The expectations theory: tests on French, German and American euro-rates

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Introduction

The expectations theory of the term structure of interest rates (ETTS) has received a great deal of attention for several years now. The interest undoubtedly stems in part from the fairly pragmatic implementation of the theory and the scope of its proposals. A widely accepted idea is that the slope of the term structure on a given date contains information about future changes in interest rates.

The implications of the ETTS have, however, long been contested by empirical work (see Shiller [1990] for a summary). According to the problem set by Campbell and Shiller [1991], the link between the slope of the term structure and the future long-term rate has the wrong sign, and the correlation between the slope of the term structure and changes in the future short-term interest rate is not as strong as expected. This work is based almost exclusively on American data from the post-war period, but some findings are atypical of this overall statement (Mankiw and Miron [1986], Fama [1984], Mishkin [1988]). The most recent work on countries other than the United States, is more favourable to the expectations theory (Gerlach and Smets [1995], Dahlquist and Jonsson [1995], Hurn *et al* [1995]).

Does this mean we should accept the idea that the theory is valid for some countries and not for others? That some interest rates contain predictive information and others do not? We shall attempt to develop this point using a methodological and pragmatic approach that differs from the one usually applied. Two main approaches are developed.

The first approach is based on the implications of the apparent non-stationarity of interest rates, which has been proven for many years now. This property is implicitly taken into account in the formulation of the usual tests of the ETTS. Nevertheless, the complete dynamics of the links between interest rates should be specified in the form of an error-correction model (ECM) that incorporates the long-term link as well as the short-term dynamics (as proposed by Engle and Granger [1987]). This omission in the test of the expectations theory can lead to specification biases (Hakkio and Rush [1989]).

The second approach aims to isolate the impact on the estimates of observations made in times of monetary tension. As a general rule, experience has shown that the estimated parameters are fairly unstable. The findings of Mankiw and Miron [1986] show that coefficients are highly dependent on the period used for the estimates. In a somewhat different context, the work of Dahlquist and Jonsson [1995] leads to the same type of conclusion. This variability of parameters, which is generally linked to turmoil on money markets, shows up as a particularly important phenomenon in the empirical applications presented in this paper. In fact, a sensitivity analysis shows that just a few observations suffice to have a major impact on the estimated parameters.

Based on this dual approach, we attempted to test the ETTS using the French, German and American euro-rates between January 1975 and October 1995. The organisation of the paper is as follows: the first section presents the three usual tests of the ETTS, along with the characteristics of the results they give. In the second section, the same tests are made within the framework of an error-correction model; the third section gives details of the data used, the stationarity test results and the

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method used to evaluate the sensitivity of estimates to observations. The last section comments on the findings of the tests based on the usual specifications and those based on ECMs.

1. The expectations hypothesis according to the usual approach

1.1 The expectations theory

The ETTS is essentially based on the assumption that there is no arbitrage opportunity: two investment strategies applied at t for the same horizon must have the same expected yield. Otherwise, all of the investors would prefer the investment with the highest expected yield, thus raising the prices of the underlying securities and thereby reducing the yield. However, it is generally accepted that different yields on different transactions could reflect a premium arising from the liquidity preference, for example, or from preferred-habitat phenomena, or even from institutional restrictions. But the expectations theory postulates that this premium is constant over time (even though it may vary according to the maturities of the securities in question). In its most traditional form, the expectations theory establishes that, save the constant premium, the yield at t on an investment with a maturity of n is equal to the expected yield at t on successive investments in short-term securities with a maturity of m at t, $t+m$, ..., $t+n-m$ (in the following m will refer to the shorter maturity or investment horizon and n to the longer maturity or investment horizon) (Shiller [1979]):

$$r(t,t+n)=\frac{m}{n}\sum_{i=0}^{\frac{n}{m}-1}E_t r(t+im,t+im+m)+\frac{m}{n}c(m,n) \text{ where } \frac{n}{m} \text{ is an integer} \tag{1}$$

and where $r(t,t+n)$ is the yield at time t of a zero-coupon bond with a maturity of $t+n$ and E_t is the expectation conditional upon the information available at time t. The premium $c(m,n)$ may depend on m and n, but it must be constant over time.

1.2 Deriving the usual tests

There has been an abundant literature over the last fifteen years on tests of the assumptions of the ETTS. Even though other specifications have been presented elsewhere, three main test forms can be distinguished. They stem directly from equation (1). In every case, the specifications are reformulated to show an interest rate movement on the left-hand side and a yield spread on the right-hand side. This is done to take into account that interest rates may be non-stationary.

The first equation is based on the *correlation between the expected change in the short-term rate and the spread between the forward rate and the short-term rate*[3]:

$$\left[E_t r(t+n-m,t+n)-r(t,t+m)\right]=\left[f(t,t+n-m,t+n)-r(t,t+m)\right]+\left[c(m,n)-c(m,n-m)\right] \tag{2}$$

$$\left[E_t r(t+m,t+n)-r(t,t+n)\right]=\frac{m}{n-m}\left[r(t,t+n)-r(t,t+m)\right]+\frac{m}{n-m}\left[c(m,n-m)-c(m,n)\right] \tag{3}$$

3 See Box 1 for the definitions of the different types of yield.

Box 1: Different types of yield

If $r(t,t+m)$ is the yield at t on a zero-coupon bond with a remaining maturity of m, the three following types of yield can be defined (see Shiller [1990]):

– the forward rate: this is the yield at t on holding a zero-coupon bond with a maturity of m from $t+n-m$ to $t+n$ ($m < n$). The forward rate can be inferred from the yield at t of a bond with a remaining maturity of n and from the yield on a bond with a remaining maturity of $n-m$:

$$f(t,t+n-m,t+n)=\frac{nr(t,t+n)-(n-m)r(t,t+n-m)}{m}$$

– the holding yield: this is the yield at t from the purchase of a zero-coupon bond with a remaining maturity of n that is resold at $t+m$ ($m < n$). It is written as:

$$h(t,t+m,t+n)=\frac{nr(t,t+n)-(n-m)r(t+m,t+n)}{m}$$

– the rollover rate: this is the yield at t from successive purchases at $t, t+m, ..., t+n-m$ of zero-coupon bonds with remaining maturities of m ($m < n$). It is written as:

$$h'(t,m,t+n)=\frac{m}{n}\sum_{i=0}^{\frac{n}{m}-1}r(t+im,t+im+m) \text{ where } \frac{n}{m} \text{ is an integer}$$

The third equation is based on the correlation between the average expected variation in the future short-term rate over a long period and the slope of the term structure. It is obtained directly by subtracting the current short-term rate r(t,t+m) from both sides of equation (1):

$$\frac{m}{n}\sum_{i=0}^{\frac{n}{m}-1}E_t r(t+im,t+im+m)-r(t,t+m)=\left[r(t,t+n)-r(t,t+m)\right]-\frac{m}{n}c(m,n) \qquad (4)$$

The last two specifications show that an increase in the spread between long-term and short-term rates should be accompanied by a future increase of both long-term and short-term rates. The initial spread will decrease, however, should the short-term rate rise by more than the long-term rate.

In fact, the ETTS implies that when one of the specifications (2) – (4) holds for any m and any n, then the other two also hold for any m and any n.

1.3 The standard results

Tests of the ETTS are usually based on estimates of the specifications (2) – (4). But they require a further assumption as to how expectations are formed. In practice, these tests are based on the joint assumption that there is no arbitrage opportunity and that expectations are rational. Equations (2) – (4) are rewritten as:

$$\left[r(t+n-m,t+n)-r(t,t+m)\right]=\alpha+\beta\left[f(t,t+n-m,t+n)-r(t,t+m)\right] \qquad (5)$$

$$\left[r(t+m,t+n)-r(t,t+n)\right]=\alpha+\beta\frac{m}{n-m}\left[r(t,t+n)-r(t,t+m)\right] \qquad (6)$$

$$\frac{m}{n}\sum_{i=0}^{\frac{n}{m}-1}\left(1-i\frac{m}{n}\right)\left[r(t+im,t+im+m)-r(t+im-m,t+im)\right]=\alpha+\beta\left[r(t,t+n)-r(t,t+m)\right] \qquad (7)$$

In their "pure" form the ETTS hypotheses require that $\alpha = 0$ and $\beta = 1$ but, in empirical work, the null premium is often dropped to concentrate on parameter β being equal to one.

Even if one is more specifically interested in the analysis of short-term securities markets (typically for securities with a maturity of one year or less), interpreting the findings of much empirical work is a delicate matter. The findings can vary from one study to the next depending on the tests run, the segment of the yield curve examined or the period under study. Nonetheless, some robust conclusions can be highlighted.

- The first specification, which is the variation in the short-term rate as a function of the spread between the forward and short-term rates, gives results that tend to favour the ETTS when the maturities are short enough: coefficient β in regression (5) is generally between 0 and 1, even if equality to 1 is rejected in most cases (Fama [1984], Fama and Bliss [1987]).
- Tests based on the second specification, which is the variation in the long-term rate as a function of the slope of the term structure, are the ones least favourable to the ETTS: the estimates of coefficient β in regression (6) are almost always negative and significantly different from 1 (Campbell and Shiller [1991], Campbell [1995], Evans and Lewis [1994]).
- The estimates of the third specification, which is the variation in the short-term rate as a function of the slope of the term structure, tend to favour the ETTS. Even though the coefficient β in regression (7) is generally significantly different from 1 for the shortest maturities, it is often positive and close to one for the shortest maturities (Campbell and Shiller [1991], Campbell [1995]).

The international dimension is also important in the analysis of the results. Comparisons in recent years have shown that developments in the American financial market tends to be unfavourable to the ETTS. In a broad international comparison based on the third specification, Gerlach and Smets [1995] concluded that the term structure of euro-dollar rates is the least favourable to the ETTS, while for countries such as France, Belgium, Italy and Spain, the theory is more broadly validated. Dahlquist and Jonsson [1995], using a test based on the first specification, were unable to reject the ETTS for interest rate data from Swedish government bonds. Hurn *et al* [1995] also obtained favourable results from interest rates on the British interbank market, using the third specification. What transpires from the various work is that the prevailing quasi-automatic rejection of the ETTS by American data should be at least mitigated in the case of other countries.

