EUROPEAN CENTRAL BANK

WORKING PAPER SERIES
NO. 569 / DECEMBER 2005

TOWARDS EUROPEAN MONETARY INTEGRATION

THE EVOLUTION OF CURRENCY RISK PREMIUM AS A MEASURE FOR MONETARY CONVERGENCE PRIOR TO THE IMPLEMENTATION OF CURRENCY UNIONS

by Fernando González
and Simo Launonen

EUROPEAN CENTRAL BANK

WORKING PAPER SERIES

NO. 569 / DECEMBER 2005

TOWARDS EUROPEAN MONETARY INTEGRATION

THE EVOLUTION OF CURRENCY RISK PREMIUM AS A MEASURE FOR MONETARY CONVERGENCE PRIOR TO THE IMPLEMENTATION OF CURRENCY UNIONS [1]

by Fernando González [2]

and Simo Launonen [3]

In 2005 all ECB publications will feature a motif taken from the €50 banknote.

1 The authors would like to thank seminar participants at the Swedish School of Economics and Business Administration and University of Vaasa, Finland, and an anonymous referee for valuable comments. The views expressed in this paper are those of the authors alone and do not necessarily reflect those of the ECB or the Eurosystem.

2 European Central Bank, Kaiserstrasse 29, D-60311, Frankfurt am Main, Germany; e-mail: Fernando.Gonzalez@ecb.int

3 SEB Merchant Banking, Unioninkatu 30, P.O. Box 630, 00101 Helsinki, Finland; e-mail: simo.launonen@seb.fi

Address
Kaiserstrasse 29
60311 Frankfurt am Main, Germany

Postal address
Postfach 16 03 19
60066 Frankfurt am Main, Germany

Telephone
+49 69 1344 0

Internet
http://www.ecb.int

Fax
+49 69 1344 6000

Telex
411 144 ecb d

ISSN 1561-0810 (print)
ISSN 1725-2806 (online)

CONTENTS

Abstract

We assess monetary convergence preceding the implementation of the European Monetary Union (EMU) through Kalman filtering estimates of the risk premium of eleven forward exchange rates of European and non-European currencies. Since all participating currencies are in effect identical from inception of a currency union, the convergence process to such an identical status should be reflected in the participating currencies' risk premiums prior to monetary union implementation. Starting from this assumption, we show the paths followed by the participating currencies towards monetary union. We find that the co-movements of risk premiums among the preceding European Monetary System (EMS) currencies differ across time periods but display a tendency to convergence to the German mark's risk premium up to EMU implementation. The paper also shows a clear pattern of asymmetry of the participating currencies in relation to the German mark.

JEL classification: F02, F31, F33, F36, G15, G18

Keywords: currency unions, European Monetary Union, foreign exchange risk premium.

Non technical Summary

This paper investigates the relationship between European and non-European currencies' risk premium in the period preceding European monetary integration. The study of these relationships is interesting because it can provide a better understanding of the progression of monetary convergence prior to the implementation of a monetary union. We focus on the launch of the euro as the most prominent event of this kind to this date.

The basic idea driving our analysis is that since the beginning of a monetary union all participating currencies are in effect identical, the convergence process to this identity should therefore be reflected in the participating currencies' risk premium prior to monetary union implementation. Foreign currency risk premiums can be interpreted as a gauge of the degree of uncertainty associated with a particular currency. In the context of monetary integration, if two currencies were seen as essentially the same currency, new arrival of information would cause a move in the same direction and magnitude for both currencies; in other words, their risk premium profile would be the same.

We use this principle to first show the evolution of convergence of the risk premium of different currencies relative to the German mark risk premium, seen as the anchor currency, and second to test the level of asymmetry of the convergence between the German and other European currencies or, in other words, the extent to which participating currencies' risk premium moved towards that of the German mark and vice versa.

We are able to show through the use of univariate representations of the risk premium, obtained through Kalman filtering technology, the paths and speed towards convergence of the European currencies participating in EMU. As regards the level of asymmetry in the convergence process, it is possible to show, through rolling window bivariate causality tests, a clear pattern of asymmetry of the different participating currencies in relation to the German mark. This asymmetry does not hold for the Dutch guilder, which was seen as proxy for the German mark almost for the entire analysed period. The analysis also shows that we cannot exclude the possibility of the U.S. playing an indirect role in the European Monetary System through a significant relationship between the German mark and U.S. dollar.

