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Three Essays on the Term Structure of Eurocurrency Rates.

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THREE ESSAYS ON THE TERM STRUCTURE OF EUROCURRENCY RATES

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ABSTRACT

This dissertation investigates the term structure relationship in financial markets by using Eurocurrency rates of several countries. The first essay tests the restrictions of the expectations hypothesis of term structure and the Fisher hypothesis in an interrelated fashion to characterize the changes in the slope and the level of Eurocurrency yield curves of numerous countries. It is argued that the Fisher relation explains the level of the yield curve and the expectations hypothesis determines the long run relationship between yields at different maturities at that level. Special emphasis is given to the information content of the yield curve for future inflation. A factor decomposition technique is used to extract the common trend driving the yield curve and it is found that this common trend contains information about the long-run behavior of the inflation rate for each country in the sample. This finding is consistent with the argument that rational agents in the market incorporate the predictable portion of the expected inflation into interest rates while setting prices. The second essay focuses on convergence of international money market term structures. According to the covered interest parity theorem, nominal yield curves should converge in the long run. The common factor driving each term structure is extracted to test for long run linkages and transitory components are used to test for short run linkages. The findings indicate that an international convergence has not occurred although the term structures of countries that are a member of the exchange rate mechanism of the European Union have a

stable long run relationship. This finding is explained as a result of the adjustable fixed exchange rate system employed. The essay also tests for and rejects the German European Union dominance hypothesis. The third essay tests for the restrictions of the rational expectations/constant term premium hypothesis of term structure. It is discussed that the commonly used single-equation regression test of the hypothesis is biased in small samples. The short rate is decomposed into its permanent and transitory components to test the theory in an unbiased regression. The results support the rational expectations theory.

CHAPTER 1

INTRODUCTION

The relationship between yields of bonds of different maturities has been widely discussed in economics and finance. Researchers place a great deal of importance on the term structure relationship since it is directly related to issues such as market efficiency, conduct of monetary policy and transmission of information in financial markets. This dissertation consists of three interrelated essays that investigate the term structure relationship in financial markets by using the Eurocurrency money market rates of eleven countries. The first essay is an explanation of the empirical observation that yields of different maturity bonds and the inflation rate appear to move together over time. The expectations hypothesis and the Fisher hypothesis are used as working hypotheses to explain this observed phenomenon. It is stated that the expectations hypothesis and the Fisher hypothesis are intimately related in a discussion of the term structure relationship since the Fisher hypothesis explains the level of nominal rates as determined by the expected inflation rate and the expectations theory explains the relationship between interest rates of different maturity at a given level of the nominal interest rate.

The expectations hypothesis of term structure (EHT, henceforth) is simple and intuitive. It states that the term structure reflects current expectations about future one period interest rate. In other words, the interest rate on a long term bond is a weighted

average of one-period interest rates over the life of the bond. With rational expectations, this definition of the EHT asserts that the term structure reflects current expectations about future interest rates. Thus, the changing slope of the term structure can be interpreted in terms of changing expectations for future interest rates. According to the expectations hypothesis, any factor other than expectations about short-term interest rates should be irrelevant because investors will substitute bonds of different maturities until an equilibrium that reflects only expectations is reached. Hence, for instance, if the term structure of interest rates is upward-sloping, the expectations hypothesis suggests that short-term interest rates are expected to rise in the future.

The well-known Fisher hypothesis, introduced by Fisher (1930), maintains that the nominal interest rate is the sum of the constant real rate and a weighted average of expected one-period inflation rates over the life of the nominal interest rate. The Fisher hypothesis simply states that a one point increase in expected inflation leads to a one point increase in the nominal interest rate leaving real interest rates unchanged. Accordingly, this hypothesis implies that nominal interest rates adjust one-for-one with expected inflation and the expected inflation rate is the sole determinant of the level of interest rates.

Since the objective of this essay is to examine the long run relationship between yields at different maturities and the inflation rate, the cointegration properties of the expectations hypothesis and the Fisher hypothesis are examined. The cointegration restrictions of the expectations hypothesis state that there should be one

common stochastic trend driving the term structure and also, that the spreads should cointegrate the yields, which in turn imposes a zero sum restriction on the cointegration vectors. These restrictions are tested by the full information maximum likelihood method of Johansen (1991). The results are mainly supportive for the expectations hypothesis and it is found that there is one common trend in the term structure for each country. The study proceeds to identify this common trend by the statistical decomposition method developed by Gonzalo and Granger (1995).

According to the Fisher hypothesis, the inflation rate is a candidate for this common factor. To test the expectations theory and the Fisher hypothesis in an interrelated manner a common factor model is proposed and the common factor from the term structure is associated with the inflation rate. If the Fisher hypothesis is correct then the two variables should be cointegrated. It is found that this restriction is valid for every country. Also tested is the long-run causality relationship between the common factor from the term structure and the inflation rate. If rational agents in credit markets correctly anticipate the predictable portion of future inflation and incorporate this portion into current yields then the common factor will be weakly exogenous in the system. It is found that, for every country, the common factor from the term structure contains information about the future path of the inflation rate.

The second essay tests for intercurrency term structure relationships and investigates long and short run linkages between money market term structures of the U.S., the U.K. , Germany and France by using 1- and 12-month Eurorates. According to the covered interest parity theorem, the term structures should converge in the long

run. To test this hypothesis, common factors in term structures are extracted by using the method of Gonzalo and Granger (1995) and the issue of long run convergence is tested by cointegration analysis. It is found that the money market term structures of these four countries do not converge. This is attributed to the flexible exchange rate regime employed by these countries. Under a flexible exchange rate regime, transmission of economic shocks may be absorbed by changes in exchange rates, leaving nominal rates untouched.

To further analyze this issue, the convergence of German and French term structures, which employ an adjustable fixed exchange rate regime, is investigated. It is found that the term structures of these countries are cointegrated, which is consistent with the notion that a fixed exchange rate regime facilitates long run convergence of nominal interest rates. However, no evidence of German dominance over France is detected. Short run linkages are also examined by using the transitory components from term structures in a multivariate vector autoregression model. It is found that a significant causality runs from Germany to France and from the U.K. to the U.S. in the short run.

The third essay imposes rational expectations and constant term premium assumptions on the expectations theory of term structure and tests the restrictions of this model. Under rational expectations, the expectations hypothesis implies exact restrictions. Specifically, it is implied that if the expectations theory holds then the yield spread should have predictive power about the future movements of the short rate over the life of the long term rate. This restriction can be tested by examining the

estimates in a single regression. It is stated in the analysis that the expectations hypothesis implies a certain restriction on the slope coefficient in this case.

Single-equation regression tests of the expectations hypothesis have been conducted many times in the past. This study reexamines the same hypothesis by utilizing two motivations. The first motivation is from econometrics theory. Bekeart, Hodrick and Marshall (1997) have shown that there are severe small-sample biases in the single-equation regression tests as has been applied in the extant literature. The reason of the bias is the extreme persistence in the short rate which translates into a large bias in OLS estimates. This study calculates the analytical estimates to small-sample biases by using the derivations from Bekeart, Hodrick and Marshall (1997) and shows that previous regressions applied to Eurocurrency rates were biased. To correct for the bias, this study estimates the cointegration structure between the interest rates and performs the Gonzalo-Granger decomposition to extract the transitory components of the short rate. The theory is tested by using only transitory components, which should eliminate the bias since transitory component does not have extreme persistence by definition. Indeed, it is found that the bias disappears in analytical estimates. It is also argued that this approach is economically meaningful since the spread should be able to predict only the transitory components of the short rate. The permanent component of the short rate is stochastic, and by definition unpredictable. Thus, the spread is expected to have predictive power about the future movements of only the transitory component of the short rate.

The results of the bias-free regressions lend support to the rational expectations/constant term premium theory. In all of the cases, the spread predicts the future movement of the transitory component of the short rate in the correct direction and is significantly different from zero. For some countries, however, the exact restriction of the theory is rejected.

CHAPTER 2

INFORMATION IN THE TERM STRUCTURE OF EURORATES ABOUT FUTURE INFLATION: A LONG TERM ANALYSIS

2.1 Introduction

The term structure of interest rates at any time is the function relating interest rates to time to maturity. The study of the term structure investigates which market forces are responsible for the varying shapes of the term structure. The term structure has been one of the most widely discussed topics in economics and finance and several theories on how investors interact to determine its shape and level have been suggested in the literature. This essay attempts to further investigate two of the earliest and most prominent hypotheses of the term structure of interest rates, namely the expectations hypothesis of the term structure (EHT) and the Fisher hypothesis. It should be stated at the outset that the EHT and the Fisher hypothesis are intimately related in understanding the term structure relationship since the Fisher hypothesis claims to explain the level of nominal interest rates as determined by the expected inflation rate and the EHT claims to explain the relationship between interest rates of different maturity for a given level of the nominal interest rate. Therefore, for a full characterization of the yield curve, these two hypotheses should be evaluated interrelatedly.

The EHT, in its pure form, states that the interest rate on a long-term bond is a weighted average of one-period interest rates over the life of the bond. With

rational expectations, this definition of the EHT asserts that the term structure reflects current expectations about future interest rates. Thus, the changing slope of the term structure can be interpreted in terms of changing expectations for future interest rates. The key assumption of this theory is that buyers of bonds do not prefer bonds of one maturity over another. With this principle, the expectations theory elegantly explains why any other factor besides the expectations of future short-term interest rates should be irrelevant because investors will substitute between bonds of different maturities until an equilibrium that reflects only expectations is reached. Hence, for instance, if the term structure of interest rates is upward-sloping, the expectations hypothesis suggests that short-term interest rates are expected to rise in the future.

The well-known Fisher hypothesis, introduced by Fisher (1930), maintains that the nominal interest rate is the sum of the constant real rate and a weighted average of expected one-period inflation rates over the life of the nominal interest rate. The Fisher hypothesis simply states that a one point increase in expected inflation leads to a one point increase in the nominal interest rate leaving real interest rates unchanged.[1] Accordingly, this hypothesis implies that nominal interest rates adjust one-for-one with expected inflation and the expected inflation rate is the sole determinant of the level of interest rates.

Mishkin (1994) argues that any theory of the term structure should be able to explain the following empirical regularities. First, interest rates on bonds of different maturities move together over time. Second, when short-term interest rates are low,

yield curves are more likely to have an upward slope and when short-term interest rates are high, yield curves are more likely to slope downward. Finally, observed yield curves almost always slope upward.

The expectations theory, with rational expectations but without a term premium, successfully explains the first empirical regularity, which states that interest rates on bonds with different maturities move together over time. Since long-term rates are related to the average of expected future short-term rates, a rise in short-term rates will also raise long-term rates, causing short- and long-term rates to move together. The expectations hypothesis also explains the second empirical observation. When short-term rates are low, investors generally expect them to rise to some normal level in the future, and the average of future expected short-term rates is high relative to the current short-term rate. Therefore, long-term interest rates will be substantially above current short-term rates, and the yield curve will then have an upward slope.

The rational (unbiased) expectations hypothesis is simple and intuitive but it has one major drawback. Since observed yield curves almost always slope upward the rational expectations hypothesis implies that the short-term interest rates will be ever increasing. However, in practice, short-term interest rates are just as likely to fall as they are to rise. This fact indicates that other explanations of the term structure relationship should be developed or the rational expectations hypothesis should be modified.

The polar alternative to the unbiased expectations hypothesis is the segmented markets theory of Culbertson (1957). The segmentation theory states that the term structure is determined by the supply and demand for bonds at each maturity and that expectations of future interest rates are irrelevant. The key assumption of this theory is that bonds of different maturities are not substitutes at all and no arbitrage relation between bonds of different maturities is expected to take place. In the segmentation theory, differing yield curve patterns are accounted for by supply and demand differences associated with bonds of different maturities. Hence, the segmentation theory can explain the empirical fact that yield curves are typically upward sloping if, on average, investors prefer bonds with shorter maturities that have less interest rate risk. Because the demand for long-term bonds will be relatively lower than for short-term bonds, the long-term bonds will have lower prices and higher interest rates and hence, the yield curve will typically slope upward.

However, although the segmentation theory can explain why yield curves usually slope upward, it has difficulty explaining the other empirical regularities. Since there are no arbitrage arguments for bonds of different maturities, there is no reason for them to move together.[2] Also, since it is not clear how demand and supply for short- versus long-term bonds changes with the level of short-term interest rates, the theory cannot explain why yield curves slope upward when short-term interest rates are low and downward when short-term interest rates are high.

A compromise between the segmentation and unbiased expectations theories is known as the preferred habitat theory of the term structure, originally proposed by Modigliani and Sutch (1966). The preferred habitat theory states that the term structure is determined both by expectations and by risk/liquidity premiums. According to this theory, the interest rate on a long-term bond will equal an average of short-term interest rates expected to occur over the life of the long-term bond plus a risk premium that responds to supply and demand conditions for that bond. The preferred habitat theory's key assumption is that bonds of different maturities are substitutes, which means that the expected return on a bond of a given maturity influences the expected return on a bond of a different maturity, but it allows investors to prefer one bond maturity over another. Investors will hold bonds that do not have the preferred maturity only if they earn a somewhat higher expected return.

A closely related version of the preferred habitat theory is the liquidity premium theory originally proposed by Hicks (1946). The liquidity premium theory explicitly recognizes a compensation for risk related to bonds with different maturities. The interest rate differences between bonds with different maturities is a compensation for risk which equilibrates desired lending and borrowing at each maturity. The liquidity premium is the premium for risk due to changing interest rates over the life of the bond and a positive premium should be offered to buyers of long-term bonds to compensate them for their increased risk.

The liquidity premium theory is consistent with all three of the empirical facts mentioned above since it is a combination of the pure expectation hypothesis

and the market segmentation theory. Since the liquidity premium theory implies a term premium that rises with a bond's maturity because of investors' preferences for short-term bonds, even if short-term rates are expected to stay the same, long-term rates will be above short-term rates and yield curve will typically slope upward. Therefore, with an inclusion of a time-invariant term premium, the expectations theory is able to provide an explanation for the behavior of the term structure.

2.2 Prior Work

Since the goal of this essay is to characterize the changes in the slope and the level of the yield curve for Eurocurrency rates, it is worthwhile to discuss the importance of an understanding of the term structure relationships in economics and finance. It has long been recognized that interest rates contain useful information about the evolution of future economic variables. For example, Fama (1975) finds the short-term nominal rate to be a good predictor of future inflation. Campbell and Shiller (1991) and Engsted and Tanggaard (1994b) show that the slope of the yield curve has significant predictive power in forecasting future changes in short term interest rates. Estrella and Hardouvelis (1991) state that a positive slope of the yield curve signals future increases in real economic activity. Jorion and Mishkin (1991) investigate whether the slope of the term structure has any predictive power in forecasting future inflation and find that it does for longer horizons. In a recent contribution, Estrella and Mishkin (1996) state that monetary policy is an important determinant of the term structure spread for European countries and show that the term structure has significant independent information regarding future growth. They

also state that the term structure has a useful role as an indicator of the tightness of monetary policy for the European Central Bank.

Engsted and Tanggaard (1994a) state several reasons for the importance of the EHT for finance and economics. The first reason is that the relationships between yields associated with bonds of different maturities are stated in the form of arbitrage arguments in the formulation of the EHT; therefore, it is related to the notion of market efficiency. Also, the EHT is important for framing monetary policy. Different theories of the term structure have different implications for whether monetary policy can or cannot directly influence any particular interest rate and the EHT implies a unique relation between the rate on any long-term bond and the rate on any shorter-term bond. If the EHT holds, expected returns from holding a sequence of short bonds is the same as the return on holding a long bond and the Central Banks cannot affect the term structure (Harris (1981), ch.17).[3]

Since the EHT and the Fisher hypotheses are so important and their implications are rich, there have been many studies that test the restrictions of these hypotheses. With rational expectations, the EHT implies that the changing slope of the term structure can only be interpreted in terms of the changing expectations for future one-period rates and that all term premia do not depend on time. Similarly, under rational expectations, the Fisher hypothesis implies an "inflation-change equation" and states that the slope of the yield curve should predict the change in the future inflation rate. Another implication of the Fisher hypothesis, under rational expectations, is that the difference between nominal interest rates and the one-period

inflation rate should predict changes in future inflation rates. This implication stems from the fact that a multiperiod nominal rate is defined as the sum of constant real rate and an average of one period inflation rates over the life of the nominal bond.