2. The expectations theory according to the cointegration approach

Most of the empirical work done to test the ETTS recognises the problem of the non-stationarity of interest rates. Generally, the variables are made stationary (see the three specifications above), which makes it possible to make econometric estimates on the basis of stationary series. Nevertheless, aspects that are directly linked to cointegration are rarely taken into account (with the notable exception of Campbell and Shiller [1987] or Dahlquist and Jonsson [1995]). As was shown by Engle and Granger [1987], a cointegration relationship between two series leads to certain restrictions in the specification of the short-term dynamics of the series. More precisely, if two variables X and Y are integrated of order one (or I(1)) and cointegrated, there is a relationship between the levels of the two variables $X_t = a+bY_t+\varepsilon_t$, where ε_t is a stationary (but not necessarily white noise) error term. In this case, the full dynamics of the system can be written as an ECM:

$$A(L)\begin{pmatrix}\Delta X_t\\ \Delta Y_t\end{pmatrix} = \begin{pmatrix}\gamma_1\\ \gamma_2\end{pmatrix}\varepsilon_{t-1} + \begin{pmatrix}u_t\\ v_t\end{pmatrix} \tag{8}$$

where $A(L)$ is a matrix polynomial in the lag operator, and u_t and v_t are white noise. Engle and Granger have shown that if X and Y are cointegrated, then γ_1 and/or γ_2 is significant.

The argument being developed here is that when interest rates are non-stationary, the premia suggested by Shiller [1990] are logical candidates for the status of a cointegration relationship. In fact, these same premia are taken as the starting points for proposing the usual specifications of (2) – (4). The specifications can then be deduced for ECMs describing the changes in yield. At this point it is observed that the ECM specifications, which fairly naturally represent a general framework for testing the ETTS, are not necessarily compatible with the three specifications (5) – (7). These could then be seen as representations that are too specific and likely to contain specification errors.

2.1 Long-term relationships

Shiller [1990] proposed three definitions of time-independent premia based on the assumption that there are no arbitrage opportunities between different types of investment (for which the yields are defined in Box 1).

The forward premium φ_f is defined by:

$$\varphi_f(n-m,n) = f(t,t+n-m,t+n) - E_t r(t+n-m,t+n) \quad 0<m<n$$

that is to say by the difference between the yield on a forward investment at t in n-m periods on a security maturing at t+n and the expected yield at t on an investment at time t+n-m on a security maturing at t+n.

The holding period premium φ_h is defined by:

$$\varphi_h(m,n) = E_t h(t,t+m,t+n) - r(t,t+m) \qquad 0<m<n$$

that is to say by the difference between the expected yield at t from buying at t a security maturing at t+n and selling it at t+m and the yield on a spot purchase at t of a security maturing at t+m.

The rollover premium φ_r is defined as:

$$\varphi_r(m,n) = r(t,t+n) - E_t h'(t,m,t+n) \quad 0<m<n \quad \text{where } \frac{n}{m} \text{ is an integer}$$

that is to say by the difference between the expected yield at t of a sequence of purchases at t, t+m, ..., t+n-m of securities with a remaining maturity of m and the yield on the spot purchase at t of a security maturing at t+n.

The interpretation of the latter two premia is of the same type as for equations (3) and (4). This means that, *ceteris paribus*, a steeper slope of the term structure, stemming from a drop in short-term rates, for example, leads to a lower holding yield and thus a rise in expected long-term rates. In the same way, a steeper slope of the term structure caused by a rise in long-term rates leads to a higher rollover yield and thus a rise in expected short-term rates, all else being equal.

If interest rates are non-stationary, the assumption that premia are constant over time leads to three cointegration relationships:

$$r(t+n-m,t+n) = f(t,t+n-m,t+n) - \varphi_f(n-m,n) + \varepsilon_1(t+n-m,t+n) \tag{9}$$

$$h(t,t+m,t+n) = r(t,t+m) + \varphi_h(m,n) + \varepsilon_2(t+m,t+n) \tag{10}$$

$$h'(t,m,t+n) = r(t,t+n) - \varphi_r(m,n) + \varepsilon_3(t+n-m,t+n) \tag{11}$$

where ε_i, for i = 1 to 3, reflects investors' expectation errors.

These cointegration relationships exist independently of the assumptions made about how expectations are formed. Indeed, cointegration requires only that the errors in the equation remain stationary, which is what happens as long as expectation errors themselves are stationary. The rationality of expectations, on the other hand, implies that these errors are white noise, which leads to errors in the form of moving averages (due to overlapping data, see below). This explains why the hypothesis of the ETTS cannot be tested directly within the framework of a cointegration relationship. The non-standard properties associated with the estimators in these regressions make it impossible to test the value of the parameters or the whiteness of the residuals. This is why the tests can only be done within the framework of an error-correction model.

The errors associated with cointegration relationships (9) – (11) are defined as follows:

$$\varepsilon_1(t+n-m,t+n)=r(t+n-m,t+n)-E_t r(t+n-m,t+n) \tag{12}$$

$$\begin{aligned}\varepsilon_2(t+m,t+n)&=h(t,t+m,t+n)-E_t h(t,t+m,t+n)\\&=-\frac{n-m}{m}\left[r(t+m,t+n)-E_t r(t+m,t+n)\right]\end{aligned} \tag{13}$$

$$\begin{aligned}\varepsilon_3(t+n-m,t+n)&=h'(t,m,t+n)-E_t h'(t,m,t+n)\\&=\frac{m}{n}\sum_{i=0}^{\frac{n}{m}-1}\left[r(t+im,t+im+m)-E_t r(t+im,t+im+m)\right]\end{aligned} \tag{14}$$

Thus, it can be seen that the errors associated with cointegration relationships, which are expressed directly as a function of the expectation errors, refer to different dates depending on the relationship. In (9) and (10), the errors stem from expectation errors made at t about $t+n-m$ and $t+m$ respectively. In equation (11) on the other hand, the error refers to expectation errors made at t about $t+m$, ..., $t+n-m$. This is an essential point in the choice of the differentiation order for the error-correction model, and also for defining the degrees of *overlapping*.

2.2 Error-correction model specifications

The existence of the cointegration relationships (9) – (11), which still has to be validated empirically, makes it possible to establish a link with the ECMs. The specification of the models is a slightly more delicate matter than is usually the case. The cointegration relationships (9) – (11) show the arbitrage between investments that are assumed to be alternatives. Yet, at time t, only one of the yields is perfectly known (this is the forward rate in (9) and the zero-coupon rates in (10) and (11)), the other yield is known after respective lags of n-m, m and n-m. Yet, the ECM specification, of course, implies that the error-correction term (term ε_{t-1} in (8)) is known at time t. Therefore, the orders of differentiation must be compatible with the number of periods required for the error-correction term to be known at time t. The specifications of the error-correction models associated with cointegration relationships (9) – (11), with no lagged terms, are respectively:

$$\begin{aligned}\left[r(t+n-m,t+n)-r(t,t+m)\right]&=a\left[r(t,t+m)-\delta f(t-n+m,t,t+m)+\varphi_f(n-m,n)\right]\\&\quad+b\left[f(t,t+n-m,t+n)-f(t-n+m,t,t+m)\right]+\eta_1(t+n-m)\end{aligned} \tag{15}$$

$$\begin{aligned}\left[h(t,t+m,t+n)-h(t-m,t,t+n-m)\right]&=a\left[h(t-m,t,t+n-m)-\delta r(t-m,t)-\varphi_h(m,n)\right]\\&\quad+b\left[r(t,t+m)-r(t-m,t)\right]+\eta_2(t+m)\end{aligned} \tag{16}$$

$$\left[h'(t,m,t+n)-h'(t-n+m,m,t+m)\right]=a\left[h'(t-n+m,m,t+m)-\delta r(t-n+m,t+m)+\varphi_r(m,n)\right] \\ +b\left[r(t,t+n)-r(t-n+m,t+m)\right]+\eta_3(t+n-m) \qquad (17)$$

The choice of the number of lags in writing the error-correction term is a natural one for the first two specifications. When writing the premium (9), the expected term (the zero coupon rate for maturity *t+n* in *n-m* periods) becomes known with a lag of *n-m* periods. In the same way, the holding yield between *t* and *t+m* on a security maturing at *t+n* only becomes known at time *t+m*. In both cases, the necessary lag is, therefore, *n-m* and *m* periods respectively. If the investment horizon is *n* periods in the third specification, the rollover yield for a sequence of investments at *t, t+m, ..., t+n-m* is fully known right from time *t+n-m*. Therefore, *n-m* periods must pass before the error-correction term is likely to influence changes in the rollover yield. The lag is indeed *n-m* periods, as shown in (17).

The first-difference terms in these equations are stationary if the yield variables are I(1). In the same way, if the expectations theory is valid, the error-correction term, which is the first term on the right-hand side, is stationary. Thus, standard econometric techniques can be used and they give convergent estimators. However, in view of the non-standard properties of the long-term parameters ("superconsistency", Stock [1987]), δ shows non-standard properties and, unlike a and b, cannot checked with statistical tests that are easy to use in a single-variable framework.

It is easy to check that the expectations theory implies that $-a = \delta = b = 1$ for the three ECM equations (15) – (17).

2.3 The consistency of the ECM specifications and the standard specifications

The problem of consistency between the ECM specifications and the usual specifications was first raised by Hakkio and Rush [1989] in a test of the efficiency hypothesis on the foreign exchange market. Their purpose was to show that when a spot rate and a forward rate are cointegrated, the best framework for testing efficiency is the ECM and that, in this case, carrying out the test with the usual specification (type (5)) can lead to a specification error.

The consistency between the usual specifications and the ECM representations must be analysed to develop this point. Of course, the various specifications are all consistent when the ETTS holds. In this case $-a = \delta = b = 1$ in (15) – (17) and $\beta = 1$ in (5) - (7).

On the other hand, the situation is more complex under the alternative assumption. If the specifications (5) and (15) based on the forward rates are compared, it can be seen that the usual specification is clearly included in the ECM, because the two equations are only equivalent for $a = -b$ and $\delta = 1$. Imposing these constraints when estimating the usual relationships can lead to a bias in the estimate of parameter β, which will be all the greater because of the strong correlation between the two variables (the spread between spot rates and the forward rates, which is present, and the change in the forward rate, which is missing.

As for specifications (6) and (16), based on the long-term rates, it is clear that (6) is not included in (16), as the two specifications are only equivalent when $a = -1$, $b = \delta = 1$, and $\beta = 1$; or in other words, when the ETTS holds. Furthermore, specifications (7) and (17) are only consistent if $a = -1$, $\delta = b$ and $\beta = 1$. In both cases, the usual specification does not appear to be a special case of the ECM. All in all, when the yields are I(1) and cointegrated, there is indeed a specification bias for the three tests based on the usual specifications.

