates; or the risk premium temporarily increased on long-term investment, perhaps because market participants expected this decrease in short-term rates to be short-lived.

3 Yield Curve and Future Inflation Rates

3.1 Methodology

The information content of the yield curve as regards the future path of inflation was initially studied by Mishkin (1990a, 1990b, 1991), Jorion and Mishkin (1991) and Fama (1990). If the expected real rate is stable enough, then the nominal rate, known at date t, helps to predict inflation, which will be known only at date $t+m$. This approach is based on the Fisher decomposition, which states that the m-period nominal interest rate can be divided into two components: the m-period ex-ante real interest rate, denoted $E_t r_t^{(m)}$, and the expected inflation rate over the next m periods, denoted $E_t \pi_t^{(m)}$:

$$i_t^{(m)} = E_t r_t^{(m)} + E_t \pi_t^{(m)}. \tag{8}$$

Under rational expectations, realized inflation can be split between expected inflation and a white noise error term:

$$\pi_t^{(m)} = E_t \pi_t^{(m)} + \varepsilon_{t+m}^{(m)}. \tag{9}$$

Combining equations (8) and (9), we obtain:

$$\pi_t^{(m)} = i_t^{(m)} - E_t r_t^{(m)} + \varepsilon_{t+m}^{(m)}.$$

The spread between inflation over the next n years and inflation over the next m years ($n > m$) gives the following inflation equation:

$$\pi_t^{(n)} - \pi_t^{(m)} = a_1^{(m,n)} + b_1^{(m,n)} S_t^{(n,m)} + \eta_{1,t+n}^{(m,n)}. \tag{10}$$

The Fisher decomposition implies that the term $a_1^{(m,n)} = -\left(E_t r_t^{(n)} - E_t r_t^{(m)}\right)$ is constant over time, i.e., the slope of ex-ante real rates is time-independent. Such a hypothesis is less restrictive than the usual Fisher relation, since it allows translations of the ex-ante real rates. Under this assumption, the estimates of $b_1^{(m,n)}$ have a probability limit of one and are consistent. The error term is defined as $\eta_{1,t+n}^{(m,n)} = \varepsilon_{t+n}^{(n)} - \varepsilon_{t+m}^{(m)}$.

Most of the empirical studies consider the tests of $b_1^{(m,n)} = 0$ and $b_1^{(m,n)} = 1$ in order to assess the predictive power of the yield curve: if the null hypothesis $b_1^{(m,n)} = 0$ is rejected, the term spread contains significant information concerning inflation; if the null hypothesis $b_1^{(m,n)} = 1$ is rejected, the term spread contains significant information about ex-post real rates, which implies that real interest rates vary over time. This comes from the fact that the nominal spread has two components: the inflation change $\left(\pi_t^{(n)} - \pi_t^{(m)}\right)$ and the ex-post real spread $\left(r_t^{(n)} - r_t^{(m)}\right)$. The real rate equation may thus be written as follows:

$$r_t^{(n)} - r_t^{(m)} = a_2^{(m,n)} + b_2^{(m,n)} S_t^{(n,m)} + \eta_{2,t+n}^{(m,n)}. \tag{11}$$

As the sum of the two terms on the left hand side of (10) and (11) gives the nominal spread, the parameters of the two regressions are constrained by $a_1^{(m,n)} + a_2^{(m,n)} = 0$ and $b_1^{(m,n)} + b_2^{(m,n)} = 1$. Thus, the test of $b_2^{(m,n)} = 0$ is equivalent to the test of $b_1^{(m,n)} = 1$. It is nonetheless instructive to compare the corrected R^2s associated with the two regressions in order to measure the component about which the nominal spread is likely to provide most information.

3.2 Empirical evidence

3.2.1 Econometric results

Inflation rates are calculated from consumer price indices (source: Main Economic Indicators of the OECD). Inflation at t for the period from t to $t+n$, is denoted $\pi_t^{(n)}$. In what follows, inflation at time t thus corresponds to inflation for the n coming years and not, as is usually the case, for the n past years. This notation makes it possible to be consistent with the usual definition of interest rates. The ex-ante real interest rate is thus defined by $E_t r_t^{(n)} = i_t^{(n)} - E_t \pi_t^{(n)}$. Graphs 5 and 6 show ex-post real interest rates for different maturities for France and Germany, respectively. Graphs 7 and 8 give the term spread, inflation changes and ex-post real interest rates for $(1,2)$, $(2,4)$ and $(3,6)$ maturities. Table 4 reports unconditional sample means and standard deviations for the term spread, the inflation change and the ex-post real interest rates over the period 1981-97. All data are measured in annualized percentage points.

Table 5 shows the estimates of the inflation equation (10) and the real rate equation (11) for m varying from 1 to 3 years and n varying from $m+1$ to 7 years. Data overlapping implies a $(12n-1)$ moving-average component in the error generating process. As in the previous section, French and German data give rather contrasting results.

For French data, the estimates of $b_1^{(m,n)}$ in the inflation equation (10) are systematically negative and significantly different from 0 for many maturity pairs. Therefore, the spreads essentially contain no information about inflation. Conversely, the estimates of $b_2^{(m,n)}$ in real rate equation (11) are always above 1 and are overwhelmingly significant. We can thus deduce that the spread is not helpful for forecasting inflation, but it has a predictive power for real interest rates.

The results with German rates tell a different story: the estimates of $b_1^{(m,n)}$ are generally significantly greater than 0 (even with bootstrapping p-values). We note that the estimates of $b_1^{(m,n)}$ are often above 1, implying negative estimates of $b_2^{(m,n)}$. This result can be understood as an overreaction by inflation expectations to changes in monetary policy or, in other words, as a clearly credible monetary policy. Moreover, the corrected R^2s of the inflation change equations are rather large: they are greater than 0.3, except in 4 cases (when $m=1$ and $n=2$, 3, 4 and for $m=2$ and $n=3$).

These results can be understood in the light of events in both countries (see Graphs 7 and 8): On the one hand, interest rates and inflation decreased almost simultaneously in Germany during the first part of the 1980s. Moreover, the worsening inflation outlook at the beginning of the 1990s was accompanied by significant monetary tightening.

On the other hand, in France, the link between inflation and interest rates was disturbed by two major events. First, the decrease in inflation during the first part of the 1980s did not imply a proportional decrease in interest rates. Second, German monetary tightening induced high interest rates in France at the beginning of the 1990s, whereas the French inflation outlook was rather favourable. These two events implied a large increase in the 1-year real interest rate, from 0 in 1980 to more than 8% during the summer of 1992. Afterwards, the nominal interest rate decreased much more rapidly than inflation, leading to a large decrease in the real interest rate.

3.2.2 Interpretation

As in the previous section, the probability limit of the estimated slope coefficient $b_1^{(m,n)}$ in (10) can be easily expressed as a function of the moments of the inflation change and the real rate spread. Indeed, we find that (Mishkin, 1981, 1990a):

$$\text{plim } b_1^{(m,n)} = \frac{1 + \rho^{(m,n)} q^{(m,n)}}{1 + \left(q^{(m,n)}\right)^2 + 2\rho^{(m,n)} q^{(m,n)}} \tag{12}$$

where

$$\rho^{(m,n)} = \text{corr}\left(E_t\left(\pi_t^{(n)} - \pi_t^{(m)}\right), E_t\left(r_t^{(n)} - r_t^{(m)}\right)\right)$$

is the correlation between the expected inflation change and the ex-ante real rate spread and

$$q^{(m,n)} = \frac{\sigma\left(E_t\left(r_t^{(n)} - r_t^{(m)}\right)\right)}{\sigma\left(E_t\left(\pi_t^{(n)} - \pi_t^{(m)}\right)\right)}$$

is the ratio of the standard deviation of the ex-ante real rate spread to the standard deviation of the expected inflation change.

Estimates of the ex-ante real rate spread $E_t\left(r_t^{(n)} - r_t^{(m)}\right)$ are obtained from fitted values of the regression of the ex-post real rate spread on 12 lags of the 1-month change in m-year inflation and 12 lags of the nominal rate spread as in:

$$\left(r_t^{(n)} - r_t^{(m)}\right) = \mu + \sum_{j=1}^{12} \delta_{3j} S_{t-j}^{(m,n)} + \sum_{j=1}^{12} \delta_{4j} \Delta\pi_{t-j}^{(m)} + w_t^{(m,n)}. \tag{13}$$

The expected inflation change is then estimated from:

$$E_t\left(\pi_t^{(n)} - \pi_t^{(m)}\right) = S_t^{(n,m)} - E_t\left(r_t^{(n)} - r_t^{(m)}\right). \tag{14}$$

The values of $q^{(m,n)}$, $\rho^{(m,n)}$ and plim $b_1^{(m,n)}$ are then obtained using relation (12).

The main puzzle requiring an explanation here lies in the differences between French and German results: the estimates of $b_1^{(m,n)}$ are systematically negative in France, whereas they are systematically positive (and often greater than 1) in Germany. This result is quite surprising since, as seen on Graphs 5 and 6, the general pattern of interest rates and inflation is the same overall in both countries.

As in the previous section, the decomposition of parameter $b_1^{(m,n)}$ is helpful. First of all, the correlation between the estimated expected inflation change and the estimated ex-ante real rate spread is clearly negative in both countries, at about $-0.8/-0.9$. The main difference comes from the ratio of the standard deviation of the estimated ex-ante real rate spread to the standard deviation of the estimated expected inflation change. Indeed, it is definitely greater than 1 with French data, whereas it is less than 1 in all cases but one in Germany.

In order to explain this result, let us now turn to the analysis of equations (13) and (14). On the one hand, we find that the inflation rate equation gives basically the same standard deviation of the estimated expected inflation change in both countries: $\sigma_{\Delta\pi}$ is slightly larger in France for the smallest maturities, but smaller for the largest maturities. On the other hand, we obtain standard deviations of the estimated ex-ante real rate spread that are far larger for France than for Germany. Substantial fluctuations in estimated ex-ante real rates over time therefore explain the inability of the French term structure to provide information about the future path of inflation.

4 Conclusion

The empirical evidence in this paper suggests that the French term structure provides no information about the future path of inflation and only a small amount of information about the future path of interest rates. Conversely, the term structure in Germany contains a highly significant amount of information about future changes in interest rates and future changes in inflation.

As far as forecasting interest rates are concerned, the greater information content of the German term structure as compared to the French term structure mainly results from the low variability of German risk premia. The great variability of French term premia can be explained by the events of the 1980-85 period: the decrease in interest rates during this period was initiated by the short-term rate, and long-term rates did not react as predicted by the EH. It looks as though market participants basically did not anticipate this major change in nominal rates or expected this decrease in short-term rates to be short-lived.