The methodology presented in the paper may be used as an alternative way for looking at the evolution in the formation of currency unions by examining the role of possible anchor currency candidates. This proposal could also be useful in the context of financial market stability in situations preceding monetary policy integration or in situations where new currencies opt to join a monetary union, e.g. new EU entrants joining the euro. Possible extensions to the paper could be the analysis of the source of risk premium by identifying, for example, country specific risks and common or systematic risks of countries participating in monetary unions, the examination of regime-switching models to identify changes in coordination in national monetary policies and the methodological treatment and analysis of the role of third party currencies (e.g. the US dollar).

1. Introduction

This paper studies the relationship of European and non-European currencies risk premium in the context of the European Monetary Integration. We study these relationships because they can provide a new measure to assess the progression of monetary convergence preceding the implementation of a currency (hereafter: monetary) unions. Since from inception of the monetary union, all participating currencies are effectively identical, the convergence to this identity should be reflected in the participating currencies' risk premiums prior to its implementation.[1]

Some authors have characterized the EMS not as a coordinated system but as an asymmetric one dominated by the German Bundesbank [MacDonald and Taylor (1991), Hagen and Fratianni (1990)]. This means that the Bundesbank determined its monetary policy autonomously and other countries surrendered their monetary policy autonomy to the German leadership. One possible explanation given for that behaviour is that by linking domestic monetary policy to that of Germany, other countries' policymakers enhanced their own credibility (Giavazzi and Pagano, 1988). This argument is known in the literature as the strict or strong German Dominance Hypothesis (GDH) in which national central banks completely surrendered their monetary policy autonomy to the Bundesbank. Under this hypothesis the relationship between national central banks and the Bundesbank is seen as unidirectional, running from changes in German policy to other EMS members' policies.

Another version of this argument is given by the weak form of the GDH. In this version a feedback among EMS countries is allowed but Germany continues playing a prominent role [Smeets (1990), Von Hagen and Frantianni (1990)]. Other authors, however, have argued that while Germany does not play a dominant and independent role within the EMS, the US interest rate has important causal influences on the EMS members' rate in addition to the German rate [Katsimbris and Miller, 1993), Artus *et al.* (1991) and Hassapis *et al.* (1999)]. Weber (1991) offers an alternative in-

[1] In the first stage of the monetary integration process participating countries agreed to increase coordination of monetary and fiscal policies. In the second stage, which begun in January 1994, member countries worked toward a common monetary policy. During this period the European Monetary Institute was created. In the last stage which started on January 1st 1999 the exchange rates of the participating countries were irrevocably fixed to the Euro. The ECB formulates a common monetary policy for the Euro area that is implemented with the help of the member nation's central banks. A chronology of events during the 1992-1998 period can be found in the Appendix A.

terpretation of the EMS where there is a bipolar system involving a hard currency country, Germany, and a soft currency country, France.

The empirical evidence in support of the GDH has mainly focused on interest rate linkages within the EMS with the purpose of capturing the direction of causation [Katsimbris and Miller (1993), Hassapis *et al.* (1999)]. This is usually done by means of bivariate VAR systems, consisting of the German interest rate and the respective rate of each of the other EMS member countries or alternatively by trivariate VAR models where the interest rate of a third country is introduced (i.e. US interest rate). This strategy consists simply in performing standard causality tests in first differenced VAR models. However, there are several reasons to be sceptical of the VAR approach. VAR models like indeed any other econometric model typically include a relatively small number of variables relative to the universe of possible variables affecting decision processes and rules out asymmetries by assuming linearity (Evans and Kuttner, 1999).

In this paper, we introduce a new way of looking at the monetary convergence process occurred in Europe. We analyse the behaviour of risk premia based on Kalman filter estimates during the eventful almost seven years (i.e. 1992-1998) period immediately preceding the actual monetary integration occurred on the first of January of 1999.[2]

It is convenient to look at this problem from the point of view of a currency external to the European currencies involved in the EMU. We decided to select the Japanese currency as such external currency. The Japanese economy has presented during this period little correlation with European economies in terms of monetary or economic magnitudes. The Japanese currency represents therefore a "third party" that has little or nothing to do with the business of monetary integration in Europe and that observes the developments taking place in the European area from the distance. The role of the US economy, however, has been more ambivalent, showing a more significant influence on both the European and Japanese economies.