To test the rational expectations versions of the EHT and the Fisher hypothesis, many researchers have investigated the predictive power of the slope of the yield curve, that is the spread between longer-term and shorter-term interest rates, for future interest rates, in the case of the EHT, and for future inflation rates, in the case of the Fisher hypothesis. These tests are usually based on single-equation restrictions or on a correlation analysis of the theoretical spread and the actual spread, as developed by Campbell and Shiller (1987, 1991).

For the EHT, evidence from these studies using U.S. bond data is generally mixed: some support the EHT but formal tests tend to reject the theory, particularly at the shorter end of term structure. Widely cited examples of this research genre include Shiller (1979), Campbell and Shiller (1987, 1991) and Shea (1992). Furthermore, a recent study by Bekeart, Hodrick and Marshall (1997) shows that there are serious biases in the single equation tests commonly applied in the literature. The results of their Monte Carlo simulations suggest that the rejections of the predictive power of the slope of the term structure should be more strongly pronounced in the U.S.

On the international side, rejection of the EHT is not as strongly supported. In fact, Hardouvelis (1994) studies the behavior of 3-month and 10-year rates in the G-7 countries and concludes that the theory does a much better job of accounting for

the behavior of interest rates outside the United States. Gerlach and Smets (1997) use a similar data set as the current paper and also argue that the term spread contains information about future short-term rates and that for many countries the rational expectations hypothesis is broadly compatible with the data. Engsted (1993) tests the EHT for the term structure of interest rates in Denmark using single equation tests as well as tests based on a cointegrated vector autoregression (VAR)-model and concludes that the theory explains the term structure quite well, especially at the long end of the spectrum. Hurn, Moody and Mustacelli (1995) test the same hypothesis in the London Interbank Market and they also conclude that the EHT provides a good description of the term structure of interest rates.

For the Fisher hypothesis, the prediction equations generally do not provide and adequate explanation at the short end of the yield curve, either using U.S. data or international data. For example, Mishkin (1990) investigates the predictive power of the term structure of nominal rates of Treasury bills for maturities of six months or less and finds that there is almost no information about the future path of the inflation. Mishkin (1991) reaches a similar conclusion for the short term structure of international countries. On the other hand, several studies indicate that longer maturity term structure, both U.S. and international, contain information about future inflation (see, for instance, Mishkin,1990). However, Tzavalis and Wickens (1996) cast doubt on this issue by showing that the forecasting ability of the term spread of the future inflation rate is poor, when the effects of changes in the U.S. monetary policy are taken into account. On the other hand, Engsted (1995)

investigates the predictive power of the spread between the nominal rate and one period inflation rate for future values of the inflation rate by using the cointegrated-VAR model of Campbell and Shiller (1987, 1991). He conducts a multicountry analysis and finds some support for this implication of the Fisher hypothesis in data.

It is important to stress that all of the above mentioned studies impose the rational expectations assumptions while testing for the EHT and the Fisher hypothesis. This assumption is necessary if the goal of the research is to examine the high frequency properties of the data; such as, discriminating between different expectation formation hypotheses, or to infer whether the variation in yield spreads are due mainly to changing expectations about future interest rates or to changes in the term premium, or to examine the predictive power of the spread for future inflation. This essay is, however, more concerned with an explanation of the empirical observation that yields of different maturity bonds and the inflation rate appear to move together over time. Hence, interest centers on the relationship between the *low-frequency* components of interest rates and the inflation rate. The important point is that in this case it is not necessary to impose the rational expectations assumption.

In the context of their present value models, Campbell and Shiller (1987) show that, under the EHT, a linear combination of short- and long-term interest rates is stationary in its levels, even though interest rates are individually stationary only in first differences. This suggests that yields are cointegrated in the context of Engle and Granger (1987). If some nonstationary variables are cointegrated then a

linear combination of them will be stationary, since low-frequency components offset each other, and they will not drift apart arbitrarily in the long-run. Thus, the cointegration theory allows formal tests of long-run comovements that arise naturally in many finance and economic models and has been used extensively in the recent literature. Hall, Anderson and Granger (1992) and Engsted and Tanggaard (1994) show that relationships between yields of different maturities can be modeled as a cointegrated system and derive the restrictions of the EHT within this context. These studies apply multivariate cointegration techniques to U.S. term structure data and find considerable support for the cointegration implications of the EHT. Other papers also test for cointegration in the term structure. Bradley and Lumpkin (1992) show that interest rates of Treasury securities are pairwise cointegrated and forecasting from vector error-correction models outperforms vector autoregression forecasts. Engsted and Tanggaard (1994b) test for the cointegration implications of the EHT in a multivariate framework for Danish term structure and find some support for the EHT. Bhar (1996) tests for and finds cointegration in interest rate futures trading on the Sydney futures exchange.

The first goal of this essay is to test the cointegration restrictions of the EHT for Eurocurrency rates. As will be explained in greater detail below, the cointegration restrictions of the EHT state that there should be one common stochastic trend driving the changes in the slope of the yield curve. If the data confirm this restriction (and they do) then the study will proceed to identify this common factor by using recently developed econometric techniques. According to

the Fisher hypothesis the expected rate of inflation is an obvious candidate for the common factor driving the term structure. Therefore, the second part of this essay tests for long-run relationships between the common factor driving the term structure and the inflation rate by utilizing, once again, the cointegration theory. The "long-run" Fisher hypothesis, as termed by Mishkin (1992), implies that in the long run the common factor and the inflation rate will be cointegrated with one-for-one adjustments even though there may not be a change in interest rates with an immediate change in the expected inflation rate in the short-run. Mishkin (1992) points out that the nonexistence of a short-run relationship does not rule out the possibility that there is a long-run Fisher effect in which inflation and interest rates share a common trend.[4] He finds support for a long-run Fisher effect in the postwar U.S. data. Mishkin (1992) also argues that Fisher (1930) originally considered the relationship between the nominal rate and inflation rate as a long run phenomena and thus, interprets the empirical evidence as consistent with Fisher's original arguments.

Several recent empirical studies also focus on the time series properties of the inflation rate and interest rates to test for the long-run Fisher relationship. Wallace and Warner (1993) apply cointegration tests and find support for both the Fisher hypothesis and the EHT. Evans and Lewis (1995) also observe cointegration between nominal interest rates and inflation and apply the DOLS estimator of Stock and Watson (1993) to estimate the long-run response of nominal interest rates with respect to inflation. They observe less-than-unity coefficients and ascribe it to

"changing dynamics of inflation" over the sample. However, in a recent article, Crowder and Hoffman (1996) apply a fully efficient estimator (Johansen, 1991a) and find estimates that are consistent with a long-run Fisher relation.

The empirical findings of Crowder and Hoffman (1996) merit closer attention. They find that the long run causal ordering between the nominal interest rate and the inflation rate is from the inflation rate to the interest rate. The interpretation of their findings is that the inflation rate is the driving source that results in cointegration implying that it contains useful information about the future path of the nominal rate, at least in the long-run. However, this is contrary to the theory raised by Fama (1975) who claims that nominal interest rates are the optimal predictors of future inflation.[5] Fama's argument rests upon the fact that if the inflation rate is to some extent predictable and if the expected real rate can be assumed constant then an efficient market will use all the relevant information about the expected inflation rate while setting the nominal interest rate. Consequently, a relationship between the nominal interest rate and the subsequently observed inflation rate is expected in a well-functioning, informationally efficient market.[6] Hence, according to this theory, the long run causal ordering of the variables should be from the nominal rate to the inflation rate. In other words, if the forecasts of agents in credit markets can capture the predictable portion of future inflation then this component will be incorporated into the nominal rate and hence, the nominal rate should be able to predict the future path of the inflation rate, at least in the long run. Thus, the findings of Crowder and Hoffman (1996) contradict the implications

of a well-functioning efficient market and should be reexamined. In fact, the findings of this study strongly suggest that nominal interest rates, to a large extent, reflect rationally expected inflation rates, which is consistent with Fama's view of the world. This point and the empirical findings are further examined in the following sections.

This essay contributes to the literature in several ways. Perhaps the most important contribution lies in the fact that this study recognizes that the EHT and the Fisher hypothesis work in an interrelated fashion to determine the level of nominal interest rates and the relationship between different maturity interest rates at that level. Hence, this essay investigates the long-run Fisher relation with respect to the common factor driving the term structure rather than a nominal rate, as has been applied in the earlier literature. In other words, the expected inflation rate is viewed as the source driving the *term structure* of interest rates and the common factor driving the term structure is extracted to test for long-run relationships with the inflation. Also, this approach provides a more efficient way to test for the long run Fisher relation since several studies indicate that more information is contained in the term structure than nominal rates. For example, Plosser and Rouwenhorst (1994) show that the information in the term structure is much richer than that contained in the level of the short-term interest rate.

The second contribution of the study is that the short maturity term structure Eurorates of numerous currencies are investigated in this essay. The studies mentioned above investigate the EHT and the Fisher effect mainly by using the

U.S. data; hence, the evidence in this essay will show to what degree the findings of the previous literature are robust. This is important because the findings from the U.S. data may be the result of one particular monetary regime and different monetary regimes may alter the information in the term structure.

A final strength of this study is that this study uses the Euromarket rates. The term structure of Eurorates has received little attention despite their size and economic significance. For Eurocurrency rates, Arshanapalli and Doukas (1994) and Mougoue (1992) conduct a cointegration analysis of Eurocurrency yields and find that yields are cointegrated. Mougoue and Szakmary (1994) impose rational expectations and perform regression tests of the EHT and conclude that long term Eurocurrency rates tend to move in the opposite direction to that predicted by the unbiased expectations theory. As mentioned in the introduction, Gerlach and Smets (1997) use data similar to those in the present paper to test the expectations hypothesis. They also impose rational expectations and constant term premia assumptions to investigate the explanatory power of the slope of the term structure for Eurorates. They conclude that, for many countries, the expectations hypothesis is broadly compatible with the high frequency properties of the data.

Although not widely found in the literature, using Eurorates for a variety of currencies has several advantages for testing the expectations hypothesis. First, as mentioned above, several papers find that the expectations hypothesis provides a much better explanation of the term structure relationship outside the U.S. and Eurorates are available for a number of countries. Also, as Gerlach and Smets

(1997) argue, Eurorates are less affected than on-shore rates by capital controls, tax considerations or legal regulations which could drive observed rates away from equilibrium levels. Finally, Eurorates for different currencies are directly comparable and do not depend on factors such as default risk, differences in duration, or the calculation of yields.

The data set consists of monthly 1-, 3-, and 6- month Eurorates and monthly inflation rates, proxied as monthly changes in CPI indexes obtained from IFS tapes, for eleven countries that include the United States, France, Germany, Belgium, Italy, the Netherlands, Britain, Denmark, Austria, Norway, Sweden. The data cover the period from January 1978 to February 1997. The Euromarket rates are end of month bid rates at around 10 a.m. Swiss time and the data are provided by the Bank for International Settlements (BIS). Following Mishkin (1992), the ordering of variables is as follows. January interest rates use the end-of-December rate data and a January observation for a one-month inflation rate is calculated from the December and January CPI data. All rates are annualized percentages.

The following section illustrates the testable cointegration implications of the expectations hypothesis and the place of the Fisher relation in this system. The fourth section discusses the statistical method of analysis to test for the hypotheses. The fifth section presents the empirical results of testing for the EHT. The sixth section identifies the common trend in the yield curve of each country and tests for the long-run Fisher relation. Concluding remarks are given in the final section.

2.3 Theoretical Background

As mentioned above, the EHT states that the yield to maturity of a k period discount bond is an average of expected 1-period yields which can be expressed in linearized form as:

$$r(\tau)_t = \frac{1}{\tau}\sum_{j=0}^{\tau-1} E_t[r_{t+j}(1)] + \theta(\tau) \qquad (2.1)$$

where the yield, $r_t(\tau)$, at time t on a pure discount bond with time to maturity τ is expressed as an average of expected 1-period yields.[7] The expectations operator is conditional on information at time t, and $\theta(\tau)$ is generally a time-invariant term premium. Engsted and Tanggaard (1994a) and Hall, Anderson and Granger (1992) show how to derive the cointegration implications of the EHT from this equation.

Consider p pure discount bonds with time to maturity $1, \tau_2 \ldots \tau_p$ then all pairs of yields, $[(r_t(1), r_t(\tau_2)], [r_t(1), r(\tau_3)], \ldots, [r_t(1), r_t(\tau_p)]$ fulfill equations of type (1). To see the cointegration implications of the EHT, consider the linear combination $\beta_1.r(1) + \ldots\ldots + \beta_p.r_t(\tau_p)$ and insert equation (1) into this combination. Then, it is obtained:

$$\beta_1 r(1) + \ldots + \beta_p r_t(\tau_p) = (\beta_1 + \ldots\ldots + \beta_p) r_t(1)$$

$$+ \frac{\beta_2}{\tau_2}\sum_{j=1}^{\tau_2-1} E_t[r_{t+j}(1) - r_t(1)] + \ldots + \frac{\beta_p}{\tau_p}\sum_{j=1}^{\tau_p-1} E_t[r_{t+j}(1) - r_t(1)] \qquad (2.2)$$

If r_{t+j} is integrated of order one then $E_t[r_{t+j}(1) - r_t(1)]$ is stationary and the left hand side of (2.2) is stationary if $\beta_1 + \beta_2 + \ldots\beta_p = 0$. This implies cointegration in the

full system of p yields and also implied is that the sum of the cointegration coefficients should equal zero. For this implication is valid for any $p \geq 2$, with p yields there should be p-1 independent cointegration vectors and all of them should obey the zero-sum restriction.

Thus, the testable cointegration restrictions of the EHT are established. Specifically, these restrictions state that a system of p interest rates should be driven by one common stochastic trend and the cointegration space should be spanned by the columns of the matrix

$$H = \big[(1,1,1,\ldots.1)', (-1,0,0,\ldots0)', \\ 0,-1,0,\ldots0)', \ldots\ldots, (0,0,0,\ldots-1)'\big]$$

so that spreads form a basis for the cointegration space. These statements constitute the first two testable hypotheses of this essay and are tested by a full information maximum likelihood analysis of cointegrating relations, proposed by Johansen (1991a).

A finding of (p-1) cointegrating relations, or one common trend, as implied by the EHT will naturally raise a question about what actually the trend is. The Fisher hypothesis states that, in the long run, there is a one-to-one relationship between the nominal interest rate and the expected inflation rate; thus, the inflation rate is an obvious candidate as the common trend. If this is the case then it can be argued that the expected inflation rate determines the level of interest rates and the EHT determines the relationship between interest rates of different maturity at that level.

A common factor model for the vector of variables, i.e. a vector of interest rates, X_t can be as follows:

$$X_t = A_1 f_t + A_2 z_t \qquad (2.3)$$

where f_t is the common factor, driving force that results in cointegration, z_t are the transitory components and A_1 and A_2 are the coefficients. Notice that the existence of such a factor model implies and also implied by cointegration among the variables of the vector X_t. This study proceeds, after testing for the cointegration implications of the EHT, to identify the common factor, f_t, and tests for the long-run Fisher hypothesis by utilizing the information in the common factor and the inflation rates for each country.

Of course, the Johansen method does not allow to identify the common trend uniquely. However, Gonzalo and Granger (1995) propose a decomposition technique that allows identification of common long-memory components in a system of cointegrated variables. Their methodology is used to identify the common factor driving the term structure and once the common factor is identified, it can be tested whether this common factor has a one-for-one relationship with the inflation rate, as it should be according to the Fisher hypothesis, by using the method of Johansen (1991a). Details of the statistical method of analysis and testing for the hypotheses are discussed in the next section.