Large fluctuations in estimated ex-ante real rate spreads over time explain the inability of the French term structure to provide information about the future path of inflation. The substantial decrease in real rate spreads at the beginning of the 1980s disturbed the link between nominal rates and inflation. By contrast, real rate spreads remained relatively stable in Germany, ensuring a lasting link between nominal rates and inflation.

It is worth noting that since the second half of the 1980s French and German interest rates and inflation have moved much more in line. Measurement of the information content of the term structure over the 1985-97 period (not reported here) indicates that the term spread is able to provide information about the future paths of interest rates as well as inflation. In other words, term premia and ex-ante real interest rate spreads appear to have been sufficiently stable over the ten last years for the term spreads to have a predictive power concerning interest rates and inflation (see graphs 7 and 8). These results are weak however, since they are based on a very short period of time.

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Table 1: Means and standard deviations of term structure variables for 1981-1997

variable	Long-term rate maturity (n, in years)					
	2	3	4	5	6	7
Panel A: France						
term spread	0.071	0.188	0.307	0.369	0.520	0.730
$S_t^{(1,n)}$	(0.440)	(0.662)	(0.800)	(0.882)	(0.910)	(0.838)
change in long-term rate	-0.813	-0.866	-0.843	-0.808	-0.776	-0.746
$i_{t+1}^{(n-1)} - i_t^{(n)}$	(1.483)	(1.437)	(1.417)	(1.400)	(1.384)	(1.371)
holding excess return	-0.885	-0.978	-0.965	-0.930	-0.893	-0.857
$\varphi_t^{(1,n)}$	(1.554)	(1.496)	(1.469)	(1.446)	(1.427)	(1.412)
change in short-term rate	-0.371	-0.758	-1.030	-1.347	-1.620	-1.688
$\frac{1}{n}\sum_{k=1}^{n-1}\left(i_{t+k}^{(1)} - i_t^{(1)}\right)$	(0.770)	(1.063)	(1.325)	(1.639)	(1.843)	(1.902)
rollover excess return	0.442	0.945	1.337	1.716	2.140	2.418
$\theta_t^{(1,n)}$	(0.777)	(1.121)	(1.389)	(1.636)	(1.810)	(1.961)
Panel B: Germany						
term spread	0.171	0.317	0.399	0.454	0.576	0.762
$S_t^{(1,n)}$	(0.364)	(0.615)	(0.795)	(0.940)	(1.073)	(1.118)
change in long-term rate	-0.669	-0.634	-0.567	-0.500	-0.444	-0.396
$i_{t+1}^{(n-1)} - i_t^{(n)}$	(1.457)	(1.354)	(1.249)	(1.158)	(1.083)	(1.025)
holding excess return	-0.840	-0.814	-0.742	-0.664	-0.596	-0.537
$\varphi_t^{(1,n)}$	(1.445)	(1.352)	(1.250)	(1.159)	(1.085)	(1.026)
change in short-term rate	-0.249	-0.477	-0.608	-0.693	-0.722	-0.559
$\frac{1}{n}\sum_{k=1}^{n-1}\left(i_{t+k}^{(1)} - i_t^{(1)}\right)$	(0.778)	(1.289)	(1.703)	(2.073)	(2.357)	(2.449)
rollover excess return	0.420	0.794	1.007	1.147	1.298	1.322
$\theta_t^{(1,n)}$	(0.722)	(1.136)	(1.388)	(1.539)	(1.638)	(1.629)

Note: the short-term rate maturity is $m = 1$ year. The theoretical relationship between holding and rollover term premia presented in section 2.1 may not be matched in empirical counterparts, mainly because the samples used to compute sample means of these premia are not necessarily the same ones. Standard deviations are in parentheses.

Table 2: Information content about future interest rates for 1981-1997
This table shows the estimates of the following equations:

$$i_{t+m}^{(n-m)} - i_t^{(n)} = \alpha_1^{(m,n)} + \beta_1^{(m,n)} \frac{m}{n-m} S_t^{(m,n)} + u_{1,t+m}^{(m,n)} \qquad \text{(i)}$$

$$\frac{m}{n} \sum_{k=1}^{\frac{n}{m}-1} \left(i_{t+km}^{(m)} - i_t^{(m)} \right) = \alpha_2^{(m,n)} + \beta_2^{(m,n)} S_t^{(m,n)} + u_{2,t+n-m}^{(m,n)} \qquad \text{(ii)}$$

maturity	Long rate equation (i)			Short rate equation (ii)		
$m-n$	$\beta_1^{(m,n)}$	$\bar{R}^2$	$t\left(\beta_1^{(m,n)}=0\right)$	$\beta_2^{(m,n)}$	$\bar{R}^2$	$t\left(\beta_2^{(m,n)}=0\right)$
(years)	(s.e.)			(s.e.)		
			Panel A: France			
1 - 2	-0.051	-0.005	-0.089	0.475	0.069	1.657
	(0.573)		[0.465;0.461]	(0.287)		[0.049;0.119]
1 - 3	-0.309	-0.003	-0.377	0.355	0.043	1.188
	(0.819)		[0.353;0.407]	(0.299)		[0.118;0.196]
1 - 4	-0.600	0.007	-0.567	0.366	0.043	1.128
	(1.059)		[0.286;0.348]	(0.324)		[0.130;0.213]
1 - 5	-0.926	0.015	-0.739	0.505	0.068	1.314
	(1.253)		[0.230;0.260]	(0.384)		[0.094;0.276]
1 - 6	-1.264	0.024	-0.896	0.573	0.074	1.549
	(1.410)		[0.185;0.254]	(0.370)		[0.061;0.280]
1 - 7	-1.605	0.032	-1.044	0.337	0.015	1.179
	(1.538)		[0.148;0.219]	(0.286)		[0.119;0.331]
2 - 3	-0.991	0.054	-1.166	—	—	—
	(0.850)		[0.122;0.205]			
2 - 4	-1.316	0.072	-1.340	-0.158	-0.001	-0.322
	(0.982)		[0.090;0.208]	(0.491)		[0.374;0.412]
2 - 5	-1.681	0.090	-1.495	—	—	—
	(1.125)		[0.068;0.202]			
2 - 6	-2.085	0.107	-1.653	0.042	-0.006	0.064
	(1.261)		[0.049;0.141]	(0.662)		[0.475;0.488]
2 - 7	-2.490	0.123	-1.793	—	—	—
	(1.389)		[0.037;0.128]			
3 - 4	-1.682	0.102	-1.701	—	—	—
	(0.989)		[0.045;0.154]			
3 - 5	-1.942	0.120	-1.793	—	—	—
	(1.083)		[0.037;0.175]			
3 - 6	-2.357	0.149	-1.935	-0.679	0.051	-1.114
	(1.218)		[0.027;0.132]	(0.609)		[0.133;0.280]
3 - 7	-2.825	0.180	-2.096	—	—	—
	(1.348)		[0.018;0.132]			

maturity $m-n$ (years)	Long rate equation (i) $\beta_1^{(m,n)}$ (s.e.)	$\bar{R}^2$	$t\left(\beta_1^{(m,n)}=0\right)$	Short rate equation (ii) $\beta_2^{(m,n)}$ (s.e.)	$\bar{R}^2$	$t\left(\beta_2^{(m,n)}=0\right)$
			Panel B: Germany			
1 - 2	0.636	0.020	0.854	0.818	0.142	2.198
	(0.744)		[0.197;0.270]	(0.372)		[0.014;0.085]
1 - 3	0.532	0.010	0.622	0.993	0.220	2.287
	(0.856)		[0.292;0.351]	(0.434)		[0.011;0.135]
1 - 4	0.490	0.006	0.537	1.269	0.347	3.171
	(0.912)		[0.296;0.370]	(0.400)		[0.001;0.077]
1 - 5	0.476	0.005	0.505	1.592	0.517	4.302
	(0.942)		[0.307;0.415]	(0.370)		[0.000;0.051]
1 - 6	0.466	0.004	0.486	1.747	0.630	6.947
	(0.960)		[0.314;0.384]	(0.252)		[0.000;0.025]
1 - 7	0.457	0.003	0.467	1.840	0.702	13.729
	(0.979)		[0.320;0.384]	(0.134)		[0.000;0.004]
2 - 3	1.375	0.098	1.422	—	—	—
	(0.967)		[0.078;0.240]			
2 - 4	1.319	0.085	1.370	1.160	0.231	2.408
	(0.963)		[0.085;0.299]	(0.482)		[0.008;0.135]
2 - 5	1.304	0.080	1.357	—	—	—
	(0.961)		[0.087;0.298]			
2 - 6	1.319	0.080	1.385	1.899	0.616	5.786
	(0.952)		[0.083;0.281]	(0.328)		[0.000;0.024]
2 - 7	1.343	0.080	1.424	—	—	—
	(0.943)		[0.077;0.269]			
3 - 4	2.398	0.270	2.694	—	—	—
	(0.890)		[0.004;0.136]			
3 - 5	2.412	0.264	2.653	—	—	—
	(0.909)		[0.004;0.121]			
3 - 6	2.404	0.260	2.612	1.702	0.415	3.698
	(0.921)		[0.005;0.151]	(0.460)		[0.000;0.065]
3 - 7	2.395	0.258	2.582	—	—	—
	(0.928)		[0.005;0.147]			

Note: The estimate of the constant is not shown in the table. The asymptotic standard deviations, in brackets, are corrected for overlapping (Hansen et Hodrick, 1980) and for heteroscedasticity (White, 1980) and are estimated as suggested by Newey and West (1987). t-stat is the Student t-distribution associated with the test of the hypothesis $\beta_i^{(m,n)} = 0$. Under the t-stat, between brackets, the p-values are evaluated with asymptotic standard deviation and by bootstrapping simulation (see section 2.2.2). For specification (ii), estimates for $m = 2$ and 3 have been made only for values of n that are multiples of m. The estimations have been carried out over the period from 1981:1 to 1997:12 minus m years for specification (i), and over the period from 1981:1 to 1997:12 minus $(n - m)$ years for specification (ii).