[2] Before the member countries can participate in the third stage of EMU the member countries have to satisfy a set of convergence criteria regarding inflation, nominal exchange rates, nominal interest rates, and government debt and deficit (Buiter, Corsetti and Pesenti, 1998).

Foreign currency risk premium series obtained through the Kalman filter approach provide a sense of the degree of uncertainty associated with a particular currency. From a rational expectations point of view, if two assets were perceived to be the same, a new piece of information arriving to the market would cause them to move in the same direction. In a process of monetary convergence like the one experienced in Europe, we could use the same principle. If two currencies were seen as essentially the same currency, new arrival of information would cause a move in the same direction for both currencies. The German mark and the Dutch guilder are an example case within the EMS since they presented a very strong risk premium co-movement during the years preceding monetary union.

We show that although the German mark and the rest of European currencies risk premium series behaved differently at the beginning of the process they eventually converged at the end. We show evidence supporting at least the weak form of the GDH where European currencies risk premium converge towards the same level of risk premium but with the German mark risk premium playing a more prominent role. We are able to show the intermediate paths followed by the member currencies before actual integration and the relative speed of convergence to monetary union and in this way, determine the path of convergence to monetary union over time.

The presentation of the paper is as follows. In section 2, we present the theoretical foundations of the paper and lay down the main definitions used. In section 2, we also relate the existence of risk premium in foreign currency markets to the forward rate puzzle, which is the rejection of the forward price as an unbiased estimate of the future spot price (Fama, 1984). In section 3, we present a brief description of the Kalman filtering methodology used to extract the risk premium and the general structure of our experiments. Data description and presentation of our empirical results comprise section 4 with conclusions closing in section 5.

2. Theoretical Background

We capitalize from the extensive empirical research done on foreign currency risk premium. Conditional on the hypothesis that the foreign exchange market is efficient or rational, the existence of time varying risk premium has been documented in the literature by Fama (1984), Hansen and Hodrick (1980), Hsieh (1984) and Frankel (1982). Consider the logarithm of a forward foreign exchange rate observed at time t to be delivered at t+1 and denote it by f_t. This forward rate can be divided into an expected future spot rate component and a risk premium component

$$f_t = E_t(s_{t+1}) - rp_t, \tag{1}$$

where $E_t(s_{t+1})$ is the rational or efficient forecast of the logarithm of the spot exchange rate at t+1, conditional on all information available at t, and rp_t is a premium term that is unobservable. The meaning of rp_t can be put in the context of an equilibrium model of international asset pricing described in Hodrick and Srivastava (1986) or Roll and Solnik (1977). Adding and subtracting s_{t+1} to the right hand side of equation (1) and defining $v_{t+1} = s_{t+1} - E_t(s_{t+1})$ we obtain

$$s_{t+1} - f_t = rp_t + v_{t+1}, \tag{2}$$

where v_{t+1} is a white noise error uncorrelated with past information. The left side of equation (2) is the excess return, er_{t+1}, and is decomposed into an unobservable risk premium component and a white noise error. We implement a methodology based in the work of Kalman (1960) from the engineering literature to identify and measure risk premium in the pricing of forward foreign exchange that involves application of signal-extraction techniques.[3] Within the Kalman filtering technique we refer to the risk premium component, rp_t, as the signal that we would like to capture and to the white noise process, v_{t+1}, as noise that is added to the signal.

Excess returns can be equivalently written in the following form

$$er_{t+1} = s_{t+1} - f_t = s_{t+1} - E_t^m(s_{t+1}) + E_t^m(s_{t+1}) - f_t = v_{t+1} + rp_t \tag{3}$$

[3] See also Wolff (1987).

where $E_t^m(\cdot)$ is the market's expectation conditional upon current information that can be different from the statistical expectation, $E_t(\cdot)$. Equation (3) states that excess returns are the sum of the market forecast error and the risk premium. In the case the uncovered interest parity holds and the market's expectation equals the statistical prediction of the exchange rate, then predictable excess returns must be equal to zero.