It should be noted that the cointegration relations implied by the EHT and the Fisher hypothesis are very special: The Granger Representation Theorem in Engle and Granger (1987) implies that if cointegration exists between some variables an

error correction variable should be included in the model, as well. With cointegrated yields, for instance, the error correction term could simply be the spread between the long and the short-term rates and the error-correction variable could still be used to improve forecasting. But the equilibrium error, which is the yield spread under the EHT and the spread between the nominal rate and the inflation rate under the Fisher hypothesis, should not be interpreted as causing changes in the dependent variable because error-correction may also arise as a result of forward-looking behavior of agents. In other words, spreads may have predictive information in addition to their time series history, which the error-correction term takes into account, because of adaptive expectations of agents. Therefore, reduced form estimates of error-correction models cannot be used to distinguish between forward-looking and backward-looking models.[8]

This analysis suggests that, under the long run Fisher hypothesis, a finding that interest rates and the inflation rate are cointegrated with one common stochastic trend is consistent with both nominal rates adjusting to the inflation rate in the long-run (adaptive expectations), as Crowder and Hoffman (1996) find, and also, with nominal rates reflecting the future inflation rate (rational expectations), as Fama (1975) claims to be the case. These two views about the long-run causal ordering between the interest rates and the inflation rate are mutually exclusive. To distinguish between these two theories, this study extracts the common trend that results in cointegration between the yield curve and inflation rate and examines which variable tends to drive this common trend to determine the causal ordering in

the long-run. It should be stressed once again that the cointegration implications discussed above are derived without assuming rational expectations/constant premia. Therefore, if the cointegration properties hold, then the variation in risk premia (in the case of the EHT) and the variation in real rate (in the case of the Fisher hypothesis) is stationary. The cointegration implications of the EHT and the Fisher hypothesis would hold both under forward (rational) looking and backward (adaptive) looking expectations, and with substantial time-variation in risk premia and real rate as long as this variation is stationary. Thus, cointegration and time-variation in risk premia (real rate) can exist together under the EHT (the Fisher hypothesis). In this framework, statistical cointegration analysis examines the *low-frequency* components of interest rates and the inflation rate and the cointegration property indicates that in the long run the EHT(the Fisher hypothesis) will hold but short-term dynamics may involve time varying premia (real rate) that cannot be captured by the cointegration property.[9]

2.4 The Statistical Analysis

Full information maximum likelihood analysis, which is used in this essay, starts with an unrestricted vector autoregression. Johansen (1991a) shows how to calculate the maximum likelihood estimators of cointegration vectors as well as conducting likelihood ratio tests on cointegrating vectors and adjustment coefficients under cointegration by using reduced rank regression methods. Specifically, rather than directly analyzing the presence of common trends, Johansen suggests starting with the k^{th} order unrestricted VAR model

$$X_t = \mu + \Pi_1 X_{t-1} + \ldots + \Pi_k X_{t-k} + \epsilon_t \qquad (2.4)$$

The reduced form error-correction model of the unrestricted VAR takes the form

$$\Delta X_t = \Gamma_t \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi X_{t-k} + \epsilon_{t,} \qquad (2.5)$$

where

$$\Gamma_i = -(I-\Pi_i-\ldots\ldots-\Pi_k), \quad (I = 1,\ldots\ldots,k-1)$$

and

$$\Pi = -(I-\Pi_1-\ldots\ldots-\Pi_k).$$

In this model, Π, the impact matrix, summarizes the information about long-run relationships in the data and cointegration is equivalent to a reduced rank of Π. Rank(Π)=r implies that there are p*r matrices α and β such that $\Pi=\alpha\beta'$, where β is the matrix of cointegration vectors and α is a corresponding matrix of factor loadings. Maximum likelihood estimation and hypothesis testing can be accomplished by regressing ΔX_t and X_{t-k} on a constant and $\Delta X_{t-1},..,\Delta X_{t-k+1}$ and extracting the residuals R_{ot} and R_{kt}, from which the residual product matrices are constructed as:

$$S_{ij} = T^{-1}\sum_{t=1}^{T} R_{it}.R_{jt} \quad , \quad i,j=0,k \qquad (2.6)$$

Then solving for

$$|\lambda S_{kk} - S_{ko} S^{-1}_{oo} S_{ok}| = 0$$

the eigenvalues $\lambda_1 > \lambda_2 > \lambda_3 > \ldots\ldots, > \lambda_r > 0$ and the associated eigenvectors $V=(v_1\ldots\ldots v_m)$ can be found. The estimates of α and β are given by $\alpha=S_{ok}\beta$ and $\beta=(v_1 \ldots\ldots v_m)$ and also, two likelihood ratio tests can be constructed for the number, r,

of cointegration vectors. The first is the *maximal eigenvalue* test is based on the statistic

$$\lambda_{max} = -T.\ln(1-\lambda_{r+1}) \qquad (2.7)$$

which tests the null hypothesis r cointegrating vectors against the alternative of r+1 cointegration vectors. The second test is the *trace* test which is based on the statistic

$$\lambda_{trace} = -T\sum_{j=r+1}^{n} \ln(1-\lambda_j), \qquad (2.8)$$

and tests the null hypothesis that at most r cointegration vectors, with more than r vectors under the alternative. These tests do not have standard asymptotic distributions but Monte Carlo simulations based critical values are available.

The second cointegration restriction of the EHT argues that the spreads form a basis for the cointegration space. This hypothesis implies that the cointegration space should be spanned by the columns of the matrix H defined above. Johansen (1991) demonstrates how to test for such hypotheses by using likelihood ratio tests and tabulates that the asymptotic distribution of the statistic is the usual χ^2. Hence, a likelihood ratio test is conducted to test for zero-sum restrictions on the cointegration vectors.

It is noteworthy that the Johansen approach to testing the EHT provides a test of the assertion that the same common stochastic trend (the expected inflation rate according to the Fisher hypothesis) underlies the behavior of each longer yield. This assertion that the same common variable underlies the time series behavior of each yield to maturity is not new to the literature on the term structure. Cox et al. (1985)

build a continuous time equilibrium model of real interest yields to maturity in which the instantaneous interest rate is common to all yields.[10]

A caveat should be noted in applying the cointegration techniques to interest rates. Cointegration theory requires that interest rates should be integrated processes. It can be argued that in a very strict sense interest rates cannot be nonstationary since they are bounded below by zero. Consistent with this, Fama and Bliss (1987) argue that interest rates follow a mean reversion process. However, many other authors suggest that time series behavior of interest rates can be better approximated as unit root processes (see, Engle and Granger, 1987; Campbell and Shiller, 1987; Shea, 1992; Hall, Anderson and Granger, 1992; and others). Following these researchers, this study also uses formal unit root tests to test for nonstationarity in Eurorates.

Once the vector error correction model (VECM) is estimated and the cointegration implications of the EHT are examined, the next step is to identify the common factor driving the term structure of each country to test the Fisher hypothesis. Park (1990) and Gonzalo and Granger (1995) develop a methodology that decomposes the cointegrating system based on Johansen's analysis into permanent and transitory components. Park (1990) offers a simple decomposition for the X_t based on the estimators from the cointegration analysis and writes the vector X_t as:

$$X_t = \beta_{\perp}(\alpha'_{\perp}\beta_{\perp})^{-1}\alpha'_{\perp}X_t + \alpha(\beta'\alpha)^{-1}\alpha' X_t \qquad (2.9)$$

where $\beta'_{\perp}\beta=0$ and similarly $\alpha_{\perp}'\alpha=0$. Gonzalo and Granger (1995) express this decomposition as a factor model, given as

$$X_t = A_1 f_t + A_2 z_t \qquad (2.10)$$

where $z_t = \beta' X_t$ (an *rx1* matrix) is defined as the attractor process, $f_t = \alpha_{\perp}' X_t$ is defined as the common factor, $A_1 = \beta_{\perp}(\alpha'_{\perp}\beta_{\perp})^{-1}$ is a constant *pxk* matrix and $A_2 = \alpha(\beta'\alpha)^{-1}$ is a constant *pxr* matrix. Gonzalo and Granger (1995) demonstrate that the estimate of $\alpha_{\perp}$ can be found by solving the following eigenvalue problem

$$|\lambda S_{oo} - S_{ok}S^{-1}_{kk}S_{ko}| = 0$$

giving the estimate of $\alpha_{\perp}$ as the eigenvectors associated with the n-m+1 smallest eigenvalues.

Significance of $\alpha_{\perp}$ shows which variable plays the dominant role in driving the common trend. Significance tests of $\alpha_{\perp}$ are conducted using a likelihood ratio test. Gonzalo and Granger (1995) demonstrate that the test statistic can be computed as

$$L = -T \sum_{j=r+1}^{n} [(1-\lambda_j^*)/(1-\lambda_j)] \qquad (2.11)$$

where the asterisk denotes estimates from the restricted model. The L-statistic is asymptotically distributed as χ^2 with (n-m)x(n-q) degrees of freedom, where q=n-m is the number of common trends. If L is significant, the null hypothesis of $\alpha_{\perp} = 0$ is rejected.

Within this context, the restrictions of the Fisher hypothesis can be tested. According to the long-run Fisher hypothesis the common factor driving the term

structure and the inflation rate will be cointegrated, with one-for-one adjustments. These two implications of the Fisher hypothesis are tested by using Johansen's method. Furthermore, if interest rates reflect rationally expected inflation rate then the common factor will drive the system in the long run. If this is not the case then the common factor will adjust to the inflation rate in the long run. These two mutually exclusive theories are tested by constructing the likelihood ratio test statistic L to determine which variable drives the common stochastic trend in the long-run. This is, naturally, the variable that has long-run information about the future path of the remaining variable.

2.5. Testing for the Expectations Hypothesis

2.5.1 Unit Root Tests

The first step in the empirical analysis is to determine the order of integration of the Eurorates. The Augmented Dickey-Fuller (ADF) tests are used to test for unit roots. The results in Table 1 indicate that the null hypothesis of nonstationarity cannot be rejected in any of the individual series. These findings are consistent with several other studies, such as Arshanapalli and Doukas (1996), that find unit roots in Eurorates. Hence it is concluded that individual rates are characterized as nonstationary, I(1), variables. The analysis continues by estimating the cointegration structure of the yield curves to test the restrictions of the EHT.

Table 1. Testing for Unit Roots In Interest Rates

	ADF

(table cont.)

Austria	-1.66	-1.51	-1.35
Belgium	-1.45	-1.36	-1.26
Britain	-1.47	-1.57	-1.62
Denmark	-2.03	-1.62	-1.32
France	-2.82	-2.25	-1.54
Germany	-1.58	-1.69	-1.74
Italy	-1.29	-1.28	-1.11
The Netherlands	-1.66	-1.50	-1.40
Norway	-1.84	-1.34	-0.96
Sweden	-2.17	-1.87	-1.45
U.S.	-1.84	-1.71	-1.65

2.5.2 Estimating the Cointegration Structure

The results of testing for the number of cointegrating relationships in the term structures are reported in Table 2. However, before discussing the findings a background on the evolution of Eurorates might be necessary. In 1992 and 1993, the European Monetary System (EMS) exchange rates came under severe pressure with an initial result of departure of the Italian lira and British pound from the system in September 1992. In the summer of 1993 the pressure returned, resulting in a great widening of the bands for the French franc and almost all the remaining members of the EMS in August 1993. The crisis is usually attributed to German unification, which created a major asymmetric shock in the system. Faced with budget deficits and inflationary fears in the aftermath of the unification, Germany was unwilling to decrease its interest rates and other members faced the dilemma of raising rates,

with the outcome of unemployment and slower growth, or watching their currency drop out or move into wider bands. It is not the purpose of this study to explore in depth the underlying reasons and the outcomes of this important crisis in the exchange rate mechanism (ERM), and excellent reviews such as Whitt (1994) are also available, however, during the crisis the Eurorates of EMS member countries, except Germany, have experienced an unusually turbulent period which may violate the normality assumption in Johansen's analysis. To account for this possibility, this study estimated the unrestricted VAR model by including dummy variables for the September 1992-August 1993 period, except for Germany and the U.S. which did not experience any unusual behavior.

Table 2. Testing for Cointegration In Yield Curves

	H_2	Trace	Trace (.95)	λmax	λmax (.95)	p-value
Austria	$r \leq 2$ $r \leq 1$ $r=0$	1.38 18.57 83.51	3.96 15.19 29.50	1.38 17.18 64.94	3.96 14.03 20.77	0.260
Belgium	$r \leq 2$ $r \leq 1$ $r=0$	0.46 26.48 96.36	3.96 15.19 29.50	0.46 26.02 69.87	3.96 14.03 20.77	0.000
Britain	$r \leq 2$ $r \leq 1$ $r=0$	2.31 30.15 100.33	3.96 15.19 29.50	2.31 27.83 70.18	3.96 14.03 20.77	0.025
Denmark	$r \leq 2$ $r \leq 1$ $r=0$	1.15 35.30 113.11	3.96 15.19 29.50	1.15 34.15 77.80	3.96 14.03 20.77	0.001

(table cont.)

France	r≤2 r≤1 r=0	0.46 37.56 93.53	3.96 15.19 29.50	0.46 37.10 55.96	3.96 14.03 20.77	0.051
Germany	r≤2 r≤1 r=0	2.54 33.25 74.73	3.96 15.19 29.50	2.54 30.71 41.47	3.96 14.03 20.77	0.022
Italy	r≤2 r≤1 r=0	1.38 55.01 174.43	3.96 15.19 29.50	1.38 53.63 119.41	3.96 14.03 20.77	0.000
The Netherlands	r≤2 r≤1 r=0	1.84 23.79 98.39	3.96 15.19 29.50	1.84 21.94 74.59	3.96 14.03 20.77	0.044
Norway	r≤2 r≤1 r=0	0.23 33.05 91.08	3.96 15.19 29.50	0.23 32.82 58.03	3.96 14.03 20.77	0.990
Sweden	r≤2 r≤1 r=0	2.77 25.73 65.01	3.96 15.19 29.50	2.77 22.95 39.28	3.96 14.03 20.77	0.144
U.S.	r≤2 r≤1 r=0	2.77 22.70 87.03	3.96 15.19 29.50	2.77 19.92 64.33	3.96 14.03 20.77	0.004

With the this background information, the results in Table 2 can be discussed. As argued above, the EHT requires that there is only one common stochastic trend in the term structure of interest rates and the *trace* and the *maximal eigenvalue* statistics of Johansen (1991) in Table 2 consistently indicate support for this restriction. For every country in the sample, two cointegration relations are detected and thus, the results state that there is only one common trend in the term structure of Eurocurrency rates which is consistent with the EHT. This finding also

indicates that identifying this common factor and associating it with an exogenous variable will provide further insight concerning the driving force of the yield curve.

The second restriction of the EHT states that spreads should form a basis for the cointegration space. Significance values for this restriction are presented in Table 2. The likelihood ratio test statistics indicate that this restriction is rejected for most of the countries in the sample, including the U.S. This rejection provides evidence contradicting the theory. However, it should be mentioned that, an alternative interpretation of this finding, particularly for the U.S. data, is that the rejection is caused by problems associated with changes in the monetary regimes. According to this view, during the era of the Federal Reserve's "new operating procedures", when the Federal Reserve gave up controlling the short term interest rate the cointegration relationship has broken down, possibly because the term premia became nonstationary in this period due to an increase in uncertainty associated with holding long-term debt. This interpretation generally leads researchers to investigate the term structure data in sub-samples, (see, for instance, Hall, Anderson and Granger (1992)). Consistent with this interpretation, Hall, Anderson and Granger (1992) find that spreads form a basis for the cointegration space after 1982, which marks the end of the Federal Reserve's "new operating procedures" although this restriction is rejected in their whole sample. Nevertheless, it should be stressed that cointegration implications of the EHT should not be affected by the changes in the monetary regime since, as Engsted and Tanggaard (1994a) point out, the low frequency relationship between interest rates at different maturities does not depend

on the process that generates the short term rate. If the EHT is true then the implications will hold over the whole sample. Therefore, this study does not attempt to further investigate the data in sub-samples.

Table 3 presents the estimates of the cointegration structure of yield curves. The main purpose here is to perform the Gonzalo-Granger decomposition to extract the permanent components of the yield curves. The common factor (henceforth, CF) driving the yield curve of each country is given as the last column of eigenvectors(m) in Table 3. For instance, the CF of the U.S. term structure is estimated as 0.083(ED1) + 0.010(ED3) + 1.101(ED6). Notice that this composition of the CF indicates that the 6-month rate is the more dominant variable in the long run, thereby providing indirect support for the EHT. To see this, observe that the EHT defines the long-term rate as a weighted average of expected short-term rates over the life of the long-term rate and therefore, the long-term rate should be weakly exogenous if agents can predict the future values of the short term rate to some extent.[11] In other words, the expected one period rate determines the yields and an innovation about it is first reflected in the long term rate in the system. This relationship is detected in the composition of the CF of each country.

Also presented in Table 3 are the estimates of cointegrating vectors. It is shown that the sum of cointegrating vectors is always fairly close to zero, even though the zero-sum restriction is generally rejected by the likelihood ratio tests. This is important because it implies that the term premia is stationary, or near stationary, in the long run. Thus, it can be argued that the overall results of the

cointegration analysis indicate that the EHT can be regarded as a reasonably good explanation of the relationship between low frequency components of Eurocurrency rates.