Table 3 : Decomposition of $\beta_i^{(m,n)}$ in equations (4) and (5) for 1981-1997

maturity $m-n$ (years)	$\hat{\beta}_i^{(m,n)}$	change in rate equation		excess return equation		$q_i^{(m,n)}$	$\rho_i^{(m,n)}$	$\tilde{\beta}_i^{(m,n)}$
		$\sigma_{\Delta r}$	$R^2_{\Delta r}$	σ_{er}	R^2_{er}			
Panel A: France								
Long rate ($i=1$)								
1 - 2	-0.051	0.463	0.099	0.617	0.159	1.332	-0.769	-0.034
1 - 3	-0.309	0.508	0.127	0.637	0.183	1.254	-0.888	-0.330
1 - 4	-0.600	0.524	0.138	0.635	0.188	1.213	-0.933	-0.638
1 - 5	-0.926	0.527	0.144	0.628	0.191	1.192	-0.956	-0.975
1 - 6	-1.264	0.529	0.149	0.623	0.193	1.177	-0.968	-1.323
1 - 7	-1.605	0.535	0.155	0.622	0.197	1.162	-0.977	-1.673
2 - 3	-0.991	0.626	0.106	0.989	0.223	1.579	-0.961	-1.123
2 - 4	-1.316	0.677	0.142	0.953	0.243	1.409	-0.969	-1.444
2 - 5	-1.681	0.719	0.171	0.950	0.259	1.321	-0.979	-1.831
2 - 6	-2.085	0.769	0.200	0.969	0.280	1.260	-0.985	-2.269
2 - 7	-2.490	0.818	0.229	0.994	0.300	1.216	-0.989	-2.714
3 - 4	-1.682	0.998	0.176	1.354	0.278	1.356	-0.983	-1.942
3 - 5	-1.942	0.977	0.199	1.285	0.296	1.315	-0.987	-2.231
3 - 6	-2.357	1.031	0.237	1.304	0.327	1.265	-0.991	-2.706
3 - 7	-2.825	1.109	0.281	1.355	0.363	1.222	-0.993	-3.251
Short rate ($i=2$)								
1 - 2	0.475	0.297	0.152	0.307	0.158	1.035	-0.148	0.480
1 - 3	0.355	0.315	0.089	0.475	0.180	1.509	0.119	0.324
1 - 4	0.366	0.398	0.091	0.560	0.162	1.407	0.151	0.356
1 - 5	0.505	0.627	0.146	0.581	0.125	0.927	-0.094	0.542
1 - 6	0.573	0.793	0.184	0.667	0.135	0.841	-0.349	0.631
1 - 7	0.337	0.901	0.223	0.953	0.234	1.058	-0.670	0.415
2 - 4	-0.158	0.245	0.080	0.477	0.243	1.950	-0.734	-0.222
2 - 6	0.042	0.415	0.096	0.636	0.193	1.534	-0.580	0.070
3 - 6	-0.679	0.398	0.157	0.654	0.329	1.643	-0.935	-0.852

maturity $m-n$ (years)	$\hat{\beta}_i^{(m,n)}$	change in rate equation $\sigma_{\Delta r}$	$\bar{R}^2_{\Delta r}$	excess return equation σ_{er}	$\bar{R}^2_{er}$	$q_i^{(m,n)}$	$\rho_i^{(m,n)}$	$\tilde{\beta}_i^{(m,n)}$
Panel B: Germany								
Long rate ($i=1$)								
1 - 2	0.636	0.533	0.134	0.485	0.113	0.911	-0.763	0.694
1 - 3	0.532	0.429	0.100	0.412	0.094	0.962	-0.740	0.574
1 - 4	0.490	0.381	0.093	0.375	0.090	0.985	-0.750	0.531
1 - 5	0.476	0.360	0.097	0.357	0.095	0.991	-0.777	0.521
1 - 6	0.466	0.350	0.104	0.347	0.103	0.993	-0.807	0.517
1 - 7	0.457	0.345	0.114	0.344	0.113	0.997	-0.836	0.511
2 - 3	1.375	1.066	0.233	0.829	0.155	0.778	-0.887	1.378
2 - 4	1.319	0.937	0.220	0.740	0.150	0.790	-0.885	1.332
2 - 5	1.304	0.835	0.212	0.661	0.145	0.792	-0.884	1.323
2 - 6	1.319	0.759	0.209	0.599	0.142	0.798	-0.987	1.345
2 - 7	1.343	0.706	0.211	0.558	0.144	0.791	-0.893	1.377
3 - 4	2.398	1.966	0.542	1.605	0.442	0.817	-0.970	2.501
3 - 5	2.412	1.803	0.554	1.488	0.458	0.825	-0.971	2.527
3 - 6	2.404	1.626	0.550	1.343	0.454	0.826	-0.971	2.523
3 - 7	2.395	1.467	0.540	1.208	0.444	0.824	-0.970	2.514
Short rate ($i=2$)								
1 - 2	0.818	0.383	0.242	0.245	0.116	0.639	-0.437	0.848
1 - 3	0.993	0.734	0.323	0.422	0.137	0.574	-0.574	1.000
1 - 4	1.269	1.169	0.469	0.638	0.210	0.546	-0.781	1.289
1 - 5	1.592	1.632	0.617	0.869	0.317	0.533	-0.904	1.617
1 - 6	1.747	2.044	0.748	1.162	0.500	0.569	-0.929	1.767
1 - 7	1.840	2.228	0.825	1.297	0.631	0.582	-0.942	1.862
2 - 4	1.160	0.635	0.340	0.372	0.152	0.586	-0.706	1.166
2 - 6	1.899	1.466	0.708	0.852	0.460	0.581	-0.952	1.932
3 - 6	1.702	0.985	0.638	0.668	0.450	0.679	-0.918	1.760

Note: $\hat{\beta}_1^{(m,n)}$ is the same as in Table 2. For the long-term rate equation, $\sigma_{\Delta r}$ and $\bar{R}^2_{\Delta r}$ are obtained from the estimate of equation (7) for $y_t^{(m,n)} = \left(i_{t+m}^{(n-m)} - i_t^{(n)}\right)$ and σ_{er} and $\bar{R}^2_{er}$ for $y_t^{(m,n)} = \varphi_t^{(m,n)}$. For the short-term rate equation, $\sigma_{\Delta r}$ and $\bar{R}^2_{\Delta r}$ are obtained from the estimate of equation (7) for $y_t^{(m,n)} = \frac{m}{n}\sum_{k=1}^{\frac{n}{m}-1}\left(i_{t+km}^{(m)} - i_t^{(m)}\right)$ and σ_{er} and $\bar{R}^2_{er}$ for $y_t^{(m,n)} = \theta_t^{(m,n)}$. $q_i^{(m,n)}$, $\rho_i^{(m,n)}$ and $\tilde{\beta}_i^{(m,n)}$, $i=1,2$, are estimated using equation (6). For the short-rate equation, estimates for $m=2$ and 3 have been made only for values of n that are multiples of m. The estimations have been carried out over the period from 1981:1 to 1997:12 minus m years for the long-term rate equation, and over the period from 1981:1 to 1997:12 minus $(n-m)$ years for the short-term rate equation.

Table 4: Means and standard deviations of Fisher decomposition variables for 1981-1997

variable	Long-term rate maturity (n, in years)					
	2	3	4	5	6	7
Panel A: France						
term spread	0.052	0.186	0.276	0.449	0.669	0.838
$S_t^{(1,n)}$	(0.448)	(0.680)	(0.806)	(0.851)	(0.795)	(0.798)
inflation change	-0.364	-0.679	-1.010	-1.352	-1.641	-1.929
$\pi_t^{(n)} - \pi_t^{(1)}$	(0.702)	(1.061)	(1.414)	(1.717)	(1.924)	(2.084)
ex-post real rate spread	0.417	0.864	1.287	1.802	2.310	2.768
$r_t^{(n)} - r_t^{(1)}$	(0.885)	(1.383)	(1.807)	(2.079)	(2.204)	(2.319)
Panel B: Germany						
term spread	0.152	0.277	0.365	0.512	0.705	0.876
$S_t^{(1,n)}$	(0.367)	(0.617)	(0.801)	(0.954)	(1.024)	(1.108)
inflation change	-0.118	-0.219	-0.284	-0.280	-0.178	-0.015
$\pi_t^{(n)} - \pi_t^{(1)}$	(0.580)	(0.914)	(1.210)	(1.475)	(1.658)	(1.733)
ex-post real rate spread	0.271	0.496	0.649	0.792	0.884	0.891
$r_t^{(n)} - r_t^{(1)}$	(0.589)	(0.908)	(1.091)	(1.190)	(1.255)	(1.287)

Note: the short-term maturity is $m = 1$ year. The means and standard deviations of the term spreads are not the same as in Table 1: they do not cover the same period, since the computation of the most recent inflation rate implies the loss of the last n years.

Table 5: Information content about future inflation for 1981-1997
This table shows the estimates of the following equations:

$$\pi_t^{(n)} - \pi_t^{(m)} = a_1^{(m,n)} + b_1^{(m,n)} S_t^{(n,m)} + \eta_{1,t+n}^{(m,n)} \quad \text{(i)}$$

$$r_t^{(n)} - r_t^{(m)} = a_2^{(m,n)} + b_2^{(m,n)} S_t^{(n,m)} + \eta_{2,t+n}^{(m,n)} \quad \text{(ii)}$$

maturity	Inflation rate equation (i)			Real interest rate equation (ii)		
$m-n$ (years)	$b_1^{(m,n)}$ (s.e.)	$\bar{R}^2$	$t\left(b_1^{(m,n)}=0\right)$	$b_2^{(m,n)}$ (s.e.)	$\bar{R}^2$	$t\left(b_2^{(m,n)}=0\right)$
Panel A: France						
1 - 2	-0.225	0.015	-0.912	1.225	0.381	4.956
	(0.247)		[0.181;0.271]	(0.247)		[0.000;0.005]
1 - 3	-0.353	0.046	-1.193	1.353	0.439	4.570
	(0.296)		[0.117;0.244]	(0.296)		[0.000;0.013]
1 - 4	-0.476	0.068	-1.396	1.476	0.429	4.332
	(0.341)		[0.081;0.202]	(0.341)		[0.000;0.022]
1 - 5	-0.451	0.043	-1.475	1.451	0.348	4.747
	(0.306)		[0.070;0.252]	(0.306)		[0.000;0.050]
1 - 6	-0.416	0.022	-1.764	1.416	0.255	6.010
	(0.236)		[0.039;0.247]	(0.236)		[0.000;0.035]
1 - 7	-0.312	0.006	-1.606	1.312	0.197	6.752
	(0.194)		[0.054;0.257]	(0.194)		[0.000;0.034]
2 - 3	-0.651	0.105	-1.720	1.651	0.439	4.362
	(0.379)		[0.043;0.159]	(0.379)		[0.000;0.016]
2 - 4	-0.839	0.145	-2.119	1.839	0.456	4.645
	(0.396)		[0.017;0.116]	(0.396)		[0.000;0.022]
2 - 5	-0.832	0.118	-2.574	1.832	0.403	5.668
	(0.323)		[0.005;0.152]	(0.323)		[0.000;0.033]
2 - 6	-0.807	0.089	-3.323	1.807	0.343	7.441
	(0.243)		[0.000;0.113]	(0.243)		[0.000;0.018]
2 - 7	-0.715	0.063	-3.957	1.715	0.300	9.493
	(0.181)		[0.000;0.094]	(0.181)		[0.000;0.008]
3 - 4	-1.128	0.169	-3.152	2.128	0.426	5.947
	(0.358)		[0.001;0.065]	(0.358)		[0.000;0.009]
3 - 5	-1.035	0.135	-4.060	2.035	0.384	7.982
	(0.255)		[0.000;0.065]	(0.255)		[0.000;0.009]
3 - 6	-0.942	0.103	-5.307	1.942	0.340	10.943
	(0.177)		[0.000;0.048]	(0.177)		[0.000;0.003]
3 - 7	-0.760	0.067	-5.097	1.760	0.297	11.804
	(0.149)		[0.000;0.073]	(0.149)		[0.000;0.006]