However, many empirical studies have found that predicted excess returns are significantly different from zero and that the excess return sign changes. For example, Fama (1984) estimated the following equation

$$\Delta s_{t+1} = \beta_0 + \beta_1 (f_t - s_t) + u_{t+1}. \tag{4}$$

His test regressed the change in the exchange rate on the forward premium. If predictable excess returns are zero, then $E_t(s_{t+1}) = f_t$ and $\beta_1 = 1$ and $\beta_0 = 0$.[4] Fama (1984) used the dollar exchange rate against the German mark, British pound and Japanese yen over the period 1975 to 1989 to found that the estimates of β_1 were in fact significantly less than one and negative. He also showed that the variance of predictable returns is greater than the variance of the expected change in the exchange rate itself when $\beta_1 < 1/2$. These results are typical of many other studies examining the same relationship.[5] What can explain that expected excess returns are significantly different from zero and that their variance is quite large relative to expected exchange rate changes? A great deal of research has been focused on this issue. Generally, there are two types of explanations: (a) foreign exchange risk premium, or (b) expectational errors. The Fama (1984) test in equation (4) can be used to see how explanations fall into these two groups. If we define the risk premium as

$$rp_t \equiv E_t^m(s_{t+1}) - f_t = E_t^m(\Delta s_{t+1}) - (f_t - s_t), \tag{5}$$

---

[4] An alternative test is the linear projection equation given by $er_{t+1} = s_{t+1} - f_t = b_0 + b_1(f_t - s_t) + u_{t+1}$. Note that this regression is equivalent to equation (4) where $\beta_1 = 1 + b_1$ and $\beta_0 = b_0$. If predictable excess returns are zero then $b_1 = 0$.

[5] Bossaerts and Hillion (1991), Bekaert and Hodrick (1993). In fact, this simple test has produced a challenge for researcher in the field of international finance and as Lewis (1995) put it, it is considered one of the main unresolved puzzles in the field.

and define the changes in the exchange rate as

$$\Delta s_{t+1} = E_t(\Delta s_{t+1}) + \varepsilon_{t+1}, \tag{6}$$

where $E_t(\cdot)$ denotes the statistical expectation and ε_{t+1} is a white noise error uncorrelated with past information.

Equation (5) states that the markets expected return for holding foreign deposits is an equilibrium premium paid for taking more risk. The market's forecast error is

$$\Delta s_{t+1} - E_t^m(\Delta s_{t+1}) = v_{t+1}, \tag{7}$$

and the excess return can be written as

$$er_{t+1} = rp_t + v_{t+1}. \tag{8}$$

If we believe that the behaviour of predictable excess returns found by Fama (1984) is due to the risk premium, the expectations made by market participants are rational and the market knows the statistical distribution of the economy. In such situation, $\varepsilon_{t+1} = v_{t+1}$ so that the predictable excess return is just equal to the risk premium rp_t. An implication of this view is that as pointed out by Fama (1984) the variance of the risk premium exceeds the variance of the market's expectations of exchange rate changes or expected depreciation. The alternative explanation based on expectational errors supposes that the risk premium in equation (8) is constant to say $\overline{rp}$, so that $er_{t+1} = \overline{rp} + v_{t+1}$. In this situation the higher variation of expected excess return found in the Fama (1984) paper must rise from predictable movements in the forecast errors v_{t+1}. Persistence or predictability of forecast errors could rise when there is presence of irrational traders in the market or from difficulties in measuring expectations of predictable returns when for example the regression equations used to measure expectations may not accurately reflect the market's expectation of returns[6]. Although both groups of explanations are usually given as mutually exclusive they can be combined to yield the behaviour of predictable excess returns showed in Fama (1984).[7]

In this paper we will take the view that time-varying risk premium is the source of predicted excess return[8]. We therefore imply that market participants act rationally and that they demand an equilibrium premium paid for taking more risk when holding foreign deposits. This in turn implies that model forecast errors must be uncorrelated with everything in the lagged information set.

3. Methodology

Since we focus our analysis on the behaviour of time-varying risk premium we should find a way to model it. With this aim we implement a methodology to identify and measure risk premium in the pricing of forward foreign exchange that involves application of signal-extraction techniques. This methodology is based in the work of Kalman (1960) from the engineering literature[9]. Kalman filtering models have been used in the extraction of time-varying risk premium by Wolff (1987) and Cheung (1993). In order to be able to apply the Kalman filter in the context of risk premium models described above, the risk premium models have to be arranged in the state space form. From equations (3) and (8) we have the following two equations model

$$er_{t+1} \equiv s_{t+1} - f_t = rp_t + v_{t+1}\,, \tag{9}$$

$$rp_t = \phi\, rp_{t-1} + u_t\,, \tag{10}$$

---

[6] This is usually associated with the so-called peso effect which gets its name from the behaviour of the Mexican peso in the early 1970s. Peso effects arise when at the time of decision making, investors rationally expect the occurrence of a future event that fails to take place.
[7] Grossman and Rogoff (1995) give a comprehensive survey of models of time-varying risk premium and expectational errors.
[8] This is also the interpretation given in Fama (1984). Other authors made the same hypothesis, see for example Hansen and Hodrick (1980), Hodrick and Srivastava (1984) and Hsieh (1984).
[9] Other studies are Anderson and Moore (1979) and Harvey (1986).