Table 3. Cointegration Structure of Yield Curves

	Eigenvalues	Eigenvectors(v)	Eigenvectors(m)
Austria	(.246,.072,.006)	4.300 0.941 0.276 -9.332 3.168 -0.626 5.117 -4.159 0.184	2.558 1.558 0.712 -4.519 2.424 -2.393 0.688 -3.756 3.793
Belgium	(.262,.107,.002)	5.620 0.848 -0.382 -8.002 2.297 0.262 2.584 -3.155 0.435	3.979 -0.480 -1.469 -4.692 3.932 0.847 1.439 -2.949 2.179
Britain	(.263,.114,.010)	6.626 0.801 0.219 -12.448 2.502 -0.223 5.903 -3.427 0.325	3.547 1.885 0.470 -7.645 0.500 -1.761 4.214 -1.745 2.612
Denmark	(.287,.138,.005)	2.944 1.020 -0.008 -6.999 0.760 -0.317 4.215 -1.698 0.610	1.281 0.669 -0.076 -3.220 0.651 -1.433 1.885 -0.980 2.617
France	(.216,.149,.002)	2.568 0.770 -0.165 -5.170 0.238 -0.133 2.642 -0.928 0.530	1.091 0.132 0.087 -2.149 1.142 1.314 1.103 -1.245 -2.470
Germany	(.165,.125,.011)	10.091 -6.205 1.150 -13.957 15.414 -1.584 3.971 -9.322 0.867	5.453 -3.275 1.392 -4.587 10.378 -4.229 -0.606 -6.712 4.952
Italy	(.277,.091,.008)	6.578 -0.775 0.031 -9.738 7.020 -1.373 3.282 -6.198 1.780	4.505 -0.369 1.462 -7.336 5.058 0.782 3.249 -3.855 -3.906
The Netherlands	(.277,.091,.008)	6.578 -0.775 0.031 -9.738 7.020 -1.373 3.282 -6.198 1.780	4.505 -0.369 1.462 -7.336 5.058 0.782 3.249 -3.855 -3.906
Norway	(.223,.133,.001)	2.127 1.131 -0.124 -7.291 0.943 -0.057 5.165 -2.066 0.509	-0.828 0.835 0.160 3.063 -0.100 -1.571 -1.797 -0.511 2.478

(table cont.)

Sweden	(.157,.095,.012)	2.008 4.003 -0.174 -0.561 -7.798 0.023 -1.520 3.971 0.551	0.917 1.612 1.108 0.413 -3.829 -0.701 -0.763 2.532 -1.514
U.S.	(.244,.083,.012)	6.551 -0.720 -0.107 -10.427 6.170 -0.125 4.037 -5.479 0.508	4.129 -0.921 0.083 -6.734 7.524 0.010 2.848 -6.686 1.101

2.6 Testing for the Long Term Fisher Hypothesis

2.6.1 Unit Roots in Inflation Rates and the Cointegration Structure

The second part of the essay focuses on the long-run relationship between the CF and inflation rate. As indicated above, the last column of the eigenvalues(m) in Table 3 constitute CF's. Before proceeding with the cointegration analysis, the order of integration in inflation rates should be determined. In prior work, the existence of a unit root in inflation rates has been questioned in empirical studies. For instance, Rose (1988) finds the inflation rates of all OECD countries to be stationary variables but Haldrup (1994) and Mishkin (1992) argue that the inflation rates of Denmark and the U.S., respectively, are characterized as nonstationary variables. Engsted (1995) examines the inflation rates of thirteen OECD countries and concludes that the inflation rates are better characterized as nonstationary variables. Crowder and Hoffman (1996) find the U.S. inflation rate to be nonstationary. Also, it should be mentioned that there are some issues related to using univariate tests while testing for unit roots in inflation rates. Schwert (1989) documents that ADF tests have greater than actual sizes when the variables contain a significant moving average component, which is the case for many of the inflation variables in this study. This causes to reject the null hypothesis of unit root too

often. However, it is also well-known that ADF test has low power which would cause to reject the null hypothesis too seldom. To remedy these problems, this study uses an additional statistic to test for nonstationarity in inflation rates based on Johansen's multivariate analysis.

The results of the ADF tests are reported in Table 4. This test provides consistent support for a unit root in inflation rates. Except for Britain, the null hypothesis of nonstationarity cannot be rejected even at conventional values. The next step is to estimate the cointegration structure between CF and the inflation rate.

Table 4. ADF Tests for Unit Roots in Inflation Rates

Austria	-1.56
Belgium	-1.64
Britain	-3.14
Denmark	-2.87
France	-1.78
Germany	-2.50
Italy	-2.44
The Netherlands	-2.51
Norway	-2.70
Sweden	-2.13
U.S.	-2.29

Results of the trace statistic to test for cointegration between CF and the inflation rate are presented in Table 5. The results strongly support the conclusion that these variables are cointegrated. This is, of course, consistent with the long-run Fisher hypothesis which states that the nominal interest rates and the inflation rate should share a common stochastic trend.

Table 5. Cointegration between Common Factor and Inflation Rate

	H_2	Trace	Trace (.95)	Test for Stationary Inflation Rates	p-value
Austria	$r \leq 1$ $r=0$	1.38 67.24	3.96 15.19	0.000	0.000
Belgium	$r \leq 1$ $r=0$	0.92 53.68	3.96 15.19	0.000	0.000
Britain	$r \leq 1$ $r=0$	2.31 44.61	3.96 15.19	0.000	0.000
Denmark	$r \leq 1$ $r=0$	2.31 44.61	3.96 15.19	0.000	0.000
France	$r \leq 1$ $r=0$	0.92 20.85	3.96 15.19	0.000	0.002
Germany	$r \leq 1$ $r=0$	2.78 56.07	3.96 15.19	0.000	0.000
Italy	$r \leq 1$ $r=0$	1.61 22.80	3.96 15.19	0.000	0.000
The Netherlands	$r \leq 1$ $r=0$	2.54 141.30	3.96 15.19	0.000	0.000
Norway	$r \leq 1$ $r=0$	0.23 50.33	3.96 15.19	0.000	0.004

(table cont.)

Sweden	$r \leq 1$ $r=0$	1.38 79.18	3.96 15.19	0.000	0.003
U.S.	$r \leq 1$ $r=0$	2.77 21.70	3.96 15.19	0.015	0.000

Estimated cointegration model is also used to provide an alternative test for unit roots in inflation rates. Specifically, within the context of Johansen's multivariate analysis, the restriction than the vector $[0,1]'$ spans the cointegration space is imposed. The null hypothesis of this test is *stationarity* as opposed to *nonstationarity* in univariate ADF tests and a likelihood ratio statistic is used to test this restriction. The statistic is distributed as $\chi^2(1)$ and the significance values are reported in Table 5. The results indicate that the null hypothesis of stationary inflation rates is soundly rejected for every country, including Britain. Thus, the conclusion of this analysis is formed as inflation rates are characterized as nonstationary processes.

The analysis also tests whether the adjustment between CF and the inflation rate is one-for-one. The results of likelihood ratio tests, indicated by p-values in Table 5, lead us to rejection of this restriction. According to the Fisher relation, without a one-for-one response the real rate will share the same permanent shocks as expected inflation. Therefore, this finding has an important implication that real rates may be characterized as non-stationary processes.[12]

However, some caveats to this conclusion are in order. Specifically, empirical findings in Crowder and Hoffman (1996) and Evans and Lewis (1995) suggest certain points that might be important when testing for the zero-sum

restriction in the Fisher hypothesis. Crowder and Hoffman (1996) argue that pre-tax nominal rates will not move one-for-one with inflation in the long run if post-tax real rates are unaffected by permanent changes in inflation. Furthermore, Evans and Lewis (1995) assert that testing for stationarity in real rates might be deceptive when the process of the inflation rate can be characterized by a regime switching model. Both studies correct for these factors in empirical analysis and conclude that nominal interest rates and the inflation rate move one-for-one in the long run. Since this study focuses on an examination of the information in the nominal yield curve regarding the future path of the inflation rate, these points are left as an avenue for future research.

2.6.2 Long Term Dynamic Relationship Between the Variables

Table 6 shows the estimates of the cointegration structure and identifies the common stochastic trend between the CF and the inflation rate, using the Gonzalo-Granger decomposition. The common trend driving the system is the last column of eigenvectors(m) for each country and, as indicated above, the orthogonal components show the contribution of each variable to the common trend. The long run causal ordering between the variables can be investigated by looking at the relative weights of the orthogonal components. For every country, it is found that the CF has a more dominant share in the common trend. For instance, the permanent component between the CF and the inflation rate of U.S. is estimated as 0.789(CF) + 0.184(INF), which shows that the CF tends to drive the system in the long run. In other words, the CF seems to be weakly exogenous in the system and

hence, it contains information about the long-run behavior of the inflation rate. Similar relationships are found for every country in the sample and thus, this result is robust internationally. It is also tested, by L statistic discussed above, if the CF drives the common stochastic trend of the system solely; i.e. the information in the inflation rates do not contribute at all to the permanent component. Significance levels of this restriction are reported in Table 6 and it is found that for a number of countries, that include Belgium, The Netherlands, Norway and Sweden, this restriction is not rejected at the 5% significance level. For the U.S., this restriction is not rejected at the 1% level although it is rejected at the 5%, which implies that the CF contains all the information about the long run behavior of the system.

Table 6. Cointegration Structure between Common Factor and Inflation Rate

	Eigenvalues	Eigenvectors(v)	Eigenvectors(m)	p-value
Austria	(.249,.006)	-0.142 0.126 0.476 0.030	-0.392 0.936 0.165 0.068	0.001
Belgium	(.205,.004)	0.221 0.192 -0.512 0.024	-0.245 0.980 0.230 0.062	0.063
Britain	(.168,.010)	-0.236 0.244 0.246 0.014	-0.511 0.889 0.110 0.049	0.003
Denmark	(.236,.003)	0.244 0.235 -0.310 0.026	-0.498 0.864 0.135 0.086	0.000
France	(.083,.004)	-0.220 0.211 0.315 0.002	-0.705 0.697 0.245 0.208	0.000
Germany	(.206,.012)	-0.158 0.195 0.482 0.030	-0.423 0.908 0.238 0.113	0.003
Italy	(.088,.007)	0.348 0.195 -0.272 0.038	-0.609 0.812 0.158 0.144	0.007

(table cont.)

The Netherlands	(.453,.011)	0.138 0.256 -0.366 0.002	-0.097 0.994 0.192 0.012	0.263
Norway	(.195,001)	-0.206 0.300 0.260 0.002	-0.237 0.983 0.146 0.036	0.190
Sweden	(.287,006)	0.251 0.352 0.213 -0.003	0.319 0.916 -0.103 0.027	0.162
U.S.	(.079,.012)	-0.182 0.241 0.364 -0.013	-0.639 0.789 0.261 0.184	0.011

The interpretation of these findings is perfectly consistent with Fama's (1975) argument that nominal rates should contain useful information to predict the future path of the inflation rate and with the contention that interest rates to a large extent reflect rationally expected future inflation. Examination of the data supports the notion that participants in credit markets display a forward looking behavior, responding to news (innovations) about future inflation and incorporating this information into prices while setting interest rates.[13]

Before further elaboration on the findings, a moment should be taken to compare the results of this study with those of Crowder and Hoffman (1996). They also consider a very similar problem in the U.S. context and investigate the long run dynamic relationship between the U.S. inflation rate and the 3-month T-bill rate by using similar statistical techniques. As stated above, they identify the inflation rate as the variable driving the common stochastic trend in the long run, which is contrary to the findings of this paper. Thus, their findings imply that the inflation rate contains useful information about the future path of the nominal rate. The major

distinction between their analysis and the present study is that Crowder and Hoffman (1996) reach their conclusions by using quarterly data for a larger data set, from 1952 to 1991. To check the robustness of the results, the analysis is also conducted by using quarterly Eurodollar data. Consistent with Crowder and Hoffman (1996), it is found that the long run causal ordering is from the nominal rates to the inflation rate with this data set although both variables contribute to the common trend.

This finding demonstrates an empirical regularity in financial markets that can be potentially important for researchers in the field. The results indicate that the frequency of observations can strongly affect the conclusions of empirical work. In other words, the emprical results suggest that the use of quarterly data is not efficient in capturing the behavior of participants in credit markets when an innovation relevant to the system occurs. To see this, suppose a shock related to the money supply takes place. The findings of this paper indicate that participants in the market revise their expectations about future inflation and incorporate this information into nominal rates. Thus, although the shock is originally related to inflation, the nominal rates drive the common stochastic trend in the long run, due to the forward looking behavior of the market participants. However, with the use of quarterly data, it cannot be observed how the nominal rates first reflect the shock since the adjustment process is over. Therefore, the statistical analysis gives a false indication about the dynamic long run behavior of the nominal rates with respect to the inflation rate. Hence, future research should be careful about the effects of observation frequency on the dynamic behavior of financial markets.

2.7 Concluding Remarks

This essay investigates the long run implications of the expectations hypothesis of term structure and the Fisher hypothesis to characterize the changes in the slope and level of nominal yield curves of short term Eurorates. The statistical analysis indicates that the yield curve of almost every country in the sample is driven by one common stochastic trend, which is consistent with the expectations hypothesis. To examine the long run Fisher hypothesis, a common trend in the nominal yield curve is identified and it is tested if this permanent component is cointegrated with the inflation rate. Johansen's tests suggest that the variables are cointegrated, which is consistent with the long run Fisher hypothesis.

A special emphasis is given to the long run causal relationship between the common factor in the nominal yield curve and the inflation rate. Contrary to the previous findings reported in the literature, it is found that the common factor in the yield curve is the driving force that results in cointegration. This implies that there is information contained in the nominal yield curve about the future path of the inflation rate which is consistent with the view that rational agents in a well-functioning efficient market incorporate the predictable portion of the inflation rate into nominal rates while setting prices. Statistical findings are robust internationally and thus, it can be argued that they are not the outcome of a particular monetary regime. Therefore, the overall findings of the essay imply that the expected inflation rate is a determinant of the level of the yield curve, as it should be according to the Fisher hypothesis, and the expectations hypothesis provides a reasonably good

explanation of the long run relationship between yields at different maturities at that level.

Finally, another point that is raised in the paper is that the use of quarterly data in macro finance may not be efficient. Specifically, the results are reversed when quarterly data are used and hence, it is argued that quarterly data are not efficient in fully capturing the dynamic behavior of market participants.

2.8 End Notes

1. Tax considerations are ignored (see Darby, 1975).

2. Unless, of course, the underlying "fundamentals" move together.

3. For instance, according to the market segmentation theory of Culbertson (1957) expectations concerning short rates would have no role in determining long rates and the Central Bank is able to permanently 'twist' the term structure by altering the supply of government bonds at the long or short end of the term.

4. However, under rational expectations version of the Fisher hypothesis, there is no distinction between the short and long term. Under rational expectations, the nominal interest rate responds instantaneously to news about expected inflation.

5. Also, Nelson and Schwert (1977), Mishkin (1981, 1984), Fama and Gibbons (1982) make similar comments.

6. Fama (195) develops and tests his theory under rational expectations and also by implicitly assuming that the inflation and interest rates are stationary. However, recently, Engsted (1995) develops a similar rational expectations version of the Fisher hypothesis that makes the same predictions by considering that interest and inflation rates are characterized as unit root variables. His conclusions support Fama's theory.

7. This is usually applied to continuously compounded yields of zero-coupon bonds, but it is widely used as an approximate expression of the equilibrium relation. A second traditional expression of the theory is that short term spot yields equal expected short term holding period yields of long term bonds. Cox et al. (1981) call the version in the used in this dissertation as "returns-to-maturity hypothesis" and the second one as "local expectations hypothesis". Cox et al. (1981) aimed to show that in a general stochastic description of the term structure it is impossible to

simultaneously impose all of the restraints of these two versions. However, Campbell (1986) and McCulloch (1987) show that the linearization technique presented in the dissertation actually satisfy the restrictions in a stochastic environment.

8. A more detailed exposition of these ideas is provided in Campbell and Shiller (1988).

9. This distinction is important because to test the exact version of the Fisher hypothesis it has to be assumed that the real rate is constant, as in Fama (1975) and Engsted (1993), as well as Mishkin (1990a, 1990b, 1991).

10. See, also, Pagan, Hall and Martin (1995) for a discussion of the connection between finance-theoretic and economic-theoretic models of the term structure.