Box 2: Overlapping

When the ETTS is valid, the form of the η_i errors associated with the error-correction models can be explained. When $-a = \delta = b = 1$, there are cointegration relationships and, by construction $\eta_i = \varepsilon_i$. Thus, even in the form of error-correction models and even when the ETTS is true, the errors show temporal autocorrelation stemming from overlapping, provided the time unit is shorter than the investment horizon (this point was not dealt with by Hakkio and Rush [1989]). Even if expectation errors in the short-term yields are assumed not to be autocorrelated, the fact that the expectations are for horizons of $n-m$ and m periods respectively (for (15) and (16)) or for m, $2m$, ..., $n-m$ periods (for (17)) leads to the use of information that is partially overlapping, which gives rise to the autocorrelation of the residuals. It is likely, for example, that the expectation errors at $t-1$ and t about a yield at $t+m$ will be correlated.

The errors associated with the forward and holding premia are written as (12) and (13), and they correspond to the expectation errors about interest rates at $t+n-m$ and $t+m$ respectively. As the time unit in our study is one month, the degrees of overlapping in the errors are $(n-m-1)$ and $(m-1)$ respectively. The errors associated with specifications (15) and (16), therefore, in keeping with the ETTS hypotheses, follow the MA($n-m-1$) and MA($m-1$) processes. The error for the rollover premium is written as (14) and combines the expectation errors at time t about the one-month rates dating from $t+m$ to $t+n-m$. The error associated with specification (17) thus follows a MA($n-m-1$) process.

These overlapping problems are usually handled with the method of generalised moments (Hansen and Hodrick [1980]). The principle is to estimate the equation first, without any correction, then determine the variance-covariance matrix containing temporal autocorrelations up to the order of the overlapping for the residuals, and then finally re-estimate the equation with a correction for autocorrelation. This correction does not modify the coefficients.

3. The data and their characteristics

3.1 The data

Empirical analysis was based on the euro-rates quoted in London. The sample covers the end-of-month data from January 1975 to October 1995. The data collected are the average of the bid and offered rates at the close of trading for maturities of 1, 3, 6 and 12 months. Intermediate maturities were not available for the whole period, so they were obtained using linear interpolation. This technique is admittedly imperfect, but it provides uniform data and avoids the inherent estimation problems in complex interpolation procedures (e.g. Nelson and Siegel [1987]).

Because the authors work for the Banque de France, French rates are the first to be studied. However, the close ties between France and Germany naturally led them to consider German rates as well. American rates are also examined as a reference, insofar as the market there has been widely studied in the literature. The choice of the euro-rates stems from a concern for uniformity between the countries under study in order to make international comparisons of the results possible, along with comparisons of the restrictions on domestic markets. Thus, even though long-run interest-rate data is available for the French and German interbank markets, the introduction of reference rates on these markets is a fairly recent development[4].

4 The PIBOR and the FIBOR were launched in 1986.

However, there are problems that come up when euro-currency rates are used. For example, the fact that foreign exchange controls remained in place in France until 1986, means that arbitrage between France's domestic interest rates and the euro-rates was imperfect. Even though this situation did not necessary prevent arbitrage between the different maturities on the euro-currency markets, it is clear that in times of foreign exchange turmoil, the existence of segmented markets would lead to serious liquidity problems[5].

3.2 Outliers

The segmentation between domestic rates and euro-rates seemed to merit consideration of aspects relating to the detection of outliers, especially as tests of the ETTS hypotheses are, in some cases, very sensitive to the presence of such outliers. In times of currency turmoil, disturbances can be serious enough to give rise to outliers in the rates quoted. This was the case during the very severe turmoil in France in 1981 to 1983, and during the less severe bouts in 1987 and in 1992 to 1993. The outliers can be accidental, stemming, for example, from a momentary liquidity shortage that coincide with the observation of the reference rate, or else they can stem from exceptional positions taken momentarily, for example, in the days leading up to a realignment in the European Exchange Rate Mechanism. These outliers often lead to an artificial acceptance of the ETTS hypotheses. During a currency crisis, the sharp rise in short-term rates causes the average slope of term structure of interest rates to flatten. This is then generally followed by a rapid fall in short-term rates and a return to a steeper slope. These movements can be big enough to change the outcome of estimates made on a large sample[6].

We used usual procedures for detecting outliers in order to deal with this problem as rigorously as possible. As we are specifically interested in the value of the coefficients in the various regression equations, we examined the *DFBETAS* statistics proposed by Besley *et al* [1980][7]. The principle is to compare the value of the coefficient β in the regression $Y_t = \beta X_t + \varepsilon_t$, $t = 1, \ldots, T$, over the whole of the period and the value of the same coefficient, when the data observed at time $t = i$ are omitted. The test statistic for each date i is defined by comparing the deviation obtained between the parameters to the standard deviation of the coefficient. Krasker *et al* [1983] suggested comparing this series to $3/\sqrt{T}$, where T is the number of observations. The variable that was used as the basis for detecting outliers is the error-correction term (associated with coefficient a) in each of the error-correction equations (15) – (17).

To illustrate the importance of detecting outliers, we consider equations (6) (variation in the long-term rate as a function of the slope of the term structure), and (7) (variation in the short-term rate as a function of the slope of the term structure) to show how much some observations can influence the estimated parameters. For French rates, we used three distinct samples for the estimates.

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5 The one-month Euro-franc rate stood at an average of 18% in 1981-82, while the rate on the domestic money market over the same period stood at 15%.

6 Gerlach and Smets [1995] mention this type of dependence in the results they obtained from equation (4) using monthly Belgian, Danish, French, Spanish, Irish, Italian and Swedish Euro-rates. Shiller *et al* [1983], using equation (2) on monthly American data from the period 1959-1982, observed that their results vis-à-vis the observations after October 1979 were highly dependent. On the other hand, Mankiw and Miron [1986], working with quarterly American data from the period 1890-1979, found that the financial crises of 1890, 1893 and 1907 did not have any effect on their findings, which were favourable to the ETTS.

7 This methodology was used in a footnote by Shiller *et al* [1983] to show the high degree of sensitivity of the Shiller [1981] results to the data from 1970.

The first covers the whole period, the second excludes the data observed in March 1983[8] and the third excludes all of the outliers. For the German and American rates, we examined only two samples. The first covers the whole period and the second the whole period except for the outliers. The results of the estimations are given in Appendix 1.

For French rates (Table A1-1), the most disrupted periods were mainly 1981 and 1982. The sensitivity of the results is clear for the estimations of the equation based on the nearest maturities of the long-term rates (i). Thus, for $m = 1$ month and $n = 3$ months, the coefficient goes from 1.23 for the whole of the sample to 0.25, when March 1983 is removed and it becomes negative at –0.23 after the 7 most disruptive observations are removed. In the same way, for the 3-6 month pair of maturities for the equation based on the short-term rate (ii), the parameter goes from 0.97 to 0.95 and 0.32 respectively (5 observations are removed). Finally, while the ETTS hypothesis is accepted for each of the 12 pairs of maturities in Table A1-1, when the whole sample is used for the estimate, there are only 5 left when the most disruptive observations are removed.

In the case of American rates, the data problems are less serious than with the French rates. However, some problems remain since the short-term rates were disrupted between 1979 and 1982, when the Fed changed its operating procedures. In December 1980, the euro-dollar rates even reached 21%. The removal of the most disruptive observations leads to a sweeping change in the estimation of the parameters in some cases (Table A1-3). On the other hand, the results for German rates are not very sensitive to the way outliers are dealt with, as their effects tend to offset each other (Table A1-2).

All in all, the situation observed warrants systematic detection of outliers for the econometric estimates made in the rest of this paper.

3.3 The statistical properties of the series

Before undertaking any analysis with an error-correction model, the degree of non-stationarity of the data used must be checked. Up until now, we have implicitly accepted that the yield was I(1) and that premia inferred from that were I(0), which makes it possible to write the error-correction models (15) – (17). In order to validate these hypotheses, we tested the zero-coupon rate processes for a unit root. These processes are the basis for defining all of the other yields. We also tested for forward, holding period and rollover premia. The stationarity of the yield spread between long and short rates in specifications (3) and (4) was also tested (see Appendix 2).

In the case of the French rates in Table A2-1, the zero-coupon rates are clearly integrated of order one and the premia are all stationary, at least up to a significance level of 5%.

The results are less clear-cut in the case of the German rates shown in Table A2-2. While the Dickey and Fuller statistics clearly point to the non-stationarity of zero-coupon rates, the ADF statistics do not make it possible to conclude systematically that the rates are integrated, particularly for the shortest and longest maturities. Yet the autoregression coefficients are very close to 1 (to the order of 0.96 – 0.98 for all maturities). In spite of the inconclusiveness of the stationarity tests, interest rate behaviour looks very similar to that of an integrated process. Furthermore, the holding and rollover premia are clearly stationary. The test also makes it possible to conclude that the forward premia are stationary, but at significance levels of 5%, or even 10% for the 9-month rate in 3 months.

The American rates in Table A2-3 also display the characteristics of the I(1) process, with autocorrelations to the order of 0.96 – 0.98. But the variations in interest rates seem highly autoregressive: the ADF statistics are only significant at a significance level of 10% for maturities of 1 to 3 months and a significance level of 5% for longer maturities. Yet, the autoregression coefficient

8 There was particular disruption in March 1983 because of the foreign exchange crisis that led to the realignment of 21 March (-2.5% for the FRF and +5.5% for the DEM. At the end of March, the one-month Euro-franc rate still stood at 45%, and the one-year rate at 18.5%.

for each of the maturities is to the order of 0.15 for 12 lags and 0.30 for 15 lags (the number of lags needed to whiten the residuals). On the whole, the premia seem to be stationary even though the significance level can reach 10% as the maturity lengthens. This is the case for the rollover premium for a maturity of more than 8 months. However, the forward premium in 10 months seems non-stationary, with an autoregression coefficient of 0.9, when the number of lags makes it possible to whiten the residuals.

These stationarity tests indicate that in almost all of the cases, the error-correction model specification is the suitable form for testing the ETTS hypotheses.

4. The empirical results

In view of the importance we gave to dealing with outliers, it is necessary to describe the approach used. The observations are selected on the basis of error-correction models, using the method described above. For each pair of maturities, we determined which observations distorted the estimate the most. These observations were removed and the error-correction models and the usual specifications were estimated using the samples with these points removed. In general, the number of observations removed was limited and, in practice, never came to more than 4% of the sample.

The analysis is made in two steps. First we presented the estimates and the tests based on the three usual specifications, obtaining results that are similar (except for the handling of outliers) to those generally obtained in the literature. Then, we examine the estimates based on the ECMs and tested the restrictions implied by the ETTS.