maturity $m-n$ (years)	Inflation rate equation (i) $b_1^{(m,n)}$ (s.e.)	$\bar{R}^2$	$t\left(b_1^{(m,n)}=0\right)$	Real interest rate equation (ii) $b_2^{(m,n)}$ (s.e.)	$\bar{R}^2$	$t\left(b_2^{(m,n)}=0\right)$
			Panel B: Germany			
1 - 2	0.458	0.079	1.447	0.542	0.109	1.716
	(0.316)		[0.074;0.137]	(0.316)		[0.043;0.102]
1 - 3	0.515	0.116	1.466	0.485	0.103	1.379
	(0.352)		[0.071;0.156]	(0.352)		[0.084;0.170]
1 - 4	0.712	0.218	2.436	0.288	0.038	0.984
	(0.292)		[0.007;0.107]	(0.292)		[0.163;0.286]
1 - 5	0.918	0.348	5.206	0.082	-0.003	0.464
	(0.176)		[0.000;0.028]	(0.176)		[0.321;0.370]
1 - 6	1.059	0.423	8.754	-0.059	-0.005	-0.487
	(0.121)		[0.000;0.005]	(0.121)		[0.313;0.401]
1 - 7	1.049	0.445	7.606	-0.049	-0.007	-0.357
	(0.138)		[0.000;0.025]	(0.138)		[0.361;0.457]
2 - 3	0.658	0.144	1.778	0.342	0.039	0.925
	(0.370)		[0.038;0.156]	(0.370)		[0.178;0.278]
2 - 4	0.931	0.304	3.447	0.069	-0.004	0.254
	(0.270)		[0.000;0.051]	(0.270)		[0.400;0.428]
2 - 5	1.162	0.471	8.358	-0.162	0.010	-1.167
	(0.139)		[0.000;0.006]	(0.139)		[0.122;0.309]
2 - 6	1.294	0.547	12.319	-0.294	0.052	-2.796
	(0.105)		[0.000;0.005]	(0.105)		[0.003;0.152]
2 - 7	1.211	0.517	8.871	-0.211	0.024	-1.543
	(0.137)		[0.000;0.031]	(0.137)		[0.061;0.331]
3 - 4	1.258	0.435	5.656	-0.258	0.026	-1.161
	(0.223)		[0.000;0.005]	(0.223)		[0.123;0.247]
3 - 5	1.451	0.598	8.935	-0.451	0.121	-2.777
	(0.162)		[0.000;0.005]	(0.162)		[0.003;0.124]
3 - 6	1.538	0.636	9.806	-0.538	0.171	-3.431
	(0.157)		[0.000;0.005]	(0.157)		[0.000;0.122]
3 - 7	1.353	0.535	7.571	-0.353	0.066	-1.976
	(0.179)		[0.000;0.026]	(0.179)		[0.024;0.227]

Note: The estimate of the constant is not shown in the table. The asymptotic standard deviations, in brackets, are corrected for overlapping (Hansen et Hodrick, 1980) and for heteroscedasticity (White, 1980) and are estimated as suggested by Newey and West (1987). t-stat is the Student t-distribution associated with the test of the hypothesis $b_i^{(m,n)} = 0$. Under the t-stat, between brackets, the p-values are evaluated with asymptotic standard deviation and by bootstrapping simulation (see section 2.2.2). The estimations have been carried out over the period from 1981:1 to 1997:12 minus m years.

Table 6 : Decomposition of $b_1^{(m,n)}$ in equation (10) for 1981-1997

maturity $m-n$ (years)	$\hat{b}_1^{(m,n)}$	inflation rate equation $\sigma_{\Delta\pi}$	inflation rate equation $\bar{R}^2_{\Delta\pi}$	real rate equation σ_{rr}	real rate equation $\bar{R}^2_{rr}$	$q^{(m,n)}$	$\rho^{(m,n)}$	$\tilde{b}_1^{(m,n)}$
Panel A: France								
1 - 2	-0.225	0.606	0.794	0.754	0.883	1.245	-0.809	-0.013
1 - 3	-0.353	0.953	0.868	1.258	0.933	1.319	-0.845	-0.224
1 - 4	-0.476	1.271	0.913	1.671	0.954	1.315	-0.881	-0.383
1 - 5	-0.451	1.444	0.928	1.862	0.960	1.290	-0.894	-0.430
1 - 6	-0.416	1.573	0.931	1.938	0.958	1.232	-0.918	-0.507
1 - 7	-0.312	1.647	0.931	2.002	0.957	1.216	-0.924	-0.534
2 - 3	-0.651	0.453	0.907	0.578	0.946	1.277	-0.914	-0.567
2 - 4	-0.839	0.790	0.953	1.017	0.973	1.287	-0.933	-0.781
2 - 5	-0.832	0.997	0.958	1.294	0.976	1.297	-0.934	-0.811
2 - 6	-0.807	1.134	0.957	1.441	0.975	1.272	-0.941	-0.871
2 - 7	-0.715	1.211	0.953	1.543	0.973	1.274	-0.941	-0.876
3 - 4	-1.128	0.385	0.955	0.477	0.971	1.240	-0.955	-1.096
3 - 5	-1.035	0.593	0.964	0.765	0.979	1.289	-0.947	-1.005
3 - 6	-0.942	0.744	0.958	0.953	0.976	1.281	-0.947	-0.987
3 - 7	-0.760	0.815	0.942	1.055	0.968	1.295	-0.938	-0.866

maturity $m-n$ (years)	$\hat{b}_1^{(m,n)}$	inflation rate equation $\sigma_{\Delta\pi}$	inflation rate equation $\bar{R}^2_{\Delta\pi}$	real rate equation σ_{rr}	real rate equation $\bar{R}^2_{rr}$	$q^{(m,n)}$	$\rho^{(m,n)}$	$\tilde{b}_1^{(m,n)}$
Panel B: Germany								
1 - 2	0.458	0.516	0.870	0.564	0.892	1.094	-0.818	0.260
1 - 3	0.515	0.841	0.929	0.897	0.940	0.967	-0.799	0.340
1 - 4	0.712	1.134	0.953	1.087	0.951	0.959	-0.792	0.602
1 - 5	0.918	1.332	0.958	1.172	0.948	0.880	-0.785	0.787
1 - 6	1.059	1.437	0.956	1.218	0.942	0.848	-0.816	0.919
1 - 7	1.049	1.432	0.952	1.242	0.940	0.868	-0.813	0.862
2 - 3	0.658	0.415	0.925	0.405	0.925	0.977	-0.842	0.575
2 - 4	0.931	0.740	0.965	0.631	0.955	0.965	-0.836	0.953
2 - 5	1.162	0.985	0.970	0.751	0.951	0.763	-0.827	1.152
2 - 6	1.294	1.132	0.970	0.828	0.947	0.732	-0.853	1.309
2 - 7	1.211	1.174	0.964	0.903	0.944	0.769	-0.844	1.195
3 - 4	1.258	0.372	0.967	0.283	0.945	0.761	-0.887	1.416
3 - 5	1.451	0.643	0.981	0.446	0.961	0.693	-0.877	1.482
3 - 6	1.538	0.840	0.981	0.574	0.960	0.683	-0.898	1.610
3 - 7	1.353	0.935	0.978	0.704	0.963	0.753	-0.879	1.388

Note: $\hat{b}_1^{(m,n)}$ is the same as in Table 5. σ_{rr} and $\bar{R}^2_{rr}$ are obtained from the estimate of equation (13). $\sigma_{\Delta\pi}$ and $\bar{R}^2_{\Delta\pi}$ are obtained from equation (14). $q^{(m,n)}$, $\rho^{(m,n)}$ and $\tilde{b}_1^{(m,n)}$ are estimated using equation (12). The estimations have been carried out over the period from 1981:1 to 1997:12 minus m years.

Appendix: Constructing yield curves for Federal Government bonds

As we need yields for a set of fixed maturities from 1 year to 10 years, we interpolate zero-coupon yield curves using securities with comparable characteristics; this then enables us to choose the estimated yield associated with each of the desired maturities.

A - French data

As in many other countries, French public debt began to rise essentially at the beginning of the 1980s. However, initiatives to harmonize and standardize government securities, designed to make the market more liquid, were not taken until the mid-1980s with the creation of OATs (*Obligations Assimilables du Trésor* - fungible Treasury bonds) in May 1985. Until the mid-1980s, the French government securities market was thus relatively illiquid and heterogeneous, comprising: irredeemable securities (*rentes perpétuelles*) and old-fashioned government bonds (*rentes amortissables* and, from 1976, *emprunt d'Etat*) and even more specific securities. Furthermore, these classes were themselves not uniform , since numerous special clauses could be included when a new security was issued, relating to aspects such as revaluation of the reimbursed capital, modification of the nominal coupon, method of reimbursement (by lot, on maturity, deferred), deferred redemption, etc. Because of the multiplicity of specific features, there is little basis for comparing the yields of these different securities.