11. Notice that this argument is very similar to why nominal rates should be weakly exogenous with respect to the inflation rate, according to the Fisher hypothesis. The reason stems from the fact that the Fisher hypothesis actually represents a present value model in which the current rate of nominal interest is an average of future one period inflation rate over the life of the nominal rate and a constant real return.

12. Observe that this finding is troublesome since it is inconsistent with standard intertemporal asset pricing models such as CCAPM. These models imply that when real rates are subject to permanent disturbances consumption growth rates should also be affected by permanent disturbances, which can easily be rejected in data, see Rose (1988) for further information on this point.

13. This is how much an analysis of "long run" Fisher hypothesis can tell us. To determine if the relationship between the nominal rates and the inflation rate is instantaneous the exact restrictions of the Fisher hypothesis under rational expectations should be tested. Engsted (1995) is a good example of such a study and also, the series of papers by Mishkin (1990, 1991a, 1991b) should be considered in this context.

CHAPTER 3

CONVERGENCE OF THE TERM STRUCTURES OF MONEY MARKET EURORATES

3.1 Introduction

This essay aims to extend the understanding on international financial markets integration by analyzing the convergence of international term structures. The focus of the study is on the issue of whether information in the term structure of one country is relevant for another. Understanding linkages among international term structures is important since it can allow us to identify the transmission of monetary policy actions from one country to another and also, since this issue is directly related to the concept of globally integrated financial markets.

The study has two major objectives and focuses on the Eurocurrency term structures of the U.S., the U.K., Germany and France for achieving these goals. The first goal of the essay is to test the implications of the covered interest parity theorem, which suggests a stable long run relationship between international term structures, such that they do not drift apart arbitrarily in the long run. Covered interest parity theorem argues that if exchange markets are efficient, then nominal interest differential should be offset by the relevant forward exchange premia. To test this theory, the cointegration structure between domestic interest rates is

estimated and the common factor driving each term structure is extracted. If the interest parity theorem holds then the common factors across countries are expected to be cointegrated with one common stochastic trend. It is noteworthy that central banks will be unable to conduct fully independent monetary policies under this scenario. Rather, central banks will be influenced by international monetary policies and developments.

In the last two decades, there have been significant advances in international capital mobility as well as in elimination of rules and regulations against financial integration which presumably facilitates a synchronization of nominal rates. However, many studies, such as Pigott (1993-1994) and Holmes and Wu (1997), find evidence suggesting that a convergence of term structures has not occurred. It is argued in this study that a major reason of dismal findings generally reported in the literature is related to the exchange rate regime employed. Specifically, it is argued that whether a relevant shock from a foreign term structure affects the domestic term structure depends on the exchange rate regime employed. Under a flexible exchange rate regime transmission of international shocks may be absorbed by changes in exchange rates, leaving nominal rates unchanged even in fully integrated capital markets. To analyze the proposition that convergence of term structures is facilitated when exchange rate flexibility is limited, this study conducts a sub-group analysis between Germany and France, which have been members of the European Union's Exchange Rate Mechanism (ERM), an adjustable fixed exchange rate mechanism,

since its inception. Removal of capital controls in the EU as well as a harmonization of economic policies and an adjustable fixed exchange rate system should facilitate long run synchronization of the term structures of Germany and France. To test these propositions, the study estimates the cointegration structure of the money market term structures (composed of 1- and 12-month Eurocurrency rates) of the countries and extracts the common factor (permanent component) from each countries term structure to test for long run relationships between international term structures. The cointegration structure is estimated by the full information maximum likelihood method of Johansen (1991) and the method of Gonzalo and Granger (1995) is used to decompose the term structure into its permanent and transitory components. Both methods are discussed in Chapter 2.

Also investigated within this context are short run linkages between international term structures. Term structures may have short run linkages as well as long run influences on each other and transitory components from the term structure can be used to test these linkages. It is empirically shown that the spreads cointegrate the yields in the term structure, i.e. constitute the transitory components, and thus, the spreads are used to test for international short run interdependencies within a multivariate vector autoregression (VAR) model.

The second goal of the study is to test for the so-called "German dominance hypothesis" (GDH) in the European Monetary System (EMS). According to this hypothesis, Germany serves as an anchor country in the EMS and it runs the

monetary policy for the whole system. If this hypothesis is correct and if the money market rates can be taken to represent the monetary actions of Central Banks, as has been suggested in the literature, then it is implied by the GDH that the money market term structure of Germany will dominate the long run behavior of the money market term structure of France, making it impossible for France to pursue its own monetary policy.[1] This proposition is examined by investigating the long run relationship between the common factor in the term structure of Germany and France, again by using the statistical cointegration analysis and the Gonzalo-Granger decomposition method. As explained in Chapter 2 of this dissertation, a likelihood ratio test can be constructed, within the context of this method, to test if one of the variables is solely responsible for the long run behavior of the system. Thus, this test statistic is employed to investigate if the common factor in Germany's term structure determines the long run behavior of the common factor from France's term structure, which should be the case if the GDH is valid.

This study contributes to the literature on international interest rate linkages in a number of ways. First, rather than using a short term rate alone, information contained in each domestic term structure is viewed as serving as a summary measure for the combined effect of each domestic and monetary and fiscal policies and the term structure of each country is decomposed into permanent and transitory components. The common factor driving each term structure, the permanent component, is extracted to test for long run relationships across countries. Several

authors, for example Plosser and Rouwenhorst (1994), argue that the information contained in the term structure is much richer than that contained in the level of short-term interest rate and thus, this analysis should provide a better measure to capture the long and short run interdependencies across countries.

Another contribution of the study is that the term structure of money market Eurorates is used. It can be argued that monetary policy actions in the short run can be expressed in terms of the changes in short term rates that such actions produce; see, Von Hagen and Fratianni (1991) among others on a discussion of this point. In other words, changes in money market rates summarize the short-run course of monetary policy. Related to this point, it should be mentioned that a permanent-transitory components decomposition approach to test for international interest rate linkages and the GDH is also present in Hafer, Kutan and Zhou (1997). However, their paper concentrates on the term structure between short term on-shore rate and a long term government bond. They find that the long term government bond constitutes the common factor in every case and thus, they effectively investigate linkages between long-term rates. While that is an important contribution, money market term structure represents a better measure to investigate the transmission of monetary policy actions and the issue of an international convergence of economic policies. Therefore, this study concentrates on the term structure of 1-month and 12-month rates. Eurorates are preferred rather than on-shore rates because they do not have differences due to differing tax laws, regulatory policies and other institutional

arrangements and thus, are better suited to examine international linkages.[2] Finally, this study includes the term structure of the U.S. in the analysis. This inclusion, which was absent in Hafer, Kutan and Zhou (1997), is important because of the sheer size of the Eurodollar market and also, since previous work (e.g. Katsimbris and Miller, 1993) indicate that the GDH is no longer supported once the linkages of European countries with the U.S. is taken into account.

Empirical findings state that a long run stable relationship does not exist between the term structures of the U.S., the U.K., Germany and France, i.e. the common factors from the term structures are not cointegrated. This implies that money market Eurorates of these countries may drift apart arbitrarily in the long run. However, a stable long-term relationship between the term structures of Germany and France is detected by cointegration tests, although the GDH is rejected. It is argued that these findings can be explained by the different exchange rate regime employed between Germany and France and the increased economic policy coordination goal of the E.U. Also, it is found that a significant short run causality runs from the term structure of Germany to that of France and similarly, from the U.K. to the U.S.

In the next section a theoretical background on international interest rate linkages is offered. Section 3 provides a brief literature review. Section 4 discusses the statistical method of analysis and testing for the hypotheses. The empirical

findings are presented in Section 5 and concluding remarks are found in the final section of the paper.

3.2 Theoretical Background

The theoretical analysis that suggests linkages among international interest rates is rather straightforward and relies on interest arbitrage.[3] Interest arbitrage implies that the interest rates on two traded one-period bonds in different currencies have the following relation:

$$r_{1t} - r_{2t} = f_t - s_t \qquad (3.1)$$

where r_{1t} and r_{2t} are the one-period interest rates in countries 1 and 2, and f_t and s_t are the natural logarithms of the forward and spot exchange rates. By definition,

$$f_t - s_t = \Delta s_{t+1} + (E_t s_{t+1} - s_{t+1}) + \Lambda_t , \qquad (3.2)$$

where E is the expectations operator, and Λ is the risk premium. Under rational expectations, the expectations error must be white noise, and therefore, stationary. Exchange rates can well be modeled as martingale (see, Meese and Rogoff, 1983, among others); therefore Δs_{t+1} is stationary. And also, it is unlikely that the risk premium should be non-stationary. In sum, this battery of stylized facts imply that international interest rates should be cointegrated in the sense of Engle and Granger (1987), with a cointegration vector of [1,-1]. This relationship also shows us that under a credible fixed rate regime countries would have the same term structure of interest rates, since the expected forward rate would equal the spot rate at all maturities.

Few would dispute that the international integration of financial markets has increased dramatically in the last two decades with technological advances and the progressive elimination of the barriers to the international flow of capital in the major industrialized countries. Furthermore, the development and growth of new financial instruments, such as currency and interest rate swaps, have further stimulated international financial integration by giving investors wider choices than traditionally available in purely domestic financial markets. It can be presumed that the increased international integration of financial markets will reduce divergences between interest rates at home and abroad and increase the degree to which yields in different national markets move together over time.

However, while increased global financial integration during the last two decades implies convergence of international term structures, it should be recognized that financial integration by itself need not lead to convergence or co-movement of national rate changes across countries for several reasons. In fact, whether additional information on foreign interest rates influences the domestic term structure depends on the exchange rate regime. Pigott (1993-1994) defines complete integration of an economy's financial markets as all participants having equal access to all markets and states three factors that would work against convergence even in the presence of complete financial integration. First, differing tax laws, regulatory policies, and other institutional arrangements may construct additional barriers for financial flows and second, key instrument characteristics such as available maturities, minimum

denominations, and liquidity generally vary across countries. But, the third and the most fundamental reason against the convergence of term structures even in the presence of integrated financial markets stems from the fact that the international economy is distinguished by the existence of multiple currencies whose values are subject to change.

Under a "pure float", or regime with no exchange rate commitments, interest rates across countries can be independent if countries pursue independent inflation objectives, even if the capital markets are integrated. Under flexible exchange rates national markets are linked through foreign exchange markets and therefore, movements in foreign interest rates can be reflected in the prospective change in the exchange value of the domestic currency, rather than in the domestic interest rates.[4] And also, when exchange rates are free to vary, divergences in macroeconomic forces will lead to cross-country differences in national interest rates. For instance, a tightening of credit that pushes up interest rates in one country's markets tends to attract funds from abroad. This inflow, however, first places upward pressure on the home currency, raising its current value above the level expected to prevail in the future and thus increasing the amount by which the currency is expected to fall subsequently. If the domestic government allows its exchange rate to float freely, this process will continue until the currency's prospective future decline is sufficient to eliminate the incentive for funds to flow in, leaving national interest rates both at home and abroad largely unaffected. (Pigott, 1993-1994).

Therefore, it can be argued that under flexible exchange rates nominal interest rate differentials can be due not only to differences in their characteristics or imperfect integration of the markets, but also from divergences in macroeconomic and other determinants and their interactions with exchange rates. The main effect of financial integration, in this context, is not to lead to interest rate convergence but rather to greatly increase the sensitivity of exchange rates to national interest rate fluctuations. In this case, financial developments in one country tend to affect conditions in the other through their impact on foreign exchange markets.

However, under a fixed exchange rate regime, domestic interest rates and monetary policy are not independent of foreign developments. In this case, a change in the real rate of return in any one country is transmitted to all nominal rates both domestically and abroad as investors attempt to maximize real rates of return and the nominal rates are closely linked while remaining interest differentials are due to disparities in the markets and (noncurrency) instrument characteristics rather than by macroeconomic disparities among the countries. It should also be noted that even in the absence of a credible fixed-rate commitment, monetary authorities may still have a long-run exchange-rate objective and may periodically intervene in the exchange market or conduct policy to further that goal. If this is the case, international interest rates could still be related even though the relationship would be looser (Kool and Tatom, 1988).

These arguments suggest that the degree of convergence between international term structures may strongly depend on the exchange rate regime and harmonization of economic policies. Within this context, it should be recognized that while the last two decades saw the elimination of barriers in front of capital movements and a general liberalization in international financial markets, in the same time span the system of exchange rates applying to the major currencies changed from one of fixed to flexible rates.

The implication is that under a flexible exchange rates regime, a finding that international term structures do not have a stable long run relationship may exist under complete financial integration. To further analyze the effect of a fixed exchange rate regime on convergence, this study conducts a sub-sample analysis by examining the cointegration relationships in bivariate systems. Since Germany and France have been members of the ERM the effect of the exchange rate regime on tests of the convergence of international term structures can be controlled, at least to some degree, by a sub-sample analysis. A finding that the term structures of Germany and France do not share a common stochastic trend will provide relatively stronger evidence against the interest parity theorem. Also, by means of this approach, the GDH can be tested. If the GDH is correct then not only will the term structures of Germany and France be cointegrated but also, the common factor of the Germany term structure will be responsible for the long run behavior of the bivariate system, i.e. it will weakly exogenous in the system so that the term

structure of France will simply change as a response information in the German term structure. This hypothesis is tested by a formal likelihood ratio test statistic. The data set of this study consists of 1-month and 12-month Eurorates of the U.S., the U.K., Germany and France. Data frequency is monthly and the time span covers the period from January 1978 to February 1997. The Eurorates are end of month bid rate at around 10 a.m. Swiss time, and the data are provided by the Bank for International Settlements (BIS). All rates are annualized percentages.

3.3 Prior Work

There have been numerous studies on international interest rate convergence in general and on the GDH in particular by using different approaches. In this review, the focus is on studies that are directly relevant to the goals of this essay. As mentioned above, in a recent study, Hafer, Kutan and Zhou (1997) examine linkages in EMS term structures by considering a decomposition approach similar to the one used in this study. Their sample include Germany, France, Belgium and the Netherlands. They also look at the GDH and, although they find that the common factors from the term structure are cointegrated, they reject the GDH. Again in a recent study, Hansen (1996) investigates that relationship between the term structures of Germany and the U.S. by using the cointegration analysis. His findings indicate that the term structures of the two countries do not share a common stochastic trend, i.e. they do not have a long run stable relation. However, he finds that the U.S. term structure significantly affects the German term structure in the

short run. Karfakis and Moschos (1990) examine interest rate linkages within the EMS system by considering a bivariate cointegration analysis. They conclude that evidence strongly support a German dominance in the EMS. However, Katsimbris and Miller (1993) conducts a further analysis of this issue by including the U.S. interest rate in the sample and by conducting statistically more powerful multivariate cointegration tests. Strikingly, they argue that the evidence no longer supports the GDH once the effect of the U.S. interest rate is taken into consideration. They find that the U.S. interest rate has significant causal relationships with the members of the EMS. It is noteworthy that, in an earlier study, de Grauwe (1989) reaches a similar conclusion in a smaller data set.

Many studies investigate international interest rate linkages by using statistical techniques other than cointegration analysis. Kool and Tatom (1988) examine the linkages between the term structures of the U.S., Canada, the U.K., West Germany and France by OLS regressions. They conclude that long term government bond rates are related closely for these countries. Pigott (1993-1994) examines convergence in covered interest differentials internationally. His conclusions emerge as, although financial markets are integrated largely, a convergence has not occured. He argues that national interest rates will remain as divergent as long as exchange rates are fixed or very nearly so.

Interest rate linkages in the Euro market has also been widely discussed in the literature. Generally, the literature approached this issued from the perspective

of a German domination in the Euro market. Among the papers that especially look at long term relationships, Kirchgassner and Wolters (1993, 1995) are particularly relevant for the present paper. Kirchgassner and Wolters (1993) examine if Germany has a dominant position in the Euromarket by using 3-month Eurorates, monthly frequency from 1980 to 1988. They conduct Johansen's multivariate cointegration analysis and find that Germany enjoys a relatively stronger position in the Euro market. They conclude that, concerning long run relationships, one might speak of a German dominance. However, they also find that there are significant short run relations that are not linked to relations with Germany. In a following paper, Kirchgassner and Wolters (1995) examine the same issue in the frequency domain by using spectral analysis. Their analysis also suggests strong relations with Germany of all the EMS countries as well as the U.S. interest rate. The present paper adds to these studies by using a larger and current data set and also, by using a decomposition technique that extracts the information in the money market term structure.