Even though they are all based on the same expectations theory, the three equations are not equivalent for any investment horizons m and n[9]. The idea is that each of them can be used to examine a different aspect of the expectations. The first equation can thus be used to test the ability of the expectations theory to forecast rates for fairly short remaining maturities (m), but at fairly distant horizons ($n-m$). Conversely, the second equation can be used to examine the short-term change (between t and $t+m$) of the yield on instruments with a fairly long remaining maturity (n). The third equation is an intermediate version in some ways. It can be used to examine the change over a fairly long period (n) in the yield on securities with a fairly short remaining maturity (m). From this point of view, even if the theory is rejected, the contrasting results from empirical tests can help identify more clearly how investors' expectations are formed.

4.1 Estimating the usual specifications

The usual specifications (5) – (7) were estimated for the main pairs of maturities from the database on French, German and American rates (Tables 1 to 3 respectively). For each of the three specifications, the configuration of the estimates is similar to that obtained in previous work:

- For estimates based on the forward rates, the coefficients are between 0.4 and 1 for the European rates, reaching the order of 1 for French rates for investment horizons from 4 to 8 months. In the case of French rates, they are close to one when toe horizon is from 4 to 8 months. For the American rates, on the other hand, the absolute values of the coefficients are smaller;
- For estimates based on variations in the long-term rate, the test yields contrasting results in the French case. The coefficients are negative when the investment horizon is 1 month but are very close to 1 when the horizon is from 3 to 6 months. On the other hand, the coefficients are often negative, in the case of German rates, or systematically negative, in the case of American rates;

9 The three specifications are equivalent in the particular case where $n = 2m$ (Campbell and Shiller [1991]).

Table 1
Estimates of usual specifications - France

This table shows the estimation results of the specifications:

$$[r(t+n-m,t+n)-r(t,t+m)] = \beta_1[f(t,t+n-m,t+n)-r(t,t+m)] + constant \quad \text{(i)}$$

$$[r(t+m,t+n)-r(t,t+n)] = \beta_2 \frac{m}{n-m}[r(t,t+n)-r(t,t+m)] + constant \quad \text{(ii)}$$

$$\frac{m}{n}\sum_{i=0}^{\frac{n}{m}-1}\left(1-i\frac{m}{n}\right)[r(t+im,t+im+m)-r(t+im-m,t+im)] = \beta_3[r(t,t+n)-r(t,t+m)] + constant \quad \text{(iii)}$$

m* - *n	**Forward rate (i)**			**Variation in long rate (ii)**			**Variation in short rate (iii)**		
	β_1	$\overline{R}^2$	p-value	β_2	$\overline{R}^2$	p-value	β_3	$\overline{R}^2$	p-value
1 - 2	0.46	4	0.1	0.42	1	18.0	0.63	8	5.4
	(0.17)			(0.43)			(0.19)		
1 - 3	0.45	6	0.0	-0.23	-0	0.1	0.51	9	0.7
	(0.15)			(0.36)			(0.18)		
1 - 4	0.80	12	39.9	0.19	-0	7.8	0.61	11	2.7
	(0.24)			(0.46)			(0.17)		
1 - 5	1.07	29	72.9	-0.01	-0	2.7	0.82	26	31.7
	(0.19)			(0.46)			(0.17)		
1 - 6	0.93	29	63.9	-0.19	-0	0.8	0.83	28	37.1
	(0.16)			(0.44)			(0.18)		
1 - 7	0.96	24	84.1	0.07	-0	4.6	0.87	33	52.7
	(0.21)			(0.47)			(0.19)		
1 - 8	0.84	24	31.0	-0.00	-0	3.8	0.89	32	58.4
	(0.16)			(0.48)			(0.20)		
1 - 9	0.62	17	0.9	-0.07	-0	3.0	0.83	31	37.1
	(0.15)			(0.49)			(0.19)		
1 - 10	0.54	15	0.0	-0.15	-0	2.0	0.77	29	20.6
	(0.13)			(0.49)			(0.18)		
1 - 11	0.55	13	0.2	-0.30	-0	0.8	0.71	26	11.4
	(0.14)			(0.49)			(0.19)		
1 - 12	0.58	15	0.8	-0.41	0	0.4	0.68	26	9.4
	(0.16)			(0.48)			(0.19)		
3 - 6	0.58	9	1.3	1.18	9	65.5	0.32	9	0.0
	(0.17)			(0.44)			(0.09)		
3 - 9	0.85	23	34.0	1.28	9	52.7	0.45	15	0.0
	(0.16)			(0.42)			(0.11)		
3 - 12	0.43	9	0.0	0.81	4	65.5	0.45	16	0.0
	(0.15)			(0.39)			(0.11)		
6 - 12	0.45	10	0.0	0.89	6	75.2	0.23	9	0.0
	(0.16)			(0.40)			(0.08)		

Notes: The estimates relate to the period 1975-95. The observations from March 1983 have been removed. The usual relationships between the β_i for $n = 2m$ are not necessarily seen, because the observations removed as outliers are selected on the basis of specifications in the form of associated error-correction models. The estimate of the constant is not shown in the table. Standard deviations, shown in parentheses, are corrected for heteroscedasticity (White [1980]) and for overlapping (see Box 2). The variance-covariance matrix is estimated as suggested by Newey and West [1987]. $\overline{R}^2$ is the R^2, in %, corrected for the number of degrees of freedom and p-value is the significance level for the test of the hypothesis β_i=1.

Table 2
Estimates of usual specifications - Germany

This table shows the estimation results of the specifications given in Table 1.

m - n	Forward rate (i)			Variation in long rate (ii)			Variation in short rate (iii)		
	β_1	$\overline{R}^2$	p-value	β_2	$\overline{R}^2$	p-value	β_3	$\overline{R}^2$	p-value
1 - 2	0.95 (0.11)	18	65.5	0.78 (0.27)	4	43.9	0.97 (0.11)	19	75.2
1 - 3	0.63 (0.10)	13	0.0	0.46 (0.22)	1	1.4	0.80 (0.09)	24	2.7
1 - 4	0.60 (0.12)	13	0.1	0.47 (0.25)	1	3.6	0.68 (0.11)	16	0.2
1 - 5	0.54 (0.13)	11	0.1	0.27 (0.26)	-0	0.6	0.62 (0.12)	15	0.1
1 - 6	0.47 (0.15)	9	0.0	-0.02 (0.26)	-0	0.0	0.57 (0.13)	13	0.1
1 - 7	0.51 (0.21)	7	1.7	0.20 (0.27)	-0	0.3	0.54 (0.16)	11	0.4
1 - 8	0.51 (0.22)	8	2.3	0.16 (0.28)	-0	0.3	0.53 (0.18)	10	0.9
1 - 9	0.55 (0.21)	10	3.1	0.08 (0.28)	-0	0.1	0.52 (0.19)	10	1.4
1 - 10	0.59 (0.21)	12	4.8	-0.01 (0.29)	-0	0.0	0.52 (0.21)	10	2.0
1 - 11	0.51 (0.24)	9	3.9	-0.11 (0.29)	-0	0.0	0.53 (0.21)	10	2.8
1 - 12	0.52 (0.23)	10	3.5	-0.29 (0.30)	-0	0.0	0.53 (0.22)	10	3.2
3 - 6	0.44 (0.14)	6	0.0	-0.17 (0.26)	-0	0.0	0.25 (0.07)	5	0.1
3 - 9	0.41 (0.21)	5	0.6	-0.26 (0.35)	-0	0.0	0.30 (0.14)	5	0.0
3 - 12	0.54 (0.21)	9	2.8	-0.48 (0.37)	1	0.0	0.35 (0.18)	6	0.0
6 - 12	0.27 (0.21)	2	0.1	-0.35 (0.44)	0	0.2	0.14 (0.12)	2	0.0

Note: Same as Table 1 except that no observations have been removed.

- The best results are obtained from the specifications based on variations in the short-term rate. The estimated coefficients are always positive for all three countries and often close to 1, especially for French rates.

The three markets show substantial differences in the tests based on the χ^2 statistic:

- For American rates, the ETTS is accepted on the 5% significance level only for the forward rate of 1 month in 7 months. If the 1% level is allowed, the ETTS hypotheses are accepted in a few more cases (e.g., in the test based on the forward rate of 1 month in 1 month and the test based on the long-term rate in 12 months for an investment over 6 months or for the short-term rate in 1 month for an investment over 8 or 9 months).

Table 3
Estimates of usual specifications - United States

This table shows the estimation results of the specifications given in Table 1.

m - n	**Forward rate (i)**			**Variation in long rate (ii)**			**Variation in short rate (iii)**		
	β_1	$\bar{R}^2$	p-value	β_2	$\bar{R}^2$	p-value	β_3	$\bar{R}^2$	p-value
1 - 2	0.61 (0.19)	3	4.6	-0.27 (0.39)	-0	0.1	0.39 (0.19)	2	0.1
1 - 3	0.25 (0.16)	1	0.0	-0.36 (0.39)	0	0.0	0.32 (0.23)	2	0.3
1 - 4	-0.00 (0.20)	-0	0.0	-0.38 (0.41)	0	0.1	0.40 (0.25)	4	1.5
1 - 5	0.11 (0.18)	-0	0.0	-0.79 (0.46)	2	0.0	0.40 (0.21)	4	0.4
1 - 6	0.20 (0.17)	-0	0.0	-1.07 (0.47)	3	0.0	0.40 (0.17)	5	0.1
1 - 7	0.45 (0.28)	3	5.0	-0.86 (0.51)	1	0.0	0.49 (0.19)	6	0.7
1 - 8	0.39 (0.23)	3	0.8	-1.03 (0.54)	2	0.0	0.52 (0.20)	7	2.0
1 - 9	0.36 (0.19)	3	0.1	-1.20 (0.56)	2	0.0	0.47 (0.23)	5	2.3
1 - 10	0.32 (0.18)	3	0.0	-1.36 (0.58)	3	0.0	0.44 (0.22)	5	1.0
1 - 11	0.36 (0.19)	4	0.1	-1.50 (0.58)	4	0.0	0.46 (0.18)	7	0.3
1 - 12	0.27 (0.21)	2	0.1	-1.64 (0.59)	4	0.0	0.46 (0.18)	7	0.3
3 - 6	-0.06 (0.19)	-0	0.0	-0.35 (0.52)	0	0.9	0.12 (0.14)	1	0.0
3 - 9	0.32 (0.27)	1	1.1	-0.68 (0.69)	1	1.4	0.23 (0.15)	2	0.0
3 - 12	0.20 (0.17)	1	0.0	-1.21 (0.74)	4	0.3	0.24 (0.15)	2	0.0
6 - 12	0.04 (0.22)	-0	0.0	-0.47 (0.70)	1	3.6	0.05 (0.13)	-0	0.0

Note: Same as Table 1 except that no observations have been removed.