The zero-coupon yield curves are constructed on the basis of fixed-rate French government bonds denominated in francs, listed on the Paris market. This definition covers most irredeemable securities and old-fashioned bonds and OATs. We eliminate the rentes perpétuelles and rentes amortissables from the data set because of the difficulty of evaluating their ex-post yield: they contained numerous special clauses; in most cases, they were redeemed before maturity; and they were particularly illiquid, which could lead to anomalies in quoted prices. Likewise, we do not use securities redeemed by lot and some emprunts d'Etat and OATs with special characteristics (such as emprunts d'Etat with deferred payment of the first coupons and OATs with exchange options).

Special treatment is necessary for estimating the short end of the yield curve in the early 1980s (from 1980 to 1983). Using the various filters described above leaves an insufficient number of government securities with a short residual maturity (typically less than 2 years). This problem is accentuated by the absence of listed short-term government securities, since Treasury bills and Treasury notes did not appear until 1986. We thus include interbank rates in the estimations; this provides a short-term anchor for the yield curve, since the first point of the estimated yield curve is defined by the call-money rate. This is of course an approximation, since there may in theory be a premium between government securities and interbank securities with the same residual maturity. However, over the period 1980-83 at least, it is not possible to estimate this premium in the absence of short-term government securities. Subsequently (i.e., from 1984), the existence of government securities with short residual maturities allows us to dispense with the interbank rates. We nevertheless kept the call-money rate in the estimations, so as to keep the curve anchored to the shortest market rate. As we are concerned with long maturities (1 year to 10 years), this approximation on the short segment of the curve is unlikely to have a decisive effect.

The number of securities used for the estimations rose sharply after 1985: between 1980 and 1984, an average of 10 securities were included, compared with an average of 18 between 1985 and 1989 and 20 between 1990 and 1997.

B - German data

In Germany, the public debt securities include bonds issued by the Federal Republic of Germany (*Anleihen der Bundesrepublik Deutschland*), bonds issued by the "German Unity" Fund (*Anleihen der Bundesrepublik Deutschland – Fonds "Deutsche Einheit"*), bonds issued by the ERP Special Fund (*Anleihen der Bundesrepublik Deutschland – ERP-Sondervermögen*), bonds issued by the Treuhand agency (*Anleihen der Treuhandanstalt*), bonds issued by the German Federal Railways and the German Federal Post Office (*Anleihen der Deutschen Bundesbahn* and *Anleihen der Deutschen Bundespost*), five-year special Federal bonds (*Bundesobligationen*), five-year special Treuhand agency bonds (*Treuhandobligationen*), special bonds issued by the German Federal Post Office (*Postobligationen*), treasury bonds issued by the German Federal Railways and the German Federal Post Office (*Schatzanweisungen der Deutschen Bundesbahn* and *Schatzanweisungen der Deutschen Bundespost*) and Federal treasury notes (*Schatzanweisungen des Bundes*) (see Deutsche Bundesbank, 1995, and Schich, 1996, for additional details). The data set has been kindly provided by the Bundesbank.

In constructing German zero-coupon yield curves, we first eliminate bonds issued by the German Federal Railways and the German Federal Post Office from the data set, because they pay an additional premium compared to other public debt securities. Moreover, we select securities with a fixed maturity and an annual coupon. The last bonds with semi-annual coupon payments matured in December 1980.

The number of securities used for the estimations appears to be large enough: it increases from 60 in 1980 to about 100 after 1984. The number of securities with a short residual maturity is rather low at the beginning of the 1980s, but never as low as for French data. Therefore, we do not include interbank rates in the estimation.

C - Method for interpolating the yield curves

French and German zero-coupon yield curves are constructed using the approach initially proposed by Nelson and Siegel (1987). The main aspects of this method can be summarized as follows. The zero-coupon yield is expressed as a non-linear function of the residual maturity:

$$i_t^{(m)}(\alpha) = \mu_1 + \mu_2 \frac{1 - e^{-m/\tau_1}}{m/\tau_1} + \mu_3 \left(\frac{1 - e^{-m/\tau_1}}{m/\tau_1} - e^{-m/\tau_1} \right) \tag{16}$$

where $i_t^{(m)}(\alpha)$ is the estimated, continuously compounded, zero-coupon yield at date t for a security with residual maturity m and for a vector of parameters $\alpha = \{\mu_1, \mu_2, \mu_3, \tau_1\}$.

This interpolation function has three main properties: μ_1 is the long-term zero-coupon yield; $(\mu_1 + \mu_2)$ denotes the instantaneous interest rate; the pair (μ_3, τ_1) makes it possible to take account of possible yield curve convexity.

The second property makes it possible to constrain estimation of the parameter μ_2 such that $(\mu_1 + \mu_2)$ is equal to the shortest market rate (in the case of French data, the call-money rate). At times of monetary tightening, this is useful from an empirical standpoint when there are few securities available on the short segment of the yield curve.

Using the standard equation for valuing a bond, the estimated price of a given security may be expressed as:

$$P_t^{(m)}(\alpha) = \sum_{k=0}^{M} c \exp\left(-(k+f)\, i_t^{(k+f)}(\alpha)\right) + 100 \exp\left(-m i_t^{(m)}(\alpha)\right) \qquad (17)$$

where c is the coupon, $P_t^{(m)}(\alpha)$ is the estimated price (expressed as a percentage of par), M is the number of full years to maturity and $f = m - M$ the fraction of any additional year. The estimated yields of the securities under review are computed using the following equation:

$$P_t^{(m)}(\alpha) = \sum_{k=0}^{M} \frac{c}{\left(1 + y_t^{(m)}(\alpha)\right)^{k+f}} + \frac{100}{\left(1 + y_t^{(m)}(\alpha)\right)^{m}} \qquad (18)$$

where $y_t^{(m)}(\alpha)$ is the estimated yield.

A criterion for minimizing the sum of the squares of the residuals can then be applied to the yields in order to estimate the parameters of the model:

$$\min_{\{\alpha\}} \sum_{k=1}^{K_t} \left\{(y_{k,t}^{(m)} - y_{k,t}^{(m)}(\alpha)\right\}^2 \qquad (19)$$

where $y_{k,t}^{(m)}$ is the observed yield to maturity of the security n, with residual maturity m, at date t; $y_{k,t}^{(m)}(\alpha)$ is the estimated yield of the security n; K_t is the number of securities used in the estimation at date t.

Fig. 1: France – nominal interest rates

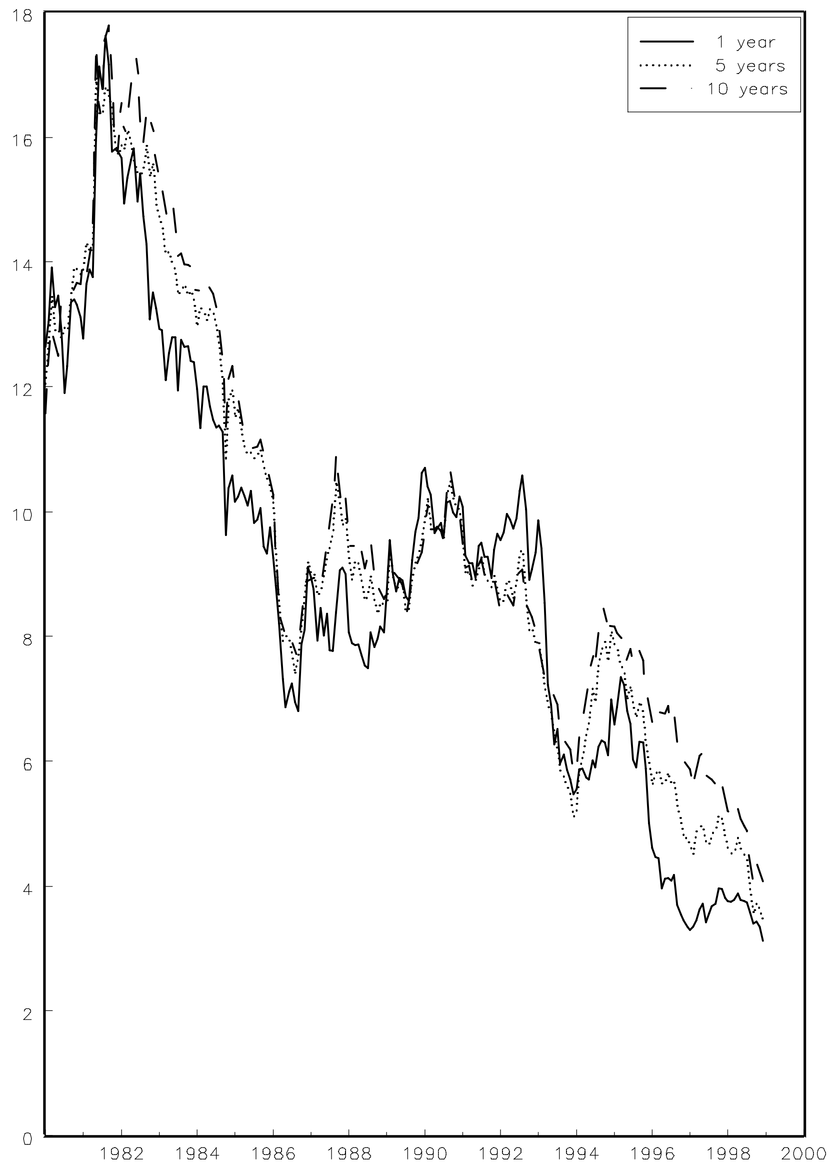
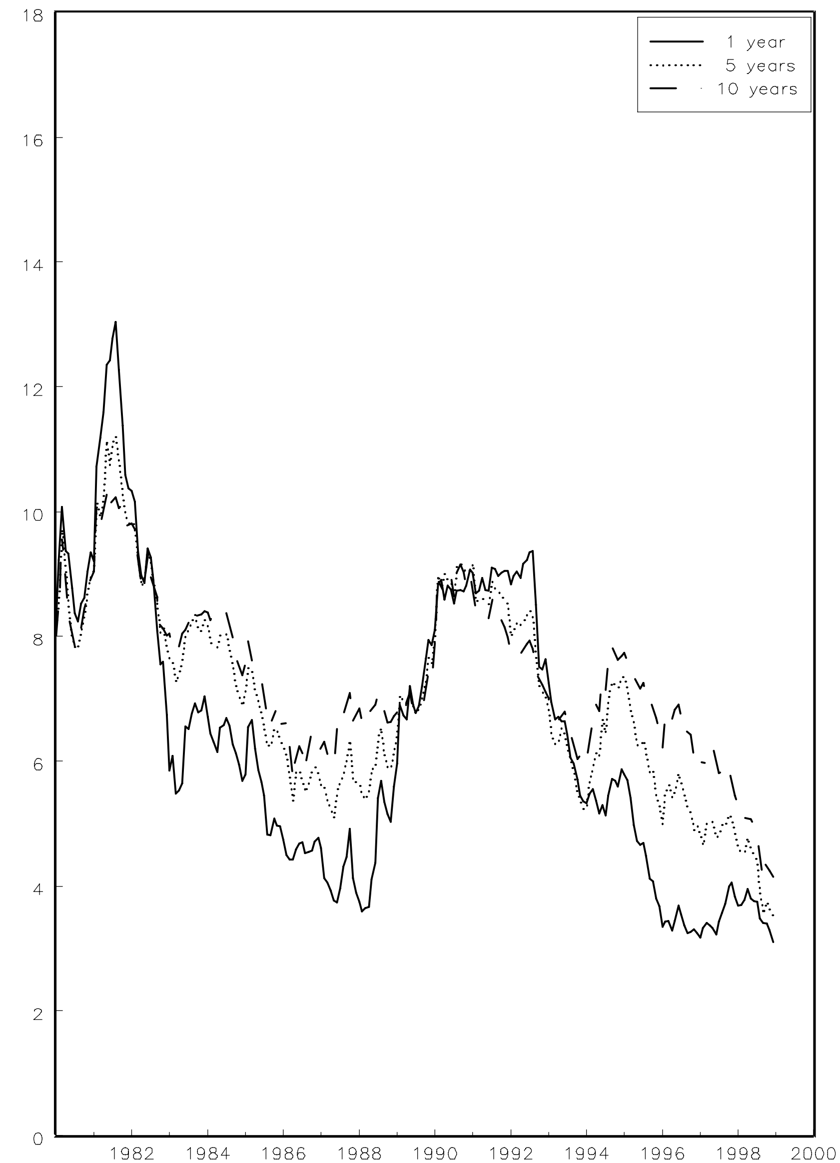
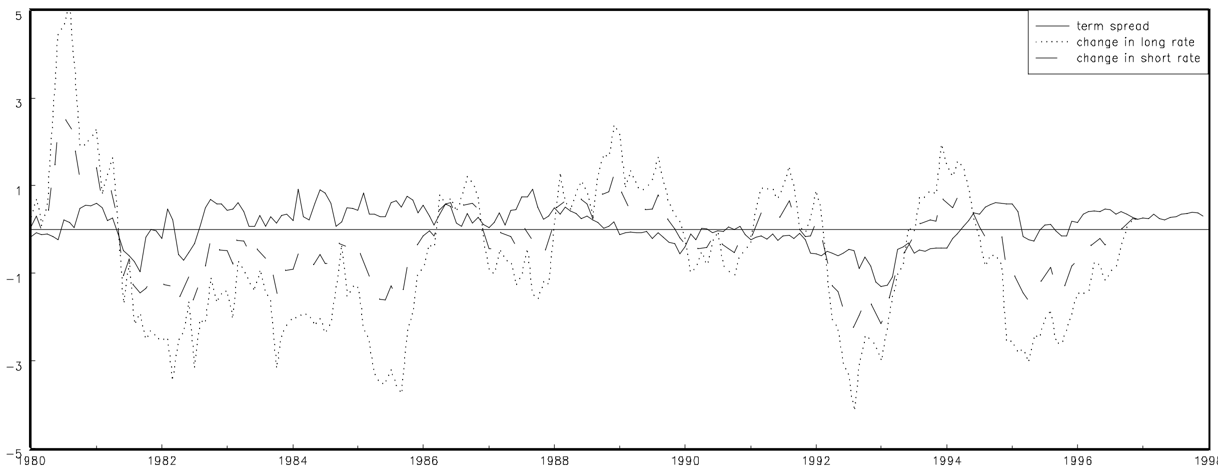