3.4 The Statistical Analysis

The statistical method of analysis used in this study is based on the full information maximum likelihood method of cointegration analysis, presented in full detail in Johansen (1991), and on the decomposition technique of Gonzalo and Granger (1995). Statistical details of these methods and how to construct test statistics are discussed in Chapter 2 of this dissertation. Therefore, the discussion

here is more general. The empirical analysis of cointegration starts with formal unit root tests of interest rates. Then, the cointegration structure between 1-month and 12-month Eurorates is estimated for each country and the common factor driving the term structure is identified, according to the Gonzalo-Granger decomposition method. The common factor (permanent component) driving the term structure is extracted to test for long run relationships between the term structures. Also, a sub-group analysis is conducted for the same relationship for every bivariate grouping. A special emphasis is given to the relationship between Germany and France and a likelihood ratio test, as described in Chapter 2, is constructed to test if the German common factor is weakly exogenous. Finally, a multivariate VAR model is estimated, by using stationary transitory components from the term structures, to test for short term Granger causality relationships between the term structures.

3.5 Empirical Findings

3.5.1 Estimation of the Cointegration Structure

It was shown in Chapter 2 (see Table 1) that Eurorates are nonstationary. Therefore, we start with the test for cointegration and with the estimation of the cointegration structure to perform the Gonzalo-Granger decomposition. Results of the Trace test of Johansen (1991) to test for cointegration between 1-month and 12-month rates are reported in Table 7.[5] For every country in the sample, the interest rates are found to be cointegrated. This result is not surprising, giving the finding of Chapter 2 of this dissertation that the term structure of every country in the sample

is cointegrated with one common stochastic trend which is consistent with the expectations theory of term structure.

Table 7. Testing for Cointegration Between 1- and 12-month Eurorates

	H_2	Trace	Trace(.95)	p-value
U.S.	$r \leq 1$ $r \leq 0$	2.31 26.28	3.96 15.19	.382
U.K.	$r \leq 1$ $r \leq 0$	2.31 20.74	3.96 15.19	.048
Germany	$r \leq 1$ $r \leq 0$	2.77 32.17	3.96 15.19	.071
France	$r \leq 1$ $r \leq 0$	0.69 31.40	3.96 15.19	.304

Table 8 presents the estimates of the cointegration structure for each country. As argued above, the term structure can be decomposed into permanent and transitory components, according to the method of Gonzalo and Granger (1995), by using the information in this table. As explained in Chapter 2, the common factor driving the term structure is found under eigenvectors(m). For instance, the common factor driving the term structure of the U.S. is constructed as 0.227(ED1) + 1.122(ED12) and the common factor driving the term structure of Britain is -0.163(ES1) + 1.578(ES12).[6] Another point observed in Table 8 is that the sum of cointegration vectors (eigenvectors(v)) is always very close to zero which is, again, consistent with the EHT which places a zero sum restriction on cointegrating

vectors. In fact, this restriction is tested by formal likelihood ratio tests and it is not rejected in any instance; p-values of testing for this restriction are also reported in Table 7. This, of course, has the implication that the spreads cointegrate the yields and the spreads are actually the transitory components of the term structure.

Table 8. Cointegration Structure Between 1-month and 12-month Rates

	Eigenvalues	Eigenvectors(v)	Eigenvectors(m)
U.S.	(.099,.010)	1.664 -0.083 -1.718 0.383	1.964 0.227 -1.989 1.122
U.K.	(.077,.010)	1.399 0.111 -1.590 0.226	1.846 -0.163 -1.257 1.578
Germany	(.120,.012)	1.957 0.369 -2.106 0.046	2.816 0.062 -2.541 2.155
France	(.125,.003)	0.675 -0.114 -0.630 0.367	0.511 -0.291 -0.559 1.706

3.5.2 Long Run Linkages Between Term Structures

Cointegration tests are conducted between the common factors from each term structure to test for convergence between domestic and foreign rates in the long run. The analysis starts with testing for the hypothesis that all the countries in the sample are cointegrated. The test results appear in Table 9 and it is indicated that this hypothesis is rejected. In other words, no long run stable relationship, a convergence of international money market term structures, is detected between the common factors from the term structures of the U.S., the U.K., Germany and France. This finding can be interpreted as changes in the term structures take place

as responses to different expectations about monetary policies and/or different underlying economic conditions. Another supported notion is that the central banks of these countries conduct independent monetary policies.

Table 9. Convergence of Money Market Term Structures: The Whole Sample

Eigenvalues	H_2	Trace	Trace(.95)	λmax	λmax(.95)
(.074,.063,.037,.009)	$r \leq 3$	2.07	3.96	2.07	3.96
	$r \leq 2$	10.75	15.19	8.67	14.03
	$r \leq 1$	25.71	29.50	14.96	20.77
	$r \leq 0$	43.40	47.18	17.68	27.16

This finding is at variance with the implications of the interest rate parity, however, it can be argued that no convergence can be due to the fact that the U.S. and the U.K. have flexible exchange rate mechanisms with France and Germany as well as with each other. As explained above, under a flexible exchange rate system international transmission of economic shocks may be absorbed by changes in exchange rates, leaving nominal interest rates untouched. In an effort to explore how much the particular exchange rate system may affect long run convergence of term structures, statistical cointegration is examined between the term structures of Germany and France in a bivariate model. Results of this analysis are reported in Table 10. In this case, it is found that the common factors of Germany and France share a common stochastic trend, implying that they do not drift apart in the long run. This is consistent with the view that under an adjustable fixed exchange rate system, nominal interest rates will be directly influenced by transmission of

monetary shocks. To further analyze this point, bivariate cointegration analyses are conducted between the common factors from the term structures of other countries, which have a flexible exchange rate system. The trace statistics reject cointegration between the common factors of any other two country in the sample and hence, the money market term structures Germany and France emerge as the only countries in this sample that share a common stochastic trend and converge in the long run. The natural implication of this finding is that Germany and France are the only countries in the sample that cannot conduct independent monetary policies. This finding is also consistent with the notion that the monetary policy coordination goal of the EMS has been achieved at least to some degree.

Table 10. Convergence of Money Market Term Structures: Cointegration in Bivariate Models

	H_2	Trace	Trace(.95)
Germany - France	$r \leq 1$ $r \leq 0$	2.77 16.27	3.96 15.19
U.K.- France	$r \leq 1$ $r \leq 0$	2.07 6.02	3.96 15.19
Germany - U.K.	$r \leq 1$ $r \leq 0$	3.47 12.86	3.96 15.19
U.S.- U.K.	$r \leq 1$ $r \leq 0$	2.31 9.08	3.96 15.19
U.S. - Germany	$r \leq 1$ $r \leq 0$	3.70 8.59	3.96 15.19
U.S. - France	$r \leq 1$ $r \leq 0$	2.77 8.59	3.96 15.19

Next, it is tested, along the lines of the GDH, if the common factor from the German term structure is solely responsible for the long run behavior of the cointegrated system between the term structures of Germany and France. In other words, it is tested if the German common factor completely determines the long run trend of the cointegration system and the French common factor simply adjusts to changes in this trend. If this is the case, then it can be argued that the GDH is valid and no contribution is made by French monetary authorities to the evolution of the French money market term structure. To test this hypothesis, a likelihood ratio test is constructed by restricting the German common factor as the only significant variable in the permanent component driving the bivariate system. However, the likelihood ratio statistic rejects this hypothesis, as reported in Table 11. Thus, it is concluded that although the common factors from the German money market term structure and the French money market term structure evolve interdependently in the long run, both variables contribute to the system. In other words, it cannot be argued that the Bundesbank determines the monetary policy and other countries simply adopts this monetary policy. This finding is in contrast with Kirchgassner and Wolters (1991) who demonstrate a dominant position for Germany in the Euromarket between 1980-1988. Our interpretation of the result of the present study is that Germany has lost its role as the anchor country in the system after the currency crisis in 1992-1993 period. Widening of exchange rate bands and the fact that some countries dropped out of the system completely may have given a chance

to European central banks to act more independently. However, we still observe that the common factor from the term structure of Germany contribute a greater share to the permanent component driving the bivariate system confirming the relatively greater role of German monetary policies in the system.

Table 11. Cointegration Structure Between the Money Market Term Structures of Germany and France

Eigenvalues	Eigenvectors(v)	Eigenvectors(m)	p-value
(.057,.012)	0.240 -0.008 -0.111 0.186	0.780 0.718 -0.921 0.534	.002

3.5.3 Short Term Linkages Between Term Structures

In addition to long run interdependence, term structures may exhibit short run linkages. To examine short run linkages, causality relationships between the transitory components (i.e. spreads) from term structures are examined by constructing a multivariate VAR model. As argued by Hafer, Kutan and Zhou (1997), movements in spreads are generally understood to stem from changes in policy and if movements in transitory components are interdependent across the countries then it can be suggested that changes in economic policies are transmitted across countries also in the short run.

Transitory components are stationary and thus, they can be used in the VAR model directly. VAR models, developed in Sims (1980), are ideally suited to study short run relationships between variables since they represent fairly well approximations to the unknown structural model by using all the information in data.

Granger causality tests are conducted as conventional F-statistics with the null hypothesis of no short run causality. The results of causality tests are reported in Table 12 and it appears that two significant short run causal relations are detected. First, it is found that the transitory component from the German term structure significantly influences the transitory component of the French term structure while the causality does not run the other way. This asymmetric relationship indicates that monetary policy shocks from Germany affects the French money market rates in the short run. This suggests a more dominant policy making role for German monetary authorities in the EMS in the short run. This finding can be contrasted with that of Hafer, Kutan and Zhou (1997) who find that the spreads (i.e. transitory component) between long and short on-shore rates across the EMS countries change independently from German policy making. The different finding of the present paper may be due to the fact that this study uses the money market term structure, which is relatively more easily influenced by monetary policy actions of Central Banks. The second causality relation runs from the U.K. to the U.S. Similarly, this finding indicates that monetary shocks from the U.K. influence the U.S. money market rates in the short run.

Table 12. Short Run Linkages Between Term Structures

	p-value
U.K. → U.S.	0.004
U.S. → UK	0.38

(table cont.)

Germany → U.S.	0.60
U.S. → Germany	0.20
France → U.S.	0.14
U.S. → France	0.07
U.K. → Germany	0.40
Germany → U.K.	0.45
U.K. → France	0.42
France → U.K.	0.32
Germany → France	0.03
France → Germany	0.20

3.6 Concluding Remarks

The Euromarket term structures of the U.S., the U.K., Germany and France are used in this study to investigate international interest rate linkages, both in the short- and the long-run. A decomposition method, due to Gonzalo and Granger (1995), is used to extract the common factor driving the term structure of each country and the long run linkages between the countries are investigated by the full information maximum likelihood cointegration analysis. Cointegration tests indicate that common factors are not cointegrated and may drift apart arbitrarily in the long run. The implication of this finding is that changes in money market term structures do not take place as a response to common expectations about future monetary policy. To further the analysis, pairs of countries in the sample are tested for long run convergence of money market term structures. This analysis indicates that only

the common factors from the term structures of Germany and France have a stable long run relationship. This point is interpreted as a result of the adjustable fixed exchange rate system employed between the EMS countries and of the goal of economic policy coordination of the EU. Also implied is that no cointegration between the countries in the sample may result from the flexible exchange rate system used, since under flexible exchange rates nominal interest rates need not change in response to international monetary shocks.

Within this framework, the issue of German dominance in the EMS is tested. It is rejected that the common factor from the German money market term structure is responsible for the long run behavior of the common factor from the French money market term structure. Rather, the common factors evolve interdependently in the long run, with each contributing to the evolution of the trend. However, an analysis of short-run linkages between money market rates, by using the transitory components from the term structures, reveals that there is significant causality runing from the German term structure to the French term structure. This indicates that actions of the German monetary authorities have a significant influence on the French money market rates in the short run.

3.7 End Notes

1. See, for example, Von Hagen and Fratianni (1990) for a discussion that supports this interpretation.

2. In fact, the Deutsche Bundesbank (the German Central Bank) uses the 3-month Eurorate to judge the convergence of European monetary policies (see, Kirchgassner and Wolters, 1993).

3. The following relationship is termed as "covered interest parity" in the literature.

4. Kool and Tatom (1988) argue that international interest rate co-movements can exist even under this case. The implicit exchange rate change can have undesirable effects on other policy objectives, such as the price level, so that interest rates will still not be independent across countries.

5. As in Chapter 2, the unrestricted VARs for France and the U.K. are estimated with a dummy variable to account for the unusually turbulent times during the EMS crisis in 1992-1993.

6. As argued in Chapter 2, this composition of the term structure is consistent with the expectations theory which states that the longer maturity interest rates in the system should be weakly exogenous.

CHAPTER 4

PREDICTING FUTURE INTEREST RATES FROM YIELD SPREADS: THE EUROCURRENCY EVIDENCE

4.1 Introduction

As discussed in Chapter 2, the expectations theory of term structure (EHT) states that the long rate is equal to an average of current and expected future short rates and, perhaps, plus a constant term premium. Also implied in the formulation of the EHT is that with rational expectations, the slope of the term structure (which is equivalent to the yield spread) will be the optimal predictor of future interest rate changes. The goal of this essay is to investigate the proposition that there is predictive power embodied in the slope of the term structure. 1- and 3-month Eurocurrency rates are used in this essay and thus, it can be said that this essay aims to test the predictive power of the money market yield curve approximated by the Euromarket term structure.

As was shown earlier, the cointegration implications of the EHT holds under both forward looking (rational) and backward looking (adaptive) expectations, and also with substantial time-variation in term premia, as long as this variation is stationary. Testing for the cointegration implications is useful to investigate the *low frequency* properties of the term structure relationship and the long term

relationships between interest rates at different maturities but if it is aimed to test how much information is contained in yield spreads about future movements of interest rates, then additional assumptions, i.e. rational expectations and constant term premium, have to be imposed. Once these assumptions have been made, the EHT places certain restrictions on the future movement of the short-term rate with respect to the spread and this exact version of the EHT can be examined by testing these restrictions.

This study tests the existence of rational expectations/constant term premium theory in the short end of the maturity spectrum, 1- and 3- month, for Eurorates of several countries. The restrictions to be tested and the underlying theory are discussed below. But before proceeding further, it should be mentioned that a very similar data set was used by Gerlach and Smets (1997) to test the same hypothesis. However, a reexamination of the theory with the same data set in a similar period of time seems necessary for a couple of reasons.

The motivation for the present study is from the results of two papers. The first one is the study by Mankiw and Miron (1986). Mankiw and Miron (1986) examine the behavior of 3- and 6- month interest rates in the U.S. over the period 1890-1979 and find that prior to the founding of the Federal Reserve System in 1915, the spread between long rates and short rates has substantial predictive power. Additionally, they find that after 1915, however, the spread contains much less predictive power. The latter finding was already known, e.g. Shiller, Campbell and

Schoenholtz (1983), but the interesting point in their study is that they show that although after the founding of the Federal Reserve System the short term interest rate behaves like a random walk (or martingale), prior to the founding of the Federal Reserve System there was a predictable portion in the short rate. They conjecture that due to the Federal Reserve's commitment to stabilizing interest rates, the predictable variations in the short-term interest rates disappeared.

To consider the implications of this important observation for evaluating the tests of rational expectations model, notice that the rational expectations model merely states that the spread reflects expected changes in the short rate. However, if the short rate can be approximated as a random walk then the spread cannot have any predictive power since, by definition, a random walk process is unpredictable. To fully comprehend this is important because it states that while testing for the predictive power of the spread, researchers have to be careful to differentiate between predictable, i.e. transitory, and unpredictable, i.e. stochastic (permanent) variations in the short rate. The fact is that, according to the rational expectations theory, the spread should predominantly explain the variations in the transitory components of the future short rate and if the unpredictable (permanent) variations dominate over predictable (transitory) variations, then a regression analysis that uses the changes in the short rate as the independent variable will find no predictive power although the spread may well have predictive power with respect to what it is supposed predict according to the theory. This point illustrates that a test of the

expectations hypothesis should decompose the short rate into its permanent and transitory components and then, test the theory by using only the transitory components. This approach, which was absent in Gerlach and Smets (1997), is followed in this essay to test for the rational expectations model in the short end of Euromarket term structure.