- On the 10% significance level, the German rates only accept the ETTS exceptionally for the three specifications, when $m = 1$ month and $n = 2$ months. When the significance level is reduced to 1%, the ETTS hypotheses are accepted for short investment horizons at the long-term rate ($m = 1$ month, $n = 2$ to 4 months) and at the short-term rate ($m = 1$ month, $n = 2$ to 3 months) and long investment horizons at the short-term rate ($m = 1$ month, $n = 9$ to 12 months), as well as for long horizons for forward investments ($m = 1$ month and $n = 7$ to 12 months, or $m = 3$ months and $n = 12$ months).
- In the case of French rates, the ETTS is more widely validated, even on the 5% significance level. This is the case for the test based on the forward rate when the investment horizon is 1 month (where $n = 4$ to 8 months) or 3 months (where $n = 9$ months), for the test based on the variation in the long-term rate when the investment horizon is 3 or 6 months ($m = 3$ or 6 months), or for the test based on the variation in the short-term rate when the short investment horizon is 1 month ($m = 1$ month, $n = 2$, 4 or 5 to 12 months). Most importantly, when the

significance level is reduced to 1%, the ETTS hypotheses are accepted for practically all pairs of maturities based on the long-term rate and for the pairs where $m = 1$ based on the short-term rate. However, in the case of the long term-rate, the result is primarily due to the very high standard deviation of the parameter, which becomes negative in most cases where the test is based on investments of 1 month.

This gives the following validity ranking of the ETTS: exceptionally for the American rates, rarely for German rates and often for French rates.

4.2 The estimates of the specifications based on the error-correction models

We directly required the premia as error-correction terms for the estimation of the error-correction models, but did not attempt to estimate the long-term parameter δ, which was later set at 1. Two things must be considered in this light: first, the stationarity tests on the premia make it possible to conclude that the premia are stationary; second, it is impossible within our analytical framework to test the value of parameter δ (particularly to see if it is equal to 1, which is the theoretical value inferred from the ETTS[10]. In other words, it is impossible to test the theory if δ has to be estimated.

We made successive estimates for each of the three premia in error-correction model form (15) – (17) for pairs of maturities that are comparable to those in the usual tests. Tables 4 to 6 show the estimates of a and b, which should equal -1 and 1 respectively under the expectations hypothesis, the associated standard deviations, the corrected R^2 and finally the significance level of the test of the joint hypothesis $-a = b = 1$.

The test based on the relationship between the variation in the short-term rate and the forward premium yields quite contradictory results. The ETTS often seems to be validated for French rates at intermediate investment horizons ($m = 1$ month and $n = 4$ to 8 months, and $m = 3$ months and $n = 6$ to 9 months). For German rates the level of the estimated coefficients is more satisfactory when n is quite high in relation to m, and the ETTS is accepted when $m = 1$ month and $n = 2$ and 9 to 12 months, and when $m = 3$ months and $n = 12$ months. Finally, for the American data, the coefficients are generally very low in absolute value, and the b parameter even turns negative for $m = 1$ month and $n = 4$ to 6 months. The ETTS is validated only exceptionally for intermediate investment horizons of the forward rate ($m = 1$ month and $n = 7$ or 8 months, $m = 3$ months and $n = 9$ months).

In the test based on the relationship between the variation in the holding period yield and the holding period premium, the estimated coefficients always have the right sign. The coefficients for the three countries nearly always vary between 0.5 and 1.5 in absolute value. In fact, the logic behind the test is *a priori* favourable to the ETTS, since unlike the preceding test, it is based on the change in interest rates in the coming months (e.g., for $m = 1$ months and $n = 12$ months, where the test is aimed at forecasting the rate in 12 months the course of the next month). Yet, even though the estimated coefficients are fairly close to the level required, the ETTS hypotheses are rejected in most cases. This is mainly due to the very precise estimates of the parameter a in the error-correction term. It can also be seen that, unlike the estimate based on the forward premium, the statistical fit is fairly good (with the $\overline{R}^2$ ranging between 0.3 and 0.9). Finally, the ETTS is validated several times, mainly when m is fairly high. In the case of French rates, the ETTS cannot be rejected when $m = 3$ or 6 months (at a very broad significance level); it also holds for American rates when $m = 3$ months and $n = 9$ or 12 months and when $m = 6$ months, and for German rates when $m = 6$ months.

As in most previous empirical work, the ETTS seems more widely validated by the test based on the rollover yield, and for all pairs of maturities in the case of French rates. It is only rejected in two cases with the American rates ($m = 1$ month and $n = 2$ months, $m = 3$ months and $n = 6$

10 Such a test is possible, but in the context of a multivariate analysis (Johansen [1988]).

months). The tests on German rates give more contradictory results, but at a significance level of 1%, the ETTS hypotheses can only be rejected in four cases ($m = 1$ month and $n = 4$ to 6 months, and $m = 3$ months and $n = 6$ months). The statistical fit is again very good, especially for the German rates, where the $\overline{R}^2$ is of the order of 0.6 – 0.7 in each case). It can be seen that, even regardless of the test result, the estimated coefficients are very close to those required by the ETTS (between 0.8 and 1.1 for the French rates, between 0.6 and 1.1 for the German and American rates, with a few rare exceptions). In contrast, the two other tests take interest rate forecasts with a distant horizon (for the forward rates) or a very near horizon (for the holding period yield). The latter involves an "average" predictive power (e.g. for $m = 1$ month and $n = 12$ months, the aim is to forecast changes in the 1-month rate over the 12 coming months).

All in all, the ECM specification leads to following results: for all three markets, the estimates based on the short-term rate are nearly always favourable to the ETTS; those based on forward rates are less favourable than the previous ones; and those based on the long-term rates are favourable only when m is high enough.

4.3 Comparison of Estimates from the Usual Specifications and those from the ECMs

When the econometric results obtained from the usual specifications are compared with those from ECMs, several important points are highlighted. The specification bias and, more especially, the sign of the estimated parameters need to be considered, along with the validity of the ETTS hypotheses. At a more qualitative level, an attempt will be made the summarise the markets' ability to "anticipate" interest-rate movements.

As a rule, two types of bias can result from the usual formulations of tests of the ETTS. The first stems from the incompleteness of the relationships between the interest rates. The second can result from the fact that the same variable can be found on both the right and left-hand sides of the estimated equations. As for the omitted-variable bias, the comparison of the usual specifications and the ECM has shown that equation (2) (forward rates) is the only one included in equation (15), whereas (3) (variations in the long-term rate) and (4) (variations in the short-term rate) cannot be considered as special cases of (16) and (17). This means that a strict comparison between the models is only possible in the case of the forward rates. Tables 1–6 show several cases where the ETTS hypotheses are rejected for the estimates based on the usual specifications but accepted with a significance level of more than 10% for the ECMs: with maturity pairs (3,6) and (6,12) for the French data; (1,10) to (1,12) and (3,12) for the German data; and (3,9) for the American data. In each of these cases, a bias shows up in the usual specification. The estimate made with the equality constraint of the ECM parameters ($-a_i = b_i$, which is the same as estimating the usual specification) gives an estimated coefficient that is far from the theoretical value imposed by the ETTS, while for the estimate based on the ECMs, the ETTS hypotheses is accepted by a χ^2-based test. On the whole the omitted variable bias is fairly small, as it affects only 7 cases out of 45.

The second source of bias can stem from the having the same variable on both the left and right-hand side of the estimated equations. This argument is put forward Campbell [1995] to justify the negative sign of the estimated coefficient in equation (3), while the parameter of equations (1) and (4) is positive. Indeed, in (3), the long-term rate is found on both sides of the equation but with opposite signs, whereas it is only found on the right-hand side of equation (4). This asymmetry could give rise to a measurement error (or a shock in expectations, which is the same thing in this case) on the long-term rate $r(t,t+n)$ that is likely to change the sign of β in specification (3) and likely only to bias β towards 0 in specification (4). This is what is shown in Tables 1–3. On the other hand, in the ECM specification, this configuration is no longer found (in the equation with the holding yield, the rate of maturity $t+n$ only shows up on the left-hand side, and the rate of maturity $t+n-1$ shows up on both sides, but with the same sign) and there are no excessive differences between the coefficients estimated from the holding yield and the rollover yield (Tables 4–6) no longer exist.

Table 4

Estimates of the error-correction models - France

This table shows the estimation results of the specifications:

$$\begin{aligned}[r(t+n-m,t+n)-r(t,t+m)] &= a_1[r(t,t+m)-f(t-n+m,t,t+m)] \\ &+b_1[f(t,t+n-m,t+n)-f(t-n+m,t,t+m)]+constant\end{aligned} \tag{i}$$

$$\begin{aligned}[h(t,t+m,t+n)-h(t-m,t,t+n-m)] &= a_2[h(t-m,t,t+n-m)-r(t-m,t)] \\ &+b_2[r(t,t+m)-r(t-m,t)]+constant\end{aligned} \tag{ii}$$

$$\begin{aligned}[h'(t,m,t+n)-h'(t-n+m,m,t+m)] &= a_3[h'(t-n+m,m,t+m)-r(t-n+m,t+m)] \\ &+b_3[r(t,t+n)-r(t-n+m,t+m)]+constant\end{aligned} \tag{iii}$$