where er_{t+1} is a $k\times1$ vector of observed variables, rp_t is a $k\times1$ vector of unobservable state variables, ϕ is the state transition matrix, and v_{t+1} and u_t are vectors of disturbance terms. The terms, u_t and v_t are independently distributed for all t and r and, u_t, v_r and rp_r are independent for all $r \leq t$. Generally, we denote equation (9) as the measurement equation and equation (10) as the state transition equation. Equation (10) denotes the generating process for the risk premium that in this case is given by an AR(1) process. The specification of a particular model for rp_t can be based on the autocorrelation and partial autocorrelation functions of the forecast error, $s_{t+1} - f_t$, which should be the same as the combined structure of the risk premium and the white noise process, v_{t+1} as in equation (9). Table 2 shows the autocorrelation and partial autocorrelation values of the forecast error. The results in Table 2 suggest a structure consistent with one of an AR(1) model.[10] An extra assumption is assumed for the model above

$$\begin{pmatrix} v_{t+1} \\ u_t \end{pmatrix} \sim iidN\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} R^2 & 0 \\ 0 & Q^2 \end{pmatrix}\right]. \tag{11}$$

The Kalman filter algorithm will allow us to compute the mean and covariance of the risk premium, rp_t, on a period-by-period basis. We assume that rp_t at $t = 0$ has a normal prior distribution with mean $rp_{0t} = 0$ and covariance matrix $V_0 = 0$. At every point in time t, after the excess return has been observed, we want to revise our prior distribution of the unknown state vector rp_t. Given the knowledge of rp_0, V_0, Q, R and ϕ, the Kalman filter will compute in a recursive manner the mean and covariance matrix of rp_t for each time period. Given the normality assumptions above, the conditional distributions $p(rp_t \mid er_t)$ and $p(rp_{t+1} \mid er_{t+1})$ are also normal distributions that can be characterized by their first two moments; the mean, $E_t(rp_t)$ and its covariance matrix $V_t(rp_t)$. See appendix B for an exposition of the recursive Kalman Filter estimation procedure used in the analysis.

[10] This is equivalent to a ARMA(1,0) model where the white noise sequence, u_{t+1}, can be interpreted as a MA(0) process.

4. Data and Empirical Results

Our data consists of daily prices of nominal exchange rates and nominal interest rates of 11 currencies. The foreign exchange rates are German mark (dem), U.S. dollar (usd), U.K. pound (gbp), Irish pound (iep), Swedish krona (sek), Dutch guilder (nlg), Belgian franc (bef), French franc (frf), Italian lira (itl), Finnish markka (fim) and Spanish peseta (esp). Both rates are average bid-ask market quotes synchronously recorded by the Bank of Finland at 12 noon EET time. The sample period is from the beginning of 1992 to June 1998. The implied forward prices are estimated using the daily nominal interest rates for a maturity of one month. We assume that that both the foreign exchange and interest rate markets are efficient and that no-arbitrage opportunities exist between the rates quoted in the forward and spot prices. An important issue about the calculation of the forecast error or excess return, $s_{t+1} - f_t$, is to find the right delivery on a forward contract made today. To find the delivery date on a forward contract made today, it is first necessary to determine today's spot value date, which is two business days in the future for trades between US dollars, European currencies or the Japanese yen. Delivery on a 30-day forward contract occurs on the calendar day in the next month that corresponds to the calendar day of the current month on which spot value is realized if this day is a working business day. If it is a weekend or a holiday, one takes the next available business day without going out of the month. In the case we have to go out of the month we take the first previous business day. This general rule is followed except when the spot value day is the last business day of the current month in which case the forward value day is the last business day of the next month.[11] Unless one matches the forward rate with the appropriate spot rate, a true return on the forward contract is not being calculated and measurement error is introduced into the analysis.

[11] Bekaert and Hodrick (1993) consider the