The second reason to motivate the present study is from a recent article by Bekaert, Hodrick and Marshall (1997). They analyze the econometrics underlying the specification tests used in all studies that test for the rational expectations model and document extreme bias and dispersion in the small-sample distributions of all standard regression-based tests, including Gerlach and Smets (1997). More importantly, perhaps, they show that the biases arise because of the extreme persistence in short interest rates; i.e. because of a highly autocorrelated (unit root like) property in short rates. The problem arises because regression statistics essentially estimate serial correlation coefficients, and there are well-known biases in OLS estimates of autocorrelation coefficients for very persistent series (see, Kendall, 1954).

The problem they state is an important one and casts doubt on the conclusions of previous studies that test the rational expectations model by OLS regressions. However, a closer look at the source of the bias in the regression tests states that the problem that causes the bias is actually related to the first motivation of the current study. Bekeart, Hodrick and Marshall (1997) state that biases are

caused in the regressions because of the extreme *persistence* in short rates and this is just another manifestation of the problem that arises when the variation in the permanent component dominates over the variation in the transitory component. By definition, it is the permanent component of the short term interest rates that cause the extreme persistence and once this component is removed from the short rates and the theory is tested on the transitory components, the bias will disappear or will become negligible since, again by definition, transitory components do **not** have *persistence*. In other words, these points suggest that the cure to two problems in testing for rational expectations model, one economic theoretic and the other is econometrics theoretic, is the same. This study is the first one that recognizes these two problems and corrects for them; hence, arguably the results of the present essay could yield new findings.

In the next section the theory and restrictions of the rational expectations model of the term structure of interest rates is examined and a brief review of the literature is provided. Although testing for the rational expectations model of the term structure is rather straightforward, different studies have found widely contradictory results, as reviewed in Essay 1, by using data drawn from different countries, different periods of time and at different maturities. The literature is vast and many papers that test the rational expectations/constant term premium theory have already been reviewed in Chapter 2; therefore, only papers that directly motivate the analysis in this essay are discussed in this Chapter. Section III reports

the analytical bias estimates contained in the conventional regression, according to the derivations in Bekeart, Hodrick and Marshall (1997) under a first-order autoregressive model for the short rate. The cointegration structure is estimated, the Gonzalo-Granger decomposition is performed and the rational expectations theory is tested in Section IV. Section V offers the concluding remarks of the paper.

4.2 Prior Work

As mentioned above, this essay concentrates on money market rates and uses 1- and 3- month Euro-currency rates. If r_t is taken as the yield on a one-month Eurocurrency and R_t is taken as the yield on three-month Eurocurrency then the EHT states that the current three-month yield is an average of the current one-month yield and the expected future one-month yields up to two periods in the future. This relationship can be expressed as

$$R_t = (1/3)(r_t + E_t r_{t+1} + E_t r_{t+2}) + \theta \qquad (4.1)$$

where E_t denotes the expectation formed at time t. Essentially, this equation represents an expected arbitrage relationship and states that the return from investing in a three-period Eurocurrency equals, up to a constant, the expected return from investing sequentially in three one-period Eurocurrencies. To derive the single-equation tests of this model, impose the rational expectations assumption so that

$$r_t = E_t r_{t+1} + \upsilon_{t+1} \qquad (4.2)$$

where υ_{t+1} is orthogonal to the information available at time t.

Also, it is easy to demonstrate some time series properties of the relationship in (1). Rewrite (1) as (where θ is subtracted)

$$R_t - r_t = S_t = (2/3)E_t\Delta r_{t+1} + (1/3)E_t\Delta r_{t+2} \qquad (4.3)$$

which illustrates that if both interest rates I(1) processes, the spread between them is I(0) under the expectations hypothesis. This simply means that R_t and r_t cointegrate with cointegrating vector [1,-1].[1] Thus, the relationship in (1) can be expressed in terms of stationary processes for the spread, S_t, and the first difference of r_t, D_t. Hence, (1) can be rewritten as

$$S_t = (1/3)(2E_tD_{t+1} + E_tD_{t+2}) + \theta \qquad (4.4)$$

Following Driffill, Psaradakis and Sola (1997) and Mankiw and Miron (1986) the empirical validity of (3) can be tested by estimating an OLS regression of $D_t + 2D_{t-1}$ on S_{t-2} and a constant. This follows by inverting (1a) to yield

$$D_t + 2D_{t-1} = \theta + \delta S_{t-2} + \upsilon_t \qquad (4.5)$$

where $\upsilon_t=(D_t-E_{t-2}D_t)-2(D_{t-1}-E_{t-2}D_{t-1})$ is a combination of the forecasting errors associated with D_t and D_{t-1}. The above relationship shows that the spread between three-month and one-month interest rates should have predictive power in forecasting changes in the one-month rate. In particular, the coefficient on S_{t-2} should be insignificantly different from 3, and that the constant term is an estimate of minus thrice the term premium if the expectations hypothesis holds.

Similar regressions in this maturity were estimated in many studies but the empirical results have consistently led researchers to reject the rational expectations

model of the term structure, especially for the U.S. term structure data. Well-known examples of this research genre include Campbell and Shiller (1991), Shiller, Campbell and Shoenholtz (1983), Mankiw and Miron (1986), Hardouvelis (1988) and Mishkin (1988). These studies differ in their use of frequency of data as well as allowing for different determinants of time-varying term premiums or different time spans for data. But a general conclusion has emerged as the rational expectations model should be rejected, although the "weak" version of the hypothesis, which states that the slope coefficient in the regression should be positive even if it does not exactly equal the theoretically predicted value of 3, has found some support. For Eurocurrency rates, Gerlach and Smets (1997) use data for 17 countries and generally find support for the rational expectations theory. Specifically, they find that in almost half of the cases the slope coefficient is insignificantly different from its theoretical value; thus, supporting the exact rational expectations theory. In addition, in all of the cases the slope coefficient is positive indicating that the spread predicts the direction of the future movements of the short-rate correctly. Of course, as forcefully argued by Bekeart, Hodrick and Marshall (1997) and also calculated in the present study, all of their regressions are subject to substantial small sample bias. In fact, evaluating the theory by using bias-free distributions may strengthen the case against the rational expectations theory, because of the positive bias, or weaken the case against the theory, because of the increased dispersion. Also, it is interesting to note that Gerlach and Smets (1997) argue that ".... the results

reinforce the conclusion in Mankiw and Miron (1986) that the easier it is to forecast future short rates, the better the data conform to the implications of the expectations hypothesis". This finding demonstrates the importance of removing the permanent component from the short rate and testing the theory by using the transitory component, which is the portion of the short rate that the spread is supposed to predict.

In other studies in the Eurocurrency markets, Kugler (1990) finds that the data for Eurofranc and EuroDM interest rates support the rational expectations hypothesis, whereas those for Eurodollar interest rates do not. As reviewed in Essay 1, Mogue and Szakmary (1994) concentrate on long-term Eurorates and conclude that long term Eurorates tend to move in the opposite direction to that predicted by the rational expectations theory.

This study decomposes the short rate into its permanent and transitory components, i.e. $[r^p \; r^t]$, by the decomposition method of Gonzalo and Granger (1995) and then, establishes a counterpart of equation (4.5) as

$$D^T_t + 2D^T_{t-1} = -3\theta + \delta S_{t-2} + \upsilon_t \qquad (4.5a)$$

where D^T_t is the first difference of r^T_t, i.e. transitory components of the short rates. Thus, this equation represents an effort to test the proposition that the spread predominantly explains the variation of the transitory component of future interest rates. As argued above, this should be an economically more meaningful way to test for the rational expectations hypothesis, since the permanent part is by definition

stochastic and unpredictable, and also this approach should take care of the econometric problem related to single-equations tests of the rational expectations model as documented by Bekeart, Hodrick and Marshall (1997). The above relationship shows that the spread between three-month and one-month interest rates should have predictive power in forecasting **transitory** changes in the one-month rate and, in the regression of the left-hand side on the spread, a coefficient of 3 should be obtained if the expectations hypothesis holds. This approach to test for rational expectations model is used in the literature in a study by Choi and Wohar (1995). They investigate the behavior of three and six month U.S. Treasury bill rates for four sub-periods between 1910 and 1989 and find that the failure of the spread to predict future short-rates during the post-1979 period results from the fact that the variation in the permanent components of the short rates dominates over the variation of the transitory components. Consistent with the arguments raised in introduction, the spread is found to have predictive power when the permanent component is removed from the short-rate.

4.3 Biases in the Single-Equation Regression Test

This section shows, drawing heavily on Bekeart, Hodrick and Marshall (1997), that the regression test of the expectations theory, conducted by estimating equation (4), is severly biased in small samples. The underlying reason of the bias is the extreme persistence (unit root like behavior) observed in the short rates. As Bekeart, Hodrick and Marshall (1997) state, the bias in estimating autocorrelations

translates into a large upward bias in the slope coefficients of standard tests of the expectations hypothesis because the dependent variables depend on future short rates and the regressors depend negatively on current short rates. In this section, first-order approximations to the small sample bias in the regression test of the expectations theory are calculated under the following AR(1) model for the short rate:

$$r(t+1) = \mu + \rho r(t) + v(t+1) \qquad (4.6)$$

As in Bekeart, Hodrick and Marshall (1997), the AR(1) model is mainly chosen for analytical tractability and to demonstrate the link between the small-sample bias and the degree of unit root like behavior in the short rate. OLS estimates of ρ in equation (5) for 1-month Eurorates of the countries in the sample are reported in Table 13. Kendall (1954) shows that there is a bias in the calculation of ρ and the "bias-adjusted ρ's" can be calculated as $(\rho + (1/T))/(1-(3/T))$. The bias adjusted values of the autocorrelation coefficients are also reported in Table 13.

Table 13. A First-order Autoregressive Model For the Short Interest Rate

	ρ	bias-adj. ρ
Austria	0.965	0.982
Belgium	0.982	0.999
Britain	0.973	0.990
Denmark	0.914	0.930
France	0.831	0.846

(table cont.)

Germany	0.975	0.992
Italy	0.894	0.910
the Netherlands	0.959	0.976
Norway	0.889	0.905
Sweden	0.874	0.889
U.S.	0.972	0.989

Bekeart, Hodrick and Marshall (1997) show that the expected value of the slope coefficient of equation (4) equals

$$E[\hat{\delta}_1] = 3 + \frac{-(1-\rho)}{n(1-\rho)-(1-\rho_n)} \sum_{j=1}^{n-1} \theta_j \tag{4.7}$$

where θ_j denotes the small-sample bias in the OLS estimate of ρ^j. They also derive the first-order approximation to θ_j as:

$$\theta_j \approx [\frac{(1+\rho)}{(1-\rho)}(1-\rho^j)+2j\rho^j][\frac{1}{T-(n-1)}] \tag{4.7}$$

From the analytical derivations, the expected value of the slope coefficient in an OLS regression of equation (4) can be calculated. The expected values for each country in the sample are reported in Table 14. The results reveal the existence of a substantial small-sample bias in the single-equation regression test. For example, the

expected value of the slope coefficient in an OLS estimate of equation (4) for the U.S. data is calculated as 4.571, rather than the asymptotic value of 3; whereas for Belgium, the expected distribution is calculated as a stunning 20.45. These extreme small-sample biases suggest that it is worthwhile to reexamine the theory by conducting bias-free tests. It is also worth noting that for longer maturities, additional bias term must be added to the analytical estimates. For example, Gerlach and Smets (1997) use 1-, 3-, 6- and 12- month rates and the regression that uses 1- and 12-month rates is even more biased in small-samples than the one that is considered in this study. Also, as indicated above, notice that the small sample biases differ across countries since the degree of persistence in the short-rate is different for each country. In sum, the analytical estimates indicate that the single-regression test of the rational expectations hypothesis should not be conducted by relying on the asymptotic theory, as has so many times been done in the literature.

Table 14. Estimates of the Small Sample Bias In The Single-Equation Regression Test

	Analytical estimate
Austria	3.954
Belgium	20.450
Britain	4.730
Denmark	3.233
France	3.097

(table cont.)

Germany	5.167
Italy	3.178
The Netherlands	3.711
Norway	3.168
Sweden	3.141
U.S.	4.571

4.4 Permanent-Transitory Decomposition of the Short Rate

In an effort to conduct unbiased regression tests of the rational expectations hypothesis and to test the theory in an economically more meaningful way, the short rate is decomposed into its permanent and transitory components and the theory is tested by using the transitory component. As argued in introduction, this approach represents an effort to test the proposition that the spread should have predictive power for only changes in transitory component, since permanent component is by definition stochastic and unpredictable. It is also shown in this section that the small sample bias in the regression test disappears, or becomes negligible, when the theory is tested by using transitory components, since the bias is due to extreme persistence in the short rate. The expectations hypothesis requires that domestic interest rates should be cointegrated and the cointegration structure between 1-month and 3-month rates is reported in Table 15. It has been established in Chapter 2 that the Eurorates at different maturities are cointegrated and thus, it is not surprising to find that 1- and 3- month rates are cointegrated.

Table 15. Testing For Cointegration Between 1- and 3-Month Rates

	H_2	Trace	Trace(.95)
Austria	$r \leq 1$ $r \leq 0$	1.62 33.79	3.96 15.19
Belgium	$r \leq 1$ $r \leq 0$	0.92 58.65	3.96 15.19
Britain	$r \leq 1$ $r \leq 0$	2.54 37.76	3.96 15.19
Denmark	$r \leq 1$ $r \leq 0$	2.31 56.23	3.96 15.19
France	$r \leq 1$ $r \leq 0$	2.31 41.32	3.96 15.19
Germany	$r \leq 1$ $r \leq 0$	2.31 36.19	3.96 15.19
The Netherlands	$r \leq 1$ $r \leq 0$	2.54 55.88	3.96 15.19
Italy	$r \leq 1$ $r \leq 0$	3.00 75.70	3.96 15.19
Norway	$r \leq 1$ $r \leq 0$	0.92 47.12	3.96 15.19
Sweden	$r \leq 1$ $r \leq 0$	2.54 28.05	3.96 15.19
U.S.	$r \leq 1$ $r \leq 0$	1.84 38.41	3.96 15.19

To perform the permanent-transitory component analysis, the cointegration structure between 1- and 12- month rates are estimated and are reported in Table 16. Transitory components are constructed by using eigenvectors(v), under the Gonzalo-

Granger decomposition, for each term structure and A1 and A2 are the coefficients. Transitory components are extracted from each term structure so that the expectations theory can be tested by estimating the equation (4.5a).

Table 16. Cointegration Structure and Permanent-Temporary Decomposition

	Eigenvalues	Eigenvectors(v)	Eigenvectors(m)	A1	A2
Austria	(.130,.007)	3.441 0.124 -3.451 0.325	3.037 0.433 -3.695 1.648	0.481 0.480	0.230 -0.060
Belgium	(.222,.004)	5.057 -0.455 -4.924 0.762	3.365 -2.430 -2.490 3.801	0.678 0.696	0.523 0.334
Britain	(.142,.011)	4.061 0.214 -4.149 0.096	3.206 -0.261 -2.816 1.582	0.776 0.760	0.295 0.048
Denmark	(.209,.010)	2.282 -0.198 -2.150 0.472	1.244 -0.580 -1.046 1.459	1.033 1.096	0.701 0.279
France	(.156,.010)	1.652 -0.502 -1.573 0.732	0.676 0.830 -0.435 -1.373	-1.633 -1.715	-0.349 -0.269
Germany	(.137,.010)	6.824 0.066 -6.791 0.344	5.345 -2.120 -4.579 3.925	0.548 0.550	0.317 0.171
the Netherl.	(.207,.011)	5.855 -0.393 -5.741 0.828	4.062 -1.911 -3.755 3.656	0.550 0.561	0.350 0.183
Italy	(.271,.013)	2.324 -0.128 -2.264 0.349	1.025 -0.348 -1.016 1.002	1.469 1.508	0.650 0.225
Norway	(..182,.004)	2.013 -0.167 -2.034 0.494	1.095 -0.015 -1.334 1.031	0.995 0.984	0.504 0.007
Sweden	(.105,.011)	4.096 0.175 -4.170 0.215	1.764 -1.155 -1.613 2.082	1.123 1.103	0.561 0.311
U.S.	(.147,.008)	5.158 -0.119 -5.053 0.395	3.609 -0.235 -3.324 1.413	0.828 0.845	0.231 0.038

However, before proceeding with that step, analytical approximations to the small sample bias in the OLS regression is calculated for this case as well. Similar to the above analysis, a first-order autoregressive model for the transitory component of the short rate is estimated, reported in Table 17, and the analytical estimates of the expected distributions of the slope coefficient in an estimate of equation (4.5a) is also calculated in Table 17. It can be observed that the persistence is much smaller and as a consequence, the expected values of the slope coefficient in equation (4.5a) is very close to their asymptotic values, for every country in the sample. For example, the "bias-adjusted" autocorrelation coefficient for the U.S. rate is now estimated as 0.477 and the analytical estimate of the expected value of the slope coefficient of equation (4a) is 3.018. For Belgium, the expected value of the slope coefficient is 3.026, very close to its asymptotic value of 3. Thus, the analytical estimates suggest that small biases are negligible and a regression test of the expectations theory by estimating equation (4a) can be conducted. The decomposition method indeed proves to be a cure to the statistical problems related to the single-equation test of the expectations hypothesis.