m - n	**Forward rate (i)**				**Variation in long rate (ii)**				**Variation in short rate (iii)**			
	a_1	b_1	$\overline{R}^2$	p-value	a_2	b_2	$\overline{R}^2$	p-value	a_3	b_3	$\overline{R}^2$	p-value
1 - 2	-0.55	0.78	8	0.7	-0.48	1.30	85	1.5	-0.60	0.90	66	3.6
	(0.16)	(0.18)			(0.22)	(0.21)			(0.19)	(0.10)		
1 - 3	-0.46	0.46	5	0.1	-0.46	1.39	73	0.0	-0.66	0.87	55	12.2
	(0.15)	(0.16)			(0.16)	(0.29)			(0.18)	(0.11)		
1 - 4	-0.80	0.66	13	33.6	-0.62	1.13	65	0.0	-1.14	1.10	55	71.1
	(0.22)	(0.24)			(0.11)	(0.35)			(0.17)	(0.13)		
1 - 5	-1.07	0.94	31	65.0	-0.67	0.92	58	0.0	-0.97	0.88	48	29.2
	(0.16)	(0.21)			(0.11)	(0.43)			(0.15)	(0.10)		
1 - 6	-0.96	1.01	29	89.7	-0.71	0.69	52	0.0	-0.90	0.86	44	46.7
	(0.15)	(0.19)			(0.11)	(0.49)			(0.16)	(0.12)		
1 - 7	-1.01	1.18	25	30.3	-0.80	0.52	52	0.0	-0.75	0.80	45	14.9
	(0.22)	(0.28)			(0.12)	(0.57)			(0.13)	(0.11)		
1 - 8	-0.88	0.99	24	41.6	-0.74	0.60	49	0.0	-0.76	0.83	43	36.2
	(0.16)	(0.21)			(0.11)	(0.64)			(0.17)	(0.13)		
1 - 9	-0.63	0.66	16	1.9	-0.73	0.60	46	0.0	-0.83	0.90	47	69.3
	(0.14)	(0.14)			(0.11)	(0.70)			(0.20)	(0.14)		
1 - 10	-0.54	0.45	15	0.0	-0.73	0.60	46	0.0	-0.85	0.91	49	79.6
	(0.13)	(0.13)			(0.11)	(0.78)			(0.23)	(0.14)		
1 - 11	-0.56	0.52	13	0.2	-0.76	0.15	43	0.0	-0.87	0.92	49	83.9
	(0.15)	(0.15)			(0.11)	(0.78)			(0.23)	(0.14)		
1 - 12	-0.59	0.56	15	1.1	-0.76	0.13	42	0.0	-0.86	0.91	50	75.8
	(0.16)	(0.15)			(0.10)	(0.81)			(0.23)	(0.13)		
3 - 6	-0.96	0.91	19	91.0	-1.21	0.87	83	28.4	-1.10	1.03	52	86.1
	(0.20)	(0.23)			(0.20)	(0.17)			(0.22)	(0.12)		
3 - 9	-1.26	1.43	33	27.5	-1.12	0.87	75	78.4	-0.85	0.95	51	66.1
	(0.21)	(0.28)			(0.17)	(0.23)			(0.21)	(0.13)		
3 - 12	-0.62	0.53	16	1.5	-1.05	0.79	68	63.4	-0.95	1.00	53	89.2
	(0.17)	(0.16)			(0.12)	(0.23)			(0.26)	(0.14)		
6 - 12	-0.92	1.02	21	50.0	-0.96	0.94	82	45.9	-1.10	1.11	58	37.0
	(0.22)	(0.27)			(0.20)	(0.18)			(0.30)	(0.16)		

Notes: The estimates relate to the period 1975-95. The observations from March 1983 have been removed. The estimate of the constant is not shown in the table. Standard deviations, shown in parentheses, are corrected for heteroscedasticity (White [1980]) and for overlapping (see Box 2). The variance-covariance matrix is estimated as suggested by Newey and West [1987]. $\overline{R}^2$ is the R^2, in %, corrected for the number of degrees of freedom and p-value is the significance level for the test of the joint hypothesis $-a_i=b_i=1$.

Table 5

Estimates of the error-correction models - Germany

This table shows the estimation results of the specifications given in Table 4.

m - n	**Forward rate (i)**				**Variation in long rate (ii)**				**Variation in short rate (iii)**			
	a_1	b_1	$\bar{R}^2$	p-value	a_2	b_2	$\bar{R}^2$	p-value	a_3	b_3	$\bar{R}^2$	p-value
1 - 2	-0.83	0.99	21	21.3	-0.59	1.26	79	0.3	-0.72	0.90	63	6.5
	(0.12)	(0.12)			(0.12)	(0.12)			(0.12)	(0.06)		
1 - 3	-0.49	0.63	19	0.0	-0.64	1.23	63	0.0	-0.79	0.97	72	1.0
	(0.09)	(0.08)			(0.09)	(0.18)			(0.09)	(0.05)		
1 - 4	-0.43	0.70	22	0.0	-0.59	1.30	51	0.0	-0.67	0.96	72	0.1
	(0.11)	(0.10)			(0.08)	(0.28)			(0.12)	(0.06)		
1 - 5	-0.39	0.68	22	0.0	-0.54	1.38	44	0.0	-0.57	0.95	74	0.0
	(0.11)	(0.10)			(0.08)	(0.35)			(0.12)	(0.06)		
1 - 6	-0.36	0.59	18	0.0	-0.56	1.16	40	0.0	-0.61	0.95	73	0.1
	(0.14)	(0.14)			(0.07)	(0.44)			(0.13)	(0.07)		
1 - 7	-0.45	0.73	18	0.3	-0.56	1.02	37	0.0	-0.64	0.97	71	1.1
	(0.17)	(0.18)			(0.07)	(0.52)			(0.16)	(0.08)		
1 - 8	-0.48	0.75	17	1.9	-0.54	1.01	33	0.0	-0.76	1.01	70	14.0
	(0.19)	(0.20)			(0.07)	(0.60)			(0.19)	(0.09)		
1 - 9	-0.57	0.84	20	6.7	-0.53	0.98	31	0.0	-0.78	1.02	70	23.3
	(0.19)	(0.19)			(0.07)	(0.67)			(0.21)	(0.10)		
1 - 10	-0.65	0.91	23	14.7	-0.52	0.92	29	0.0	-0.79	1.03	70	31.1
7	(0.19)	(0.19)			(0.07)	(0.74)			(0.23)	(0.10)		
1 - 11	-0.56	0.84	20	17.7	-0.51	0.84	28	0.0	-0.85	1.06	70	34.7
	(0.25)	(0.22)			(0.07)	(0.80)			(0.26)	(0.11)		
1 - 12	-0.59	0.85	20	23.6	-0.48	0.73	25	0.0	-0.88	1.07	70	31.4
	(0.26)	(0.22)			(0.07)	(0.84)			(0.27)	(0.12)		
3 - 6	-0.27	0.52	13	0.0	-0.65	1.04	77	0.0	-0.35	0.81	68	0.0
	(0.12)	(0.11)			(0.15)	(0.14)			(0.15)	(0.08)		
3 - 9	-0.40	0.67	13	0.5	-0.87	0.57	60	0.0	-0.60	0.96	67	2.2
	(0.20)	(0.21)			(0.17)	(0.29)			(0.21)	(0.10)		
3 - 12	-0.62	0.88	19	14.1	-0.90	0.26	52	0.0	-0.76	1.02	67	27.0
	(0.20)	(0.20)			(0.14)	(0.38)			(0.27)	(0.12)		
6 - 12	-0.31	0.53	7	0.6	-0.68	1.05	77	6.8	-0.43	0.83	62	3.7
	(0.22)	(0.22)			(0.19)	(0.19)			(0.26)	(0.13)		

Note: Same as Table 4 except that the March 1983 observation was not removed.

Are the ETTS hypotheses validated more frequently when both the usual and ECM specifications are used? Table 7 recapitulates the number of times the ETTS hypotheses are validated at the 10% significance level from the results presented in Tables 1–6. The results of the test on variations in the long-term rate shows no gains on this point, even though the signs of the parameters obtained for the ECMs are correct. On the other hand, the advantage is large for the other two tests, particularly for variations in the short-term rate. For the latter test, the ETTS hypotheses are validated 14 times with the ECM for the French data and only 7 times with the usual specification. The respective results are 6 and 1 times for the German data and 12 and 0 times for the American data.

Table 6
Estimates of the error-correction Models - United States

This table shows the estimation results of the specifications given in Table 4.

m - n	**Forward rate (i)**				**Variation in long rate (ii)**				**Variation in short rate (iii)**			
	a_1	b_1	$\overline{R}^2$	p-value	a_2	b_2	$\overline{R}^2$	p-value	a_3	b_3	$\overline{R}^2$	p-value
1 - 2	-0.55	0.93	15	0.0	-0.36	1.33	84	0.0	-0.33	0.82	74	0.0
	(0.18)	(0.22)			(0.19)	(0.20)			(0.19)	(0.11)		
1 - 3	-0.25	0.33	1	0.0	-0.59	1.25	72	0.1	-0.96	1.05	66	23.6
	(0.17)	(0.15)			(0.15)	(0.30)			(0.23)	(0.12)		
1 - 4	-0.03	-0.06	0	0.0	-0.63	1.30	68	0.0	-0.81	0.97	60	28.1
	(0.21)	(0.22)			(0.14)	(0.40)			(0.18)	(0.12)		
1 - 5	-0.13	-0.02	2	0.0	-0.51	1.59	59	0.0	-0.86	0.93	51	71.9
	(0.20)	(0.22)			(0.15)	(0.52)			(0.17)	(0.11)		
1 - 6	-0.20	-0.07	6	0.0	-0.63	1.10	53	0.0	-0.66	0.85	52	9.0
	(0.19)	(0.24)			(0.15)	(0.70)			(0.16)	(0.09)		
1 - 7	-0.39	0.19	5	8.1	-0.67	0.98	51	0.0	-0.68	0.80	42	17.3
	(0.29)	(0.37)			(0.14)	(0.82)			(0.17)	(0.12)		
1 - 8	-0.36	0.19	5	3.5	-0.66	1.02	49	0.0	-0.71	0.83	43	19.7
	(0.25)	(0.35)			(0.14)	(0.89)			(0.16)	(0.12)		
1 - 9	-0.41	0.38	3	0.7	-0.65	1.05	48	0.0	-0.73	0.86	43	22.7
	(0.19)	(0.26)			(0.13)	(0.95)			(0.17)	(0.13)		
1 - 10	-0.38	0.47	4	0.3	-0.65	1.07	46	0.0	-0.80	0.93	46	44.6
	(0.18)	(0.22)			(0.13)	(0.99)			(0.19)	(0.14)		
1 - 11	-0.38	0.49	4	0.4	-0.64	1.08	45	0.0	-0.86	0.99	49	53.7
	(0.19)	(0.25)			(0.12)	(1.03)			(0.22)	(0.15)		
1 - 12	-0.36	0.43	2	1.4	-0.64	1.07	43	0.0	-0.90	1.04	50	50.4
	(0.22)	(0.29)			(0.12)	(1.06)			(0.26)	(0.16)		
3 - 6	-0.06	-0.06	1	0.0	-0.18	1.74	83	0.0	0.15	0.45	59	0.0
	(0.20)	(0.19)			(0.20)	(0.21)			(0.20)	(0.12)		
3 - 9	-0.30	0.14	3	12.4	-0.45	1.86	71	15.5	-0.65	0.83	46	24.5
	(0.35)	(0.44)			(0.29)	(0.54)			(0.21)	(0.12)		
3 - 12	-0.24	0.29	1	0.0	-0.52	1.98	65	7.5	-0.73	0.93	47	18.0
	(0.19)	(0.24)			(0.22)	(0.64)			(0.24)	(0.16)		
6 - 12	-0.02	-0.09	0	1.7	-0.50	1.39	81	22.6	-0.13	0.55	47	11.4
	(0.35)	(0.44)			(0.29)	(0.28)			(0.42)	(0.23)		

Note: Same as Table 4 except that the March 1983 observation was not removed.