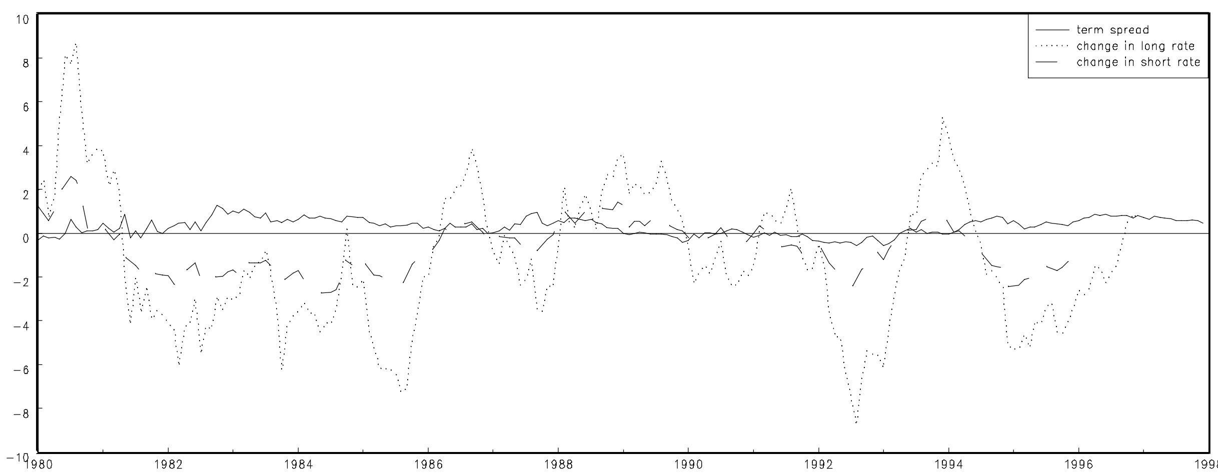
Fig. 2: Germany – nominal interest rates



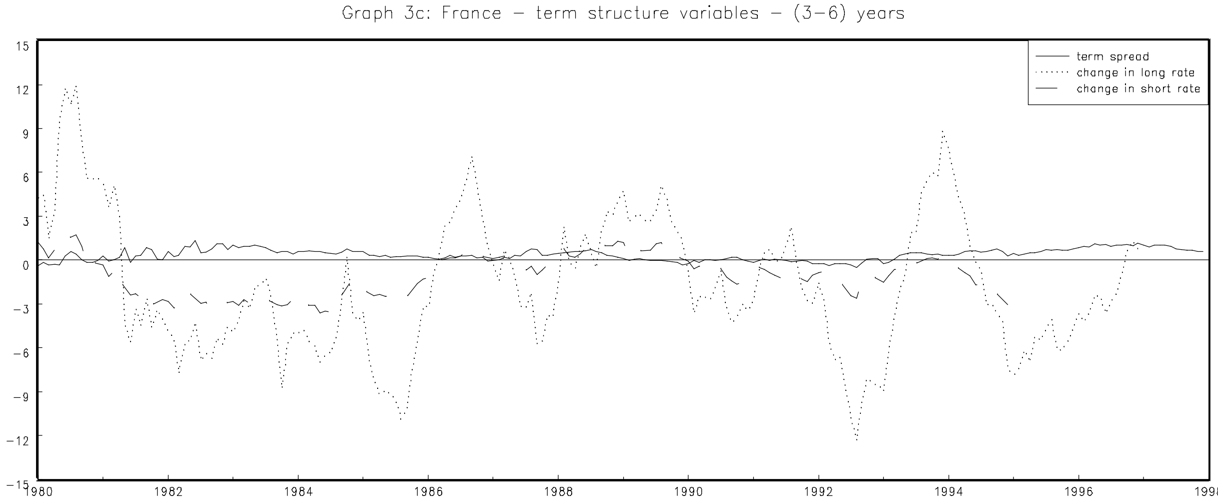
Graph 3a: France – term structure variables – (1–2) years



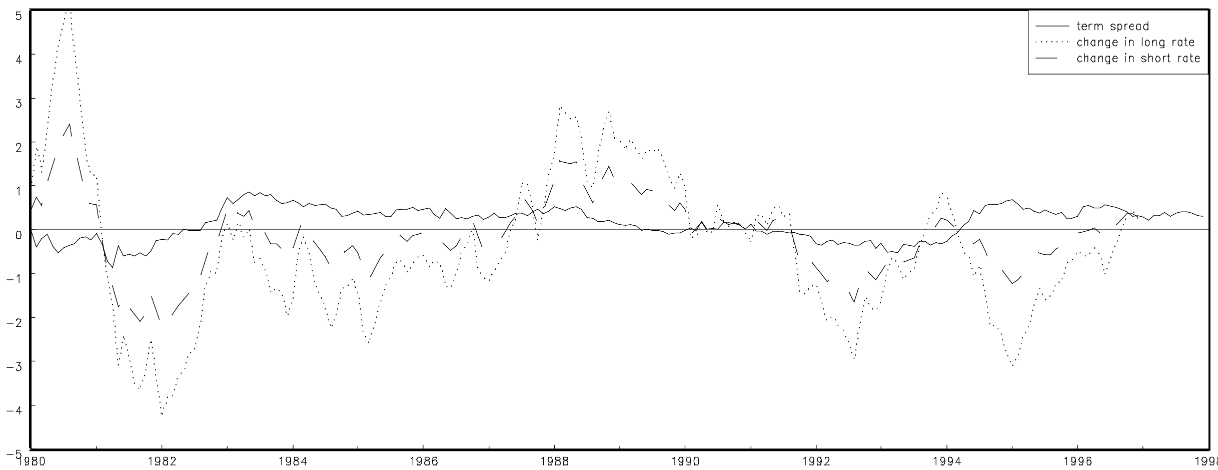
Graph 3b: France – term structure variables – (2–4) years



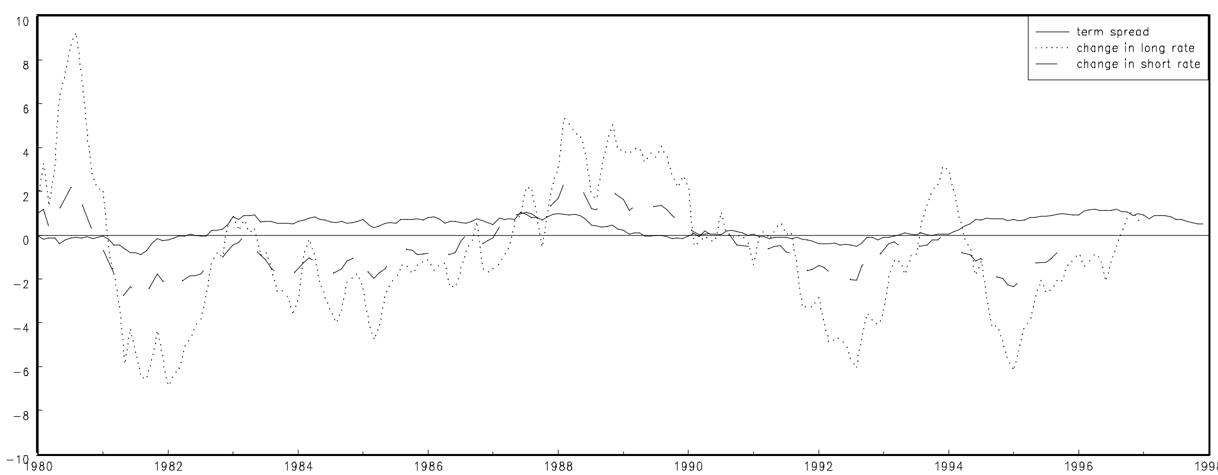
Graph 3c: France – term structure variables – (3–6) years



Graph 4a: Germany – term structure variables – (1–2) years



Graph 4b: Germany – term structure variables – (2–4) years



Graph 4c: Germany – term structure variables – (3–6) years

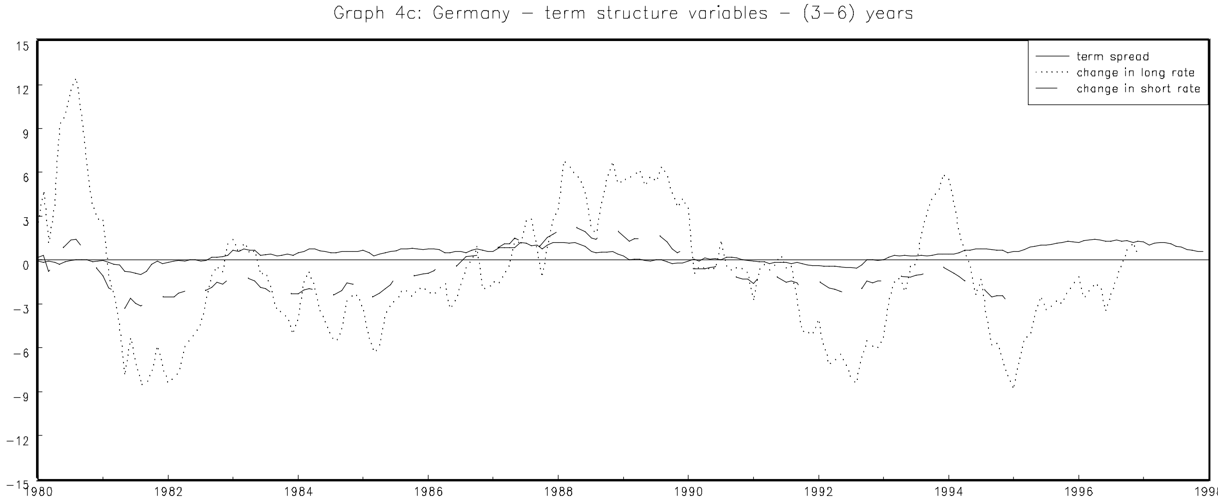


Fig. 5: France – ex-post real interest rates

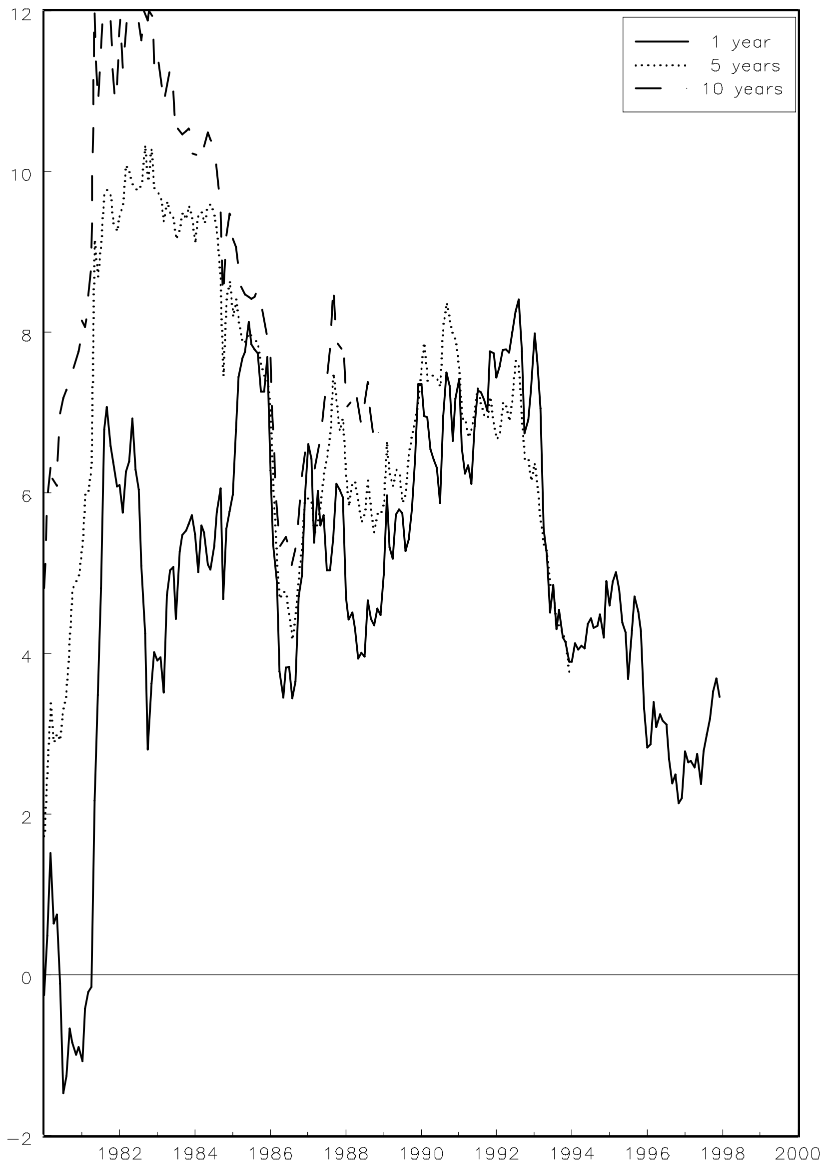
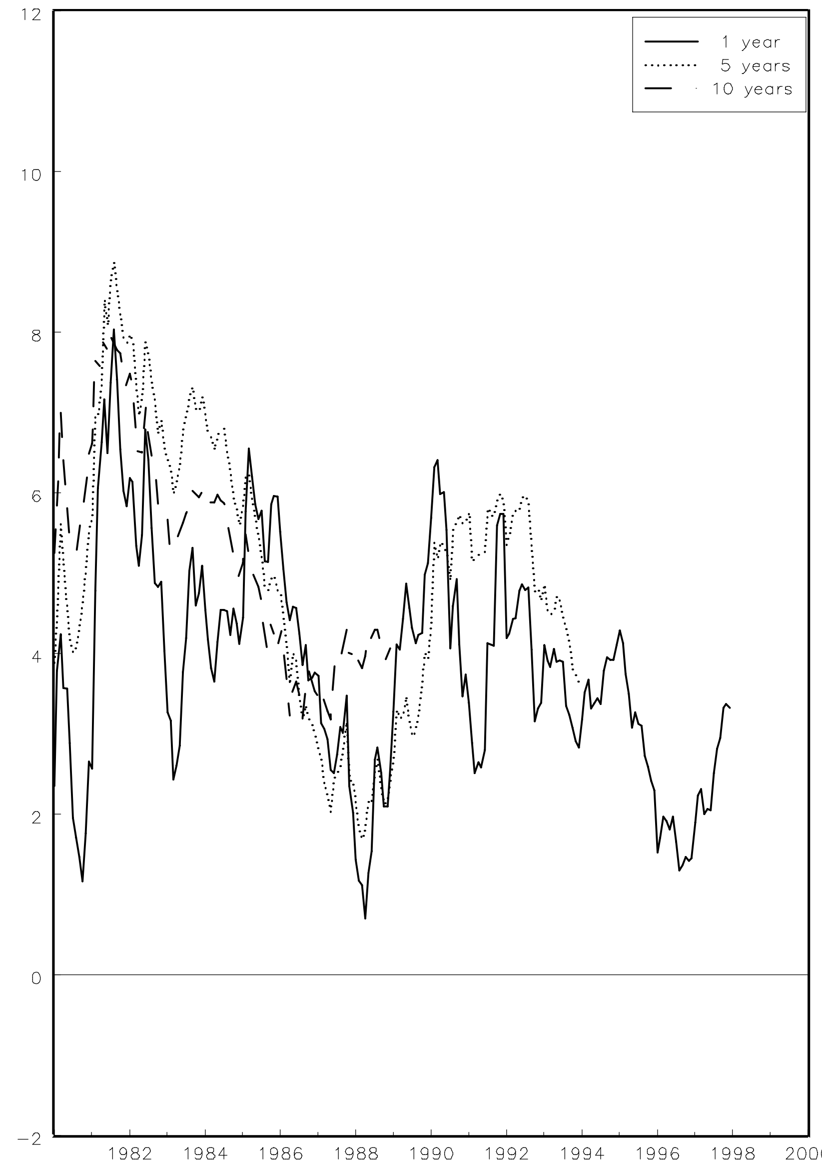
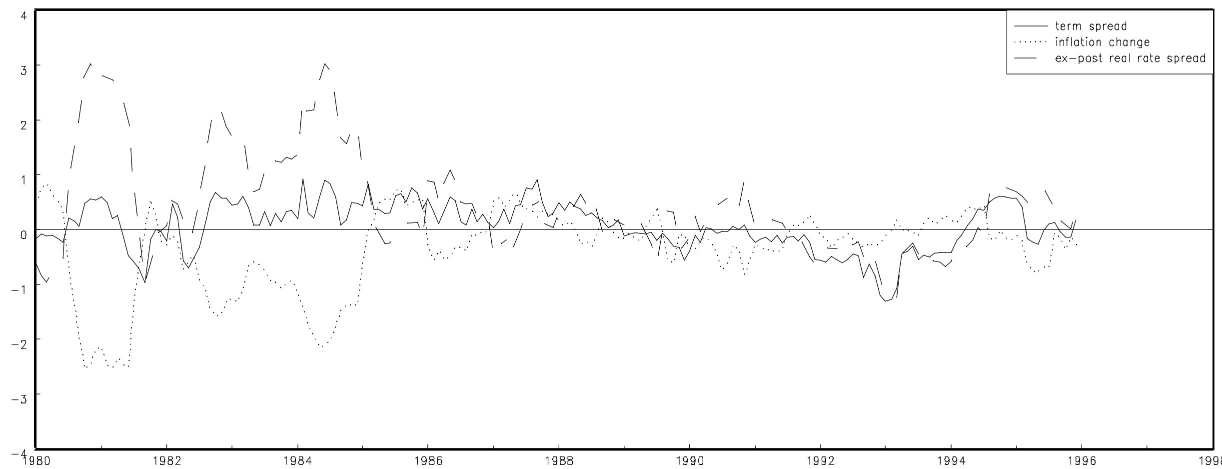