Table 17. Estimates of the Small Sample Bias In the Regression Test Using Only the Transitory Component

	ρ	bias-adjusted ρ	analytical estimate
Austria	0.476	0.486	3.019

(table cont.)

Belgium	0.565	0.576	3.026
Britain	0.471	0.481	3.018
Denmark	0.309	0.317	3.011
France	0.235	0.242	3.009
Germany	0.521	0.532	3.022
Italy	0.034	0.038	3.004
The Netherlands	0.339	0.347	3.012
Norway	0.121	0.126	3.006
Sweden	0.161	0.167	3.007
U.S.	0.467	0.477	3.018

4.5 Testing for the Rational Expectations Hypothesis

Equation (4.5a) is estimated by OLS regressions for 1- and 3-month Eurorates of all 11 countries in the sample and the findings are reported in Table 18. Again, the rational expectations hypothesis requires that the slope coefficient, δ, equals 3. The other hypotheses test are $\theta=0$; $\delta=0$; and the joint hypothesis that $\theta=0$, $\delta=3$ which states that the rational expectations theory holds exactly without a term premium in the term structure. Table 18 provides estimates of the parameters

in equation (4.5a) together with the estimated standard errors and the p-values for the hypotheses. It should be mentioned that, since the expectations theory predicts two months ahead 3-month interest rate, employing monthly overlapping data in the estimation of equation (4.5a) results in serially correlated error terms and the OLS standard errors are not efficient in this case. To correct for this, a procedure suggested by Newey and West (1987) is employed to obtain an efficient estimate of the variance-covariance matrix.

Table 18. Testing for the Rational Expectations/Constant Term Premium Theory

Country	Parameter Estimates		p-Values for hypothesis tests				
	θ (s.e.)	δ (s.e.)	$\theta=0$	$\delta=0$	$\delta=3$	$\theta=0$ $\delta=3$	R^2
Austria	-0.149 (.038)	0.944 (.222)	0.000	0.000	0.000	0.000	.38
Belgium	-0.295 (.091)	2.717 (.406)	0.000	0.001	0.487	0.000	.32
Britain	-0.677 (.048)	1.364 (.156)	0.165	0.000	0.000	0.000	.34
Denmark	-0.551 (.150)	2.300 (.307)	0.000	0.000	0.024	0.000	.44
France	-0.182 (.075)	0.950 (.115)	0.016	0.000	0.000	0.000	.52
Germany	-0.172 (..055)	2.450 (.347)	0.002	0.000	0.114	0.000	.35
Italy	-0.574 (.146)	2.680 (.217)	0.000	0.000	0.142	0.000	.58

(table cont.)

The Netherlands	-0.244 (.074)	2.756 (.581)	0.001	0.000	0.676	0.000	.44
Norway	-0.148 (.104)	1.628 (.139)	0.157	0.000	0.000	0.000	.55
Sweden	-0.132 (.140)	3.754 (.322)	0.345	0.000	0.020	0.048	.54
U.S.	-0.254 (.049)	1.545 (.224)	0.000	0.000	0.000	0.000	.40

The results of the empirical analysis can be summarized as follows. First, only for relatively few countries in the sample, it is supported that the rational expectations hypothesis, with a constant term premium, is fully valid. In other words, the exact restriction of the rational expectations theory, which states that the slope coefficient should be insignificantly different from the theoretically predicted value of 3, finds support in data only for Belgium, the Netherlands, Germany and Italy. For the other countries, the null hypothesis that $\delta=3$ is rejected. This finding can be interpreted as an effect of errors in expectations formation by agents and/or with the existence of a time-varying premia in the term structure. Second, in all of the eleven cases, the slope coefficient is positive and significantly different from zero. Thus, the "weak" version of the rational expectations hypothesis is supported. There is predictive power embodied in the yield spread for the future movement of the transitory component of the short rate. Considering that the regression tests are bias free in this case and the predictive power of the spread is measured with respect

to the portion of the short rate that it is supposed to predict, this empirical finding indicates that there is an element of truth in the rational expectations theory. And third, the joint hypothesis of rational expectations/no term premium, which has sometimes been called the "unbiased expectations" hypothesis, is rejected at 5% significance level for all countries, except for Sweden. Coupled with the observation that the intercept term in the regression is almost always significantly different from zero, this finding supports the existence of a term premium in the term structure. Overall, the results are rather supportive of the rational expectations theory. It seems that the money market spread predicts the cumulative movements of the transitory component of the short rate exactly for some countries and fairly closely for some other countries. These findings support the notion that the rational expectation theory can be regarded as a useful benchmark in monetary economics and decision making in financial markets and also that monetary authorities can place an emphasis on the money market spread as an indicator variable.

4.6 Concluding Remarks

This study tests the rational expectations hypothesis for 1- and 3-month Eurorates of 11 countries. It is argued that the conventional single-equation regression tests are extremely biased in small samples due to unit root like persistence in the short rate. To eliminate the bias in the regression analysis of the rational expectations theory, the short rate is decomposed into its permanent and transitory components, by means of a recently developed time series technique, and

then, the theory is tested by using only the transitory components. The transitory components are by definition free of extreme persistence and the calculated analytical estimates of the expected distribution of the slope coefficient have negligible bias. It is also argued that this approach represents an economically meaningful way to test for the predictive power of the spread since the permanent component is by definition stochastic and unpredictable; thus, the transitory component remains as the part the spread is supposed to predict.

The empirical findings provide support for the rational expectations hypothesis. In all of the regressions the slope coefficient is positive indicating that the spread predicts the direction of the future movements of the transitory component of short rate correctly. This findings is robust across currencies and thus, it can be argued that it is not an outcome of a particular monetary regime. For several countries in the sample, it is found that the slope coefficient is insignificantly different from the theoretically predicted value; thereby, providing support for the exact restriction of the rational expectations theory. For other countries, this restriction and thus, the exact rational expectations theory is rejected.

The supportive findings of this study provides that the rational expectations theory, with a constant term premium, can be used as a benchmark in monetary economics and modeling in financial markets, at least until a better model is developed. The money market spread, consistently across currencies, has predictive

power embodied in it and hence, it is recommended that monetary authorities pay close attention to the spread as an indicator variable.

4.8 End Notes

1. This implication had already been demonstrated in Chapter 2 for a multivariate system. Here, the same relationship is displayed for two rates just to make the arguments more easily tractable.

CHAPTER 5

CONCLUSIONS

This dissertation examines the term structure relationship in Eurocurrency markets for eleven countries. The first essay is an attempt to understand the empirical observation that yields of bonds at different maturities and the inflation rate appear to move together over time. Therefore, the analysis in this essay concentrates on the low frequency components of interest rates and the inflation rates and tries to unfold the long term relations. The expectations hypothesis of term structure and the Fisher relation are used as working hypotheses and these hypotheses are evaluated interrelatedly to fully characterize the long run properties of the term structure relationship. The cointegration implications of the expectations hypothesis of term structure imply that there should be one common stochastic trend driving the changes in the yield curve and the expected inflation rate is an obvious candidate for the common trend according to the Fisher relation. a full information maximum likelihood method is used to test for the cointegration properties of the expectations hypothesis and a factor decomposition technique is used to identify the common trend driving the term structure. Generally, the cointegration implications of the expectations hypothesis of term structure is supported and also, the common factor and the inflation rate is found to be cointegrated, supporting the Fisher

relation. Perhaps more importantly, it is found that the common factor driving the term structure contains information about the behavior of the inflation rate for every country. This is consistent with the view that rational agents in financial markets incorporate the predictable portion of the future inflation rate into yields while setting prices.

The second essay focuses on intercurrency relationships between term structures. The covered interest parity theorem is used as the working hypothesis of this essay. It is investigated if a convergence between the money market term structures of the U.S., the U.K., Germany and France has occurred over the last two decades. The covered interest parity theorem argues that a convergence should be valid. The last two decades has seen a liberalization in international financial markets and an increased capital mobility, which should serve to facilitate convergence of nominal yield curves. However, a factor that can work against convergence even under complete financial integration is the nature of the exchange rate regime employed. It is argued that under a flexible exchange rate regime the transmission of monetary shocks can be absorbed by changes in exchange rates, leaving nominal rates unaffected. To control for the effect of the exchange rate mechanism, at least to some degree, the relationship between the term structures of Germany and France are examined in a bivariate setting. Germany and France are members of the exchange rate mechanism of the European Union, which is an adjustable fixed exchange rate system.

The statistical cointegration analysis is used in the empirical analysis. Common factors driving the money market term structures are extracted by using the method developed by Gonzalo and Granger (1995) and the relationship across the countries is examined by Johansen's (1991) analysis. The results do not support converge. The term structures are not cointegrated and can drift apart arbitrarily. To examine if the exchange rate system can have an impact, cointegration is tested between the money market term structures of Germany and France. It is found that they are cointegrated which supports that an adjustable fixed exchange rate regime may be necessary for convergence of nominal yield curves even under financial markets integration. However, no sign of German dominance over the French money market rates is detected.

In addition to long run linkages, the empirical analysis also investigates short run linkages. Transitory components from term structures are used to detect short run causality relations in a multivariate vector autoregression setting. The results indicate a significant causality running from Germany to France.

The third essay imposes the rational expectations and constant term premia assumptions on the expectations hypothesis of term structure and tests for the implications of this model. The rational expectations hypothesis implies that the yield spread should contain predictive power about the future movement of the short rate over the life of the long term bond. This implication can be tested by estimating a single-equation regression and it is argued that the rational expectations hypothesis

restricts the slope coefficient of the regression. This restriction has been tested in many papers and in fact, in a recent paper this hypothesis is tested for Eurocurrency rates that are used in this dissertation. However, motivations from the extant literature necessitate a reexamination of the rational expectations hypothesis.

First, in a recent study, it is shown by Bekeart, Hodrick and Marshall (1997) that the standard single-equation regression test of the rational expectations theory is severly biased in small samples, for U.S. data. By using the analytical approximation derived in their paper, this study calculates the analytical estimates to the small sample bias and shows that the single-equation regression test is also biased for Eurocurrency rates. This implies that the results of previous studies may suffer from statistical biases and should be reexamined. Bekeart, Hodrick and Marshall (1997) also show that the underlying cause of the small-sample bias is extreme persistence of the short rate. Therefore, this study proposes to extract the permanent component of the short rate and to test the rational expectations theory by using only the transitory component of the short rate. This approach should provide bias-free statistics since, by definition, transitory components do not have extreme persistence. This decomposition is accomplished by using the Gonzalo and Granger (1995) method.

Also, this approach should provide an economically more meaningful way to test for the theory. The permanent component is stochastic and thus, unpredictable. Therefore, the transitory component is the only part of the short rate that the spread

is supposed to predict and a better measurement of the theory can be conducted by using the transitory component of the short rate. This is also consistent with the motivation in Mankiw and Miron (1986) who find that when the short rate behaves like a random walk, dismal results are found for the rational expectations theory. Also, it is noteworthy that calculated analytical bias estimates do not state that single-equation regression is biased in this case.

The empirical analysis indicates that there is some truth in the rational expectations theory, even though the exact restriction of the hypothesis is rejected for a number of countries. For each country, it is found that the slope coefficient in the regression is positive and significant. This states that the spread predicts at least the direction of future changes in the short rate correctly and there is some predictive power embodied in the spread. Even more impressive is that for some countries the exact restriction of the rational expectations hypothesis on the slope coefficient is not rejected. Considering that the regressions are bias-free, some support is lent to the rational expectations hypothesis in financial markets.

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VITA

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DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Cetin Ciner

Major Field: Business Administration (Finance)

Title of Dissertation: Three Essays on the Term Structure of Eurocurrency Rates

Approved:

Geoffrey Booth
Major Professor and Chairman

Dean of the Graduate School

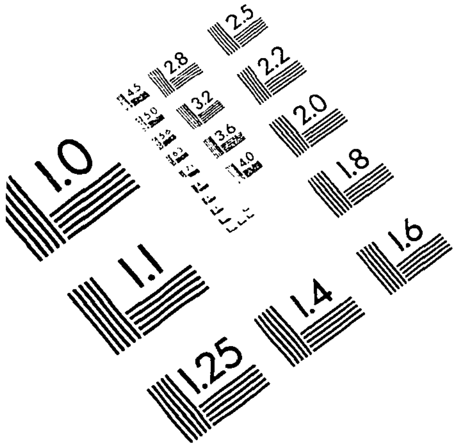
EXAMINING COMMITTEE:

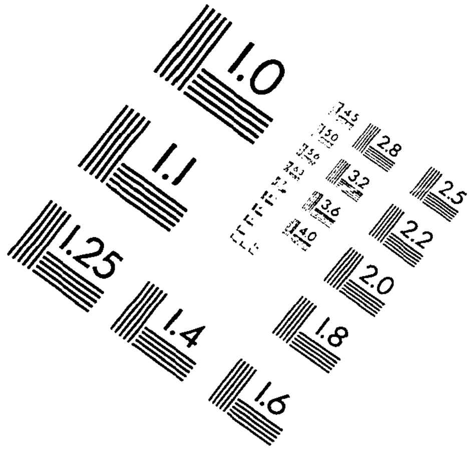
Thomas Calhoun

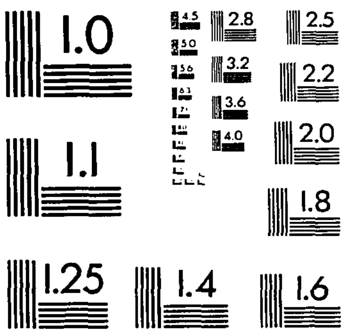
Date of Examination:

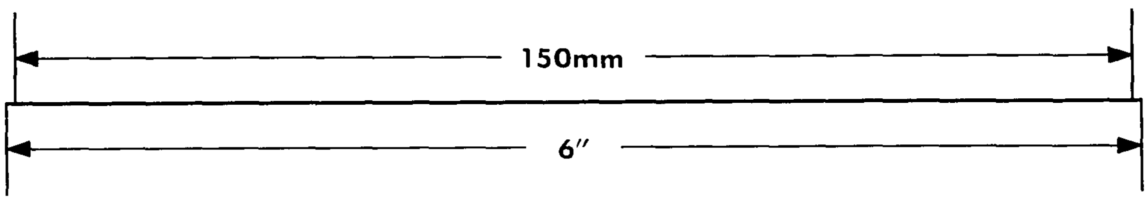
April 28, 1998

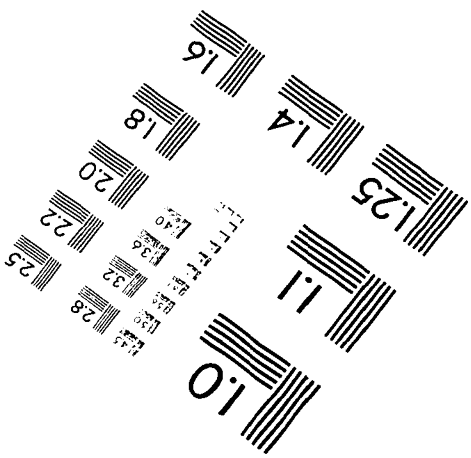
IMAGE EVALUATION TEST TARGET (QA-3)

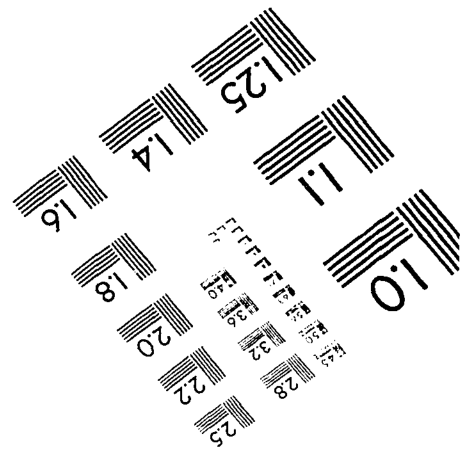












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