Qualitatively, the results obtained for the usual specifications with maturity pairs of (1, 2) to (1,12) months show a clear contrast between the tests based on the forward rate and the variation in the short-term rate and the test based on the variation in the long-term rate. In the first instance, the coefficients obtained are comparable overall from one test to the next in terms of level and change. However, the coefficients for the variation in the long-term rate tend to diminish as the maturities of the rates increase. This movement is particularly visible in the American data and is partly due to differences in the nature of the tests. The tests on the forward rate and the variation in the short-term rate try to see if the markets are able to anticipate a short-term rate for investment horizons that are further and further into the future, while the test on the variation in the long-term rate assumes a fixed forecasting horizon of one month (for maturity pairs of (1,2) to (1,12)) but for an increasingly long investment horizon. The configuration that emerges from the results can be summed up as follows: for the three countries, the markets seem to have fairly satisfactory foresight of changes in short-term rates, but they are poor predictors of long-term rate movements.

Table 7
Number of times the ETTS hypotheses hold true
At the 10% significance level

Country	Specification	Forward rate	Long rate	Short rate	Total
France................................	usual ECM	6 8	5 4	7 14	18 26
Germany............................	usual ECM	1 5	1 0	1 6	3 11
United States	usual ECM	0 1	0 2	0 12	0 15

Note: See also Tables 1–6.

The configuration of the ECM results does not establish a distinction that is as clear as the one emerging from the usual specifications. The two representations of forward rates give estimated parameters that are comparable in absolute value. In the test of the variation in the long-term rate, the estimates of the two coefficients from the ECM seem to be relatively homogeneous for the German and American data and qualitatively close to the theoretical values, unlike the estimates from the usual specification. However, the gain from the ECM specification is marginal for the French data. In the test of the variation in the short-term rate, the ECM parameters are fairly stable and closer to the theoretical values than in the usual specifications. All in all, the use of ECMs to test the ETTS hypotheses on maturity pairs (1,2) to (1,12) months makes it possible to argue that German and American operators on the euro-rates market seem to have fairly satisfactory foresight for both short-term and long-term rates, whereas, on the French market, only the short-term rates are correctly foreseen.

Conclusion

This paper presents three tests of the hypotheses of the expectations theory of the term structure of interest rates based on the usual specifications found in the literature, on the one hand, and in form of error-correction models on the other hand. The estimates based on the euro-franc, euro-Deutschemark and euro-dollar rates for the period 1975-95 produce some results.

The monetary turmoil that occurred during the estimate period has a very large impact on the estimates for the French rates. This dependence is less noticeable for American rates and negligible in the case of German rates. As a rule, the test based on the average variation in the short-term rate lead to the acceptance of the hypotheses of the expectations theory in nearly every case with an error-correction model, and more rarely with the usual specifications. The advantage of error-correction models seems less apparent in the test based on the forward rate and negligible in the test based on the long-term rate.

This illustrates the contrasts usually seen in the literature between the test based on the variation in the long-term rate and those based on the variation in the short-term rate. However, this difference is less marked in the case of error-correction models as long as the estimated coefficients have the right sign for both tests. This contrast is still surprising nonetheless. The forecast horizon for the test of the variation in the long-term rate (which is equivalent to a test of the holding yield) is in fact fairly short, compared to the forecast horizon of the test based on the variation in the short-term rate (which is equivalent to a test of the rollover yield). In the first instance, the horizon is 1, 3 and 6 months, as opposed to 1 to 12 months in the second test. The argument that can be put forward to explain this difference is based on the fact that the forecasting errors are smoothed out for the rollover yield and therefore tend to cancel each other out.

Finally, the comparison of the results obtained for each country with the tests based on error-correction models gives rise to a typology that is somewhat different from that derived from the usual specifications. While the expectations theory often holds for the French data in both cases, the results obtained from American rates in relation to those from Germany rates are more favourable with error-correction models than with the usual specifications.

Appendix 1: Impact of outliers based on estimates of usual specifications

Table A1-1
French rates

This table shows the estimation results of the specifications:

$$\left[r(t+m,t+n)-r(t,t+n)\right]=\beta_1\frac{m}{n-m}\left[r(t,t+n)-r(t,t+m)\right]+constant \qquad \text{(i)}$$

$$\frac{m}{n}\sum_{i=0}^{\frac{n}{m}-1}\left(1-i\frac{m}{n}\right)\left[r(t+im,t+im+m)-r(t+im-m,t+im)\right]=\beta_2\left[r(t,t+n)-r(t,t+m)\right]+constant \qquad \text{(ii)}$$

for which the samples are defined as follows:

1. All observations between January 1975 and October 1995;
2. All observations except those from March 1983;
3. All observations except those from March 1983 and the observations selected from the test of *DFBETAS*.

m - n	**Sample**	**Variation in long rate (i)**				**Variation in short rate (ii)**			
		β_1	$\sigma_{\beta 1}$	$\overline{R}^2$	p-value	β_2	$\sigma_{\beta 2}$	$\overline{R}^2$	p-value
1 - 3	1	1.23	0.21	21	27.3	1.10	0.08	59	23.5
	2	0.25	0.45	-0	9.4	0.73	0.22	15	21.9
	3	-0.23	0.36	-0	0.1	0.51	0.18	9	0.7
1 - 6	1	0.93	0.40	9	86.2	1.03	0.08	58	54.9
	2	-0.01	0.49	-0	2.2	0.84	0.19	26	42.4
	3	-0.19	0.44	-0	0.8	0.83	0.18	28	37.1
1 - 12	1	0.53	0.42	2	25.4	0.93	0.08	60	39.3
	2	-0.12	0.55	-0	4.3	0.68	0.19	25	9.2
	3	-0.41	0.48	0	0.4	0.68	0.19	26	9.4
3 - 6	1	0.94	0.37	7	65.5	0.97	0.19	26	88.8
	2	0.89	0.47	5	65.5	0.95	0.23	21	82.3
	3	1.18	0.44	9	65.5	0.32	0.09	9	0.0
3 - 12	1	0.56	0.38	2	24.7	0.89	0.13	36	42.0
	2	0.60	0.47	2	39.0	0.86	0.16	30	37.4
	3	0.81	0.39	4	65.5	0.45	0.11	16	0.0
6 - 12	1	0.81	0.38	5	61.7	0.90	0.19	22	61.7
	2	0.82	0.41	5	66.3	0.91	0.21	20	66.3
	3	0.89	0.40	6	75.2	0.23	0.08	9	0.0

Notes: The outliers are selected on the basis of the correction term of ECMs (16) – (17). The estimates relate to the period 1975-95. The observations from March 1983 have been systematically removed. The usual relationships between the β_i for $n = 2m$ are not necessarily seen, because the observations removed as outliers are selected on the basis of the associated error-correction models and may be different from one test to the next. The estimate of the constant is not shown in the table. Standard deviations, shown in parentheses, are corrected for heteroscedasticity (White [1980]) and for overlapping (see Box 2). The variance-covariance matrix is estimated as suggested by Newey and West [1987]. $\overline{R}^2$ is the R^2, in %, corrected for the number of degrees of freedom and p-value is the significance level for the test of the hypothesis $\beta_i = 1$.

Table A1-2
German rates

This table shows the estimation results of the specifications given in Table A1-1, using the samples:

1. All observations between January 1975 and October 1995;
2. All observations except those selected from the test of *DFBETAS*.

m - n	Sample	Variation in long rate (i)				Variation in short rate (ii)			
		β_1	$\sigma_{\beta 1}$	$\overline{R}^2$	p-value	β_2	$\sigma_{\beta 2}$	$\overline{R}^2$	p-value
1 - 3	1	0.34	0.26	0	1.2	0.70	0.11	16	0.6
	2	0.46	0.22	1	1.4	0.80	0.09	24	2.7
1 - 6	1	-0.23	0.27	-0	0.0	0.55	0.14	11	0.1
	2	-0.02	0.26	-0	0.0	0.57	0.13	13	0.1
1 - 12	1	-0.47	0.30	0	0.0	0.53	0.22	10	3.2
	2	-0.29	0.30	-0	0.0	0.53	0.22	10	3.2
3 - 6	1	-0.28	0.29	0	0.0	0.36	0.14	4	0.0
	2	-0.17	0.26	-0	0.0	0.25	0.07	5	0.0
3 - 12	1	-0.62	0.38	1	0.0	0.41	0.23	5	1.2
	2	-0.48	0.37	1	0.0	0.35	0.18	6	0.0
6 - 12	1	-0.40	0.47	1	0.3	0.30	0.24	2	0.3
	2	-0.35	0.44	0	0.2	0.14	0.12	2	0.0

Note: Same as Table A1-1 except that the March 1983 observation was not removed.

Table A1-3
American rates

This table shows the estimation results of the specifications given in Table A1-1, using the samples:

1. All observations between January 1975 and October 1995;
2. All observations except those selected from the test of *DFBETAS*.

m - n	Sample	Variation in long rate (i)				Variation in short rate (ii)			
		β_1	$\sigma_{\beta 1}$	$\overline{R}^2$	p-value	β_2	$\sigma_{\beta 2}$	$\overline{R}^2$	p-value
1 - 3	1	-0.46	0.43	0	0.1	0.37	0.25	2	1.3
	2	-0.36	0.39	0	0.1	0.32	0.23	2	0.3
1 - 6	1	-0.59	0.59	0	0.1	0.46	0.19	4	0.5
	2	-1.07	0.47	3	0.0	0.40	0.17	5	0.1
1 - 12	1	-0.71	0.93	0	6.4	0.45	0.18	6	0.3
	2	-1.64	0.59	4	0.0	0.46	0.18	7	0.3
3 - 6	1	-0.18	0.56	-0	3.5	0.41	0.28	2	3.5
	2	-0.35	0.52	0	0.9	0.12	0.14	1	0.0
3 - 12	1	-0.56	0.93	0	9.4	0.33	0.20	2	0.1
	2	-1.21	0.74	4	0.3	0.24	0.15	2	0.0
6 - 12	1	-0.46	0.70	1	3.6	0.27	0.35	1	3.6
	2	-0.47	0.70	1	3.6	0.05	0.13	-0	0.0

Note: Same as Table A1-1 except that the March 1983 observation was not removed.