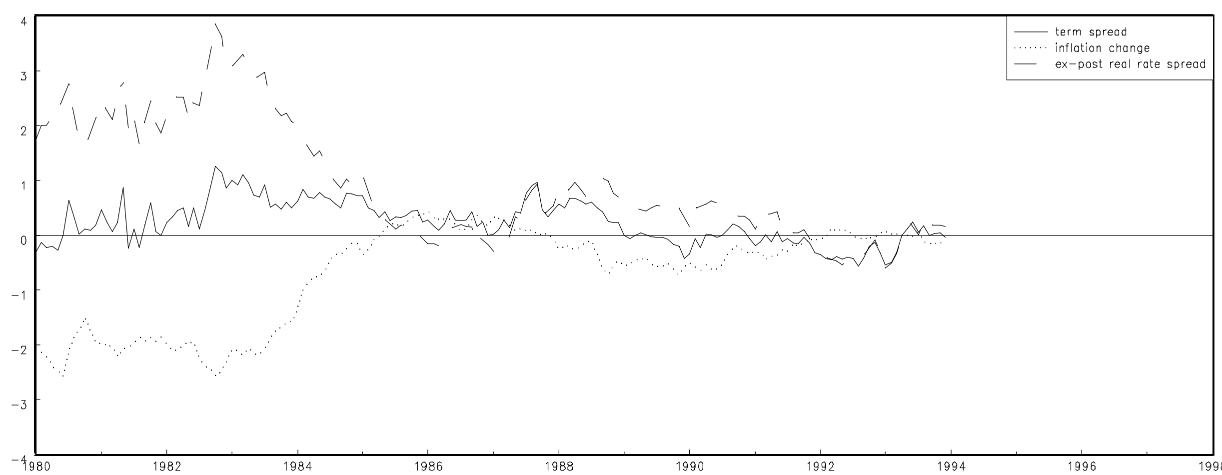
Fig. 6: Germany – ex-post interest rates



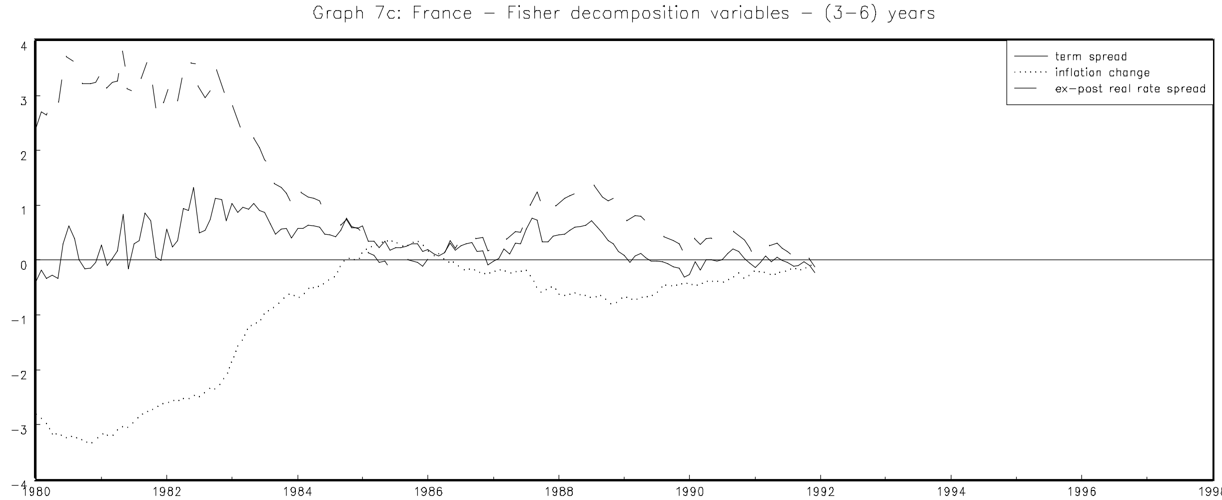
Graph 7a: France - Fisher decomposition variables - (1-2) years



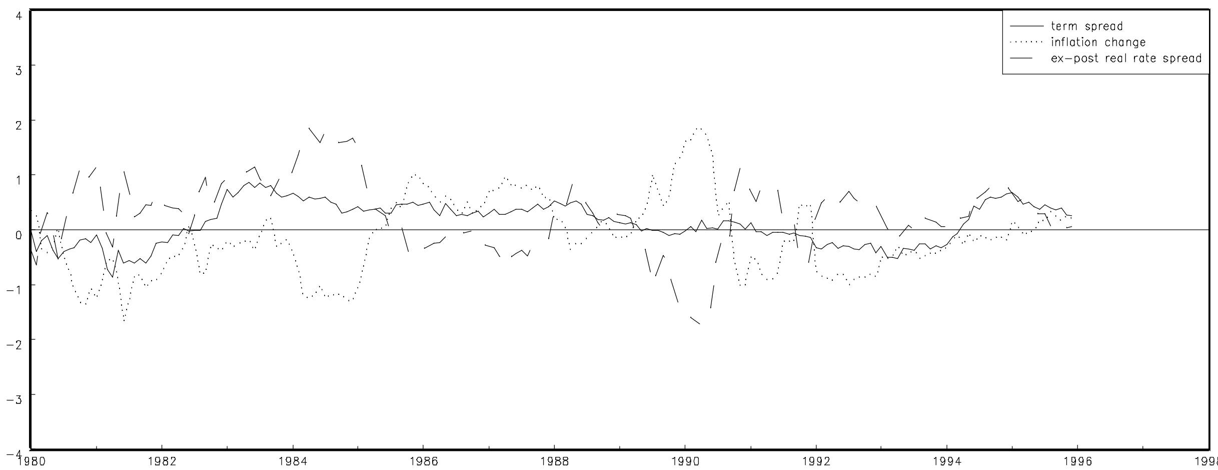
Graph 7b: France - Fisher decomposition variables - (2-4) years



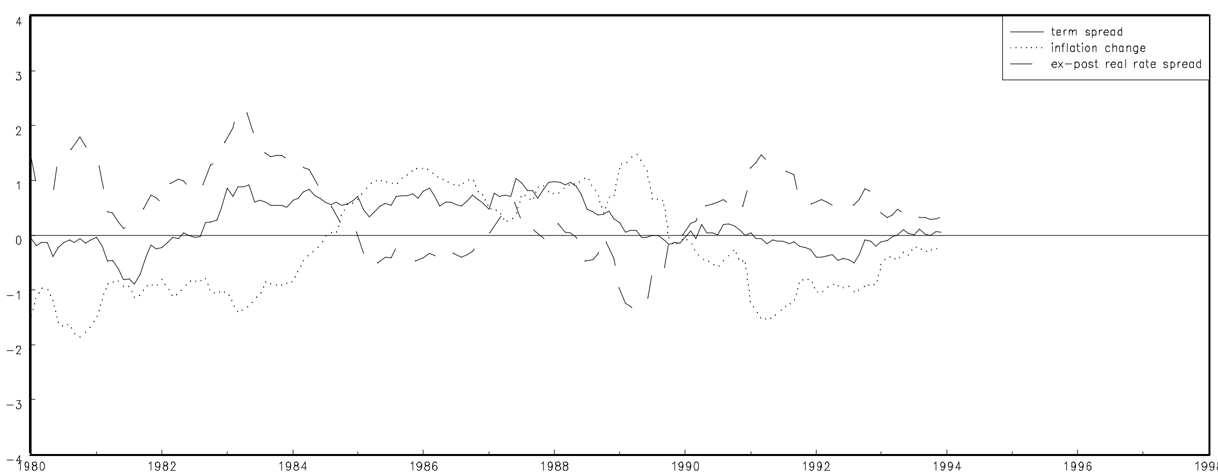
Graph 7c: France - Fisher decomposition variables - (3-6) years



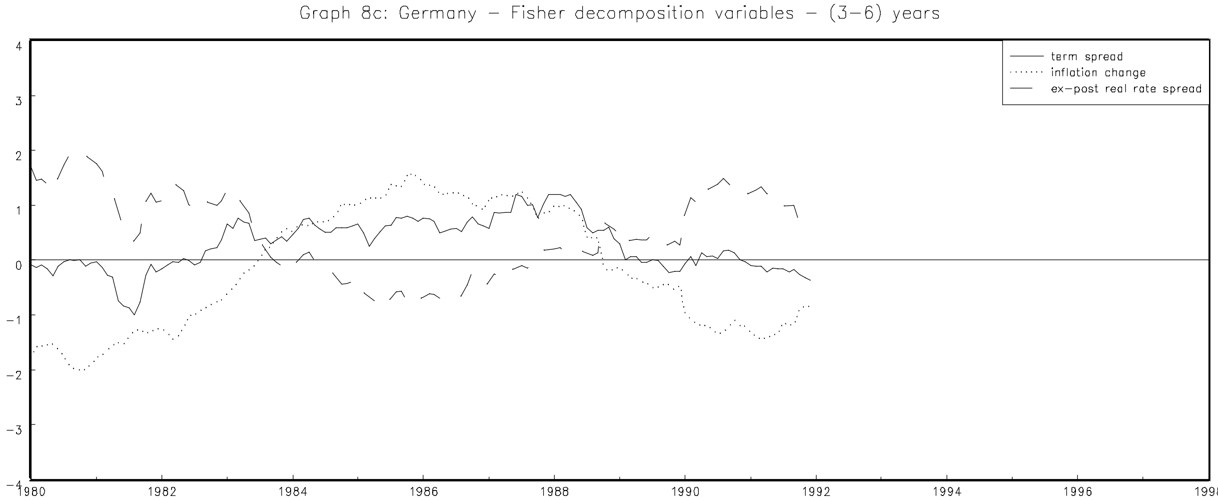
Graph 8a: Germany – Fisher decomposition variables – (1–2) years



Graph 8b: Germany – Fisher decomposition variables – (2–4) years



Graph 8c: Germany – Fisher decomposition variables – (3–6) years



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