Appendix 2: Stationarity tests

The estimates relate to end-of-month data from the period 1975-95. The number of lags was chosen to whiten the residuals for the ADF tests (at the 10% level for the Box-Pierce statistic. The critical values for the DF and ADF tests are 2.57 for a 10% level, 2.88 for a 5% level and 3.46 for a 1% level. The observations of French rates from March 1983 have been removed.

Table A2-1
French rates

Maturity	**Zero-coupon rate**				**Differential from 1-month rate**	
	Level		**Variation**			
	DF	ADF	DF	ADF	DF	ADF
1	-3.52	-1.83	-16.82	-6.14	—	—
2	-2.86	-1.01	-15.36	-6.08	-10.02	-3.67
3	-2.26	-0.69	-13.98	-6.13	-10.02	-3.67
4	-2.03	-0.57	-13.67	-6.20	-9.31	-3.90
5	-1.81	-0.46	-13.34	-6.29	-8.79	-4.04
6	-1.61	-0.37	-13.03	-6.37	-8.41	-4.13
7	-1.56	-0.37	-13.09	-6.35	-8.12	-4.09
8	-1.50	-0.37	-13.16	-6.33	-7.86	-4.04
9	-1.46	-0.39	-13.23	-6.29	-7.62	-3.98
10	-1.41	-0.42	-13.31	-6.24	-7.40	-4.03
11	-1.38	-0.47	-13.41	-6.18	-7.21	-4.01
12	-1.36	-0.53	-13.50	-6.10	-7.03	-4.00

m - n	**Forward premium**		**Holding premium**		**Rollover premium**	
	DF	ADF	DF	ADF	DF	ADF
1 - 2	-13.91	-5.39	-13.91	-5.39	-13.91	-5.39
1 - 3	-9.16	-5.14	-12.58	-5.45	-9.01	5.19
1 - 4	-6.86	-5.18	-12.45	-5.67	-6.97	-4.70
1 - 5	-6.43	-5.18	-12.08	-5.73	-5.93	-5.00
1 - 6	-5.87	-5.31	-11.70	-5.78	-5.26	-4.82
1 - 7	-5.50	-4.25	-11.91	-6.06	-4.73	-5.73
1 - 8	-5.71	-5.03	-11.95	-6.07	-4.39	-3.78
1 - 9	-5.57	-3.70	-11.97	-6.06	-4.06	-5.28
1 - 10	-5.37	-4.47	-12.00	-6.04	-3.85	-4.59
1 - 11	-5.24	-3.50	-12.02	-6.00	-3.79	-4.99
1 - 12	-4.55	-4.71	-12.04	-5.95	-3.47	-5.60
3 - 6	-6.23	-5.96	-6.23	-5.96	-6.23	-5.96
3 - 9	-4.87	-4.01	-6.02	-6.28	-4.76	-3.88
3 - 12	-4.71	-4.62	-5.77	-5.11	-4.06	-3.69
6 - 12	-4.46	-3.15	-4.46	-3.15	-4.46	-3.15

Table A2-2
German rates

Maturity	Zero-coupon rate				Differential from 1-month rate	
	Level		Variation			
	DF	ADF	DF	ADF	DF	ADF
1	-1.83	-2.87	-14.74	-3.56	—	—
2	-1.58	-2.82	-13.74	-3.52	-9.78	-2.78
3	-1.42	-2.84	-12.93	-7.58	-9.78	-2.78
4	-1.37	-2.11	-12.69	-7.51	-8.44	2.33
5	-1.33	-2.09	-12.50	-7.52	-7.57	-2.80
6	-1.32	-2.07	-12.38	-7.62	-7.02	-2.80
7	-1.30	-2.07	-12.22	-7.60	-6.64	-2.78
8	-1.28	-2.89	-12.07	-7.59	-6.31	-2.74
9	-1.27	-2.88	-11.93	-7.59	-6.03	-2.70
10	-1.26	-2.87	-11.79	-7.60	-5.78	-2.66
11	-1.25	-2.86	-11.66	-3.96	-5.57	-2.62
12	-1.25	-2.85	-11.54	-3.99	-5.39	-2.59

m - n	Forward premium		Holding premium		Rollover premium	
	DF	ADF	DF	ADF	DF	ADF
1 - 2	-13.29	-3.96	-13.29	-3.96	-13.29	-3.96
1 - 3	-8.85	-4.18	-12.59	-8.30	-9.20	-6.64
1 - 4	-5.93	-3.38	-12.20	-10.58	-6.80	-8.41
1 - 5	-4.87	-3.53	-11.98	-7.46	-5.39	-6.56
1 - 6	-4.73	-3.44	-11.84	-7.49	-4.77	-3.33
1 - 7	-5.70	-3.05	-11.90	-7.57	-4.57	-3.33
1 - 8	-4.22	-3.06	-11.73	-7.51	-4.31	-4.60
1 - 9	-3.68	-3.02	-11.57	-7.48	-4.10	-3.32
1 - 10	-3.53	-3.00	-11.43	-7.46	-3.91	-3.74
1 - 11	-2.58	-3.15	-11.29	-7.46	-3.61	-3.60
1 - 12	-2.55	-3.18	-11.17	-7.48	-3.39	-3.20
3 - 6	-5.47	-3.23	-5.47	-3.23	-5.47	-3.23
3 - 9	-4.46	-3.17	-5.45	-3.35	-4.39	-3.05
3 - 12	-3.23	-2.70	-5.40	-3.87	-3.73	-2.91
6 - 12	-4.03	-2.98	-4.03	-2.98	-4.03	-2.98

Table A2-3

American rates

Maturity	**Zero-coupon rate**				**Differential from 1-month rate**	
	Level		**Variation**			
	DF	ADF	DF	ADF	DF	ADF
1	-1.94	-2.51	-11.74	-2.82	—	—
2	-1.87	-2.47	-11.44	-2.82	-7.91	-3.11
3	-1.84	-2.40	-11.40	-2.86	-7.91	-3.11
4	-1.81	-2.34	-11.44	-2.90	-6.90	-3.00
5	-1.78	-2.27	-11.52	-2.94	-6.30	-3.73
6	-1.76	-2.20	-11.61	-3.01	-5.92	-3.73
7	-1.74	-2.18	-11.55	-3.02	-5.72	-3.86
8	-1.71	-2.16	-11.49	-3.06	-5.52	-3.73
9	-1.69	-2.14	-11.43	-3.07	-5.34	-3.52
10	-1.66	-2.11	-11.37	-3.10	-5.18	-3.45
11	-1.64	-1.82	-11.31	-3.13	-5.03	-2.87
12	-1.63	-1.57	-11.26	-3.17	-4.90	-2.82

m - n	**Forward premium**		**Holding premium**		**Rollover premium**	
	DF	ADF	DF	ADF	DF	ADF
1 - 2	-10.75	-3.82	-10.75	-3.82	-10.75	-3.82
1 - 3	-8.02	-3.89	-13.69	-3.49	-8.20	-3.52
1 - 4	-6.04	-3.41	-10.82	-3.21	-6.78	-3.65
1 - 5	-5.30	-3.53	-10.86	-3.19	-5.90	-3.59
1 - 6	-4.55	-3.47	-10.92	-3.20	-5.21	-3.65
1 - 7	-4.32	-3.54	-11.15	-2.96	-4.83	-3.63
1 - 8	-4.19	-3.47	-11.08	-2.92	-4.56	-3.59
1 - 9	-3.51	-3.30	-11.00	-2.89	-4.19	-3.55
1 - 10	-2.98	-3.44	-10.92	-2.88	-3.79	-3.52
1 - 11	-3.03	-2.48	-10.85	-2.88	-3.55	-3.50
1 - 12	-3.00	-2.93	-10.78	-2.88	-3.39	-3.48
3 - 6	-5.95	-3.55	-5.95	-3.55	-5.95	-3.55
3 - 9	-4.10	-2.96	-5.99	-3.09	-4.43	-3.35
3 - 12	-2.94	-3.13	-5.95	-3.04	-3.32	-3.00
6 - 12	-3.91	-2.92	-3.91	-2.92	-3.91	-2.92

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Comments on paper by E. Jondeau and R. Ricart by Stefan Gerlach (BIS)

This paper contains a very thorough test of the expectations hypothesis of the term structure of interest rates using short term Euro-market interest rates for the period 1975-95. There are several aspects of the paper which I like.

First, the use of data for several countries – France, Germany and the United States – is particularly interesting since, as noted in the paper, tests of the expectations hypothesis tend to fare better on non-US than on US data. In light of this and the fact that an overwhelming proportion of research on the term structure has focused on US data, more comparative work is warranted. Indeed, the authors find that the results for France, and to a lesser extent Germany, are less at odds with the expectations hypothesis than the results for the US.

Second, the entire short end of the yield curve (that is, maturities between one and twelve months) is considered. Since the short end is probably the most interesting part of the yield curve for monetary policy purposes, it is nice to see a full spectrum of short rates used. While there doesn't seem to be any major differences across maturities, the results appear somewhat more supportive of the expectations hypothesis when the short interest rate is the one month rate, and the long rate is the twelve months rate. One minor problem, however, is that since the authors only have access to interest rates with 1, 3, 6 and 12 months maturities, they are forced to interpolate the yields for the missing maturities. This induces measurement errors on the constructed yields. While these errors are probably not important, it would be of interest to know a bit more about how large the interpolations errors are likely to be.

Third, three implications of the expectations hypothesis are tested: loosely speaking, whether (i) the spread between forward and spot interest rates predicts changes in short rates, (ii) whether the spread between long and short rates predicts changes in long rates, and (iii) whether the spread between long and short rates predicts changes in short rates. One interesting finding is that the expectations hypothesis fares best when the third implication is tested.

Fourth, the authors use two econometric approaches. They first estimate a set of "standard" equations, which relate the dependent variable to the spread between a long and a short interest rate (or between a forward and a spot interest rate). Next they go on to estimate error-correction models. An interesting point is that while the "standard" and error-correction equations are consistent when the expectations hypothesis hold, they allow for different alternatives hypotheses. One striking finding is that the authors reject the expectations hypothesis much more frequently when the "standard" equations are estimated.

Fifth and finally, the authors demonstrate that the results are sensitive to the inclusion of a few data points, that is, there is considerable sub-sample instability in the estimates. Since there is little work on the temporal stability of term structure relationships, this finding suggests that more work on the causes of this instability is warranted. Furthermore, it suggests that the information content of the yield spreads for future short-term interest rates varies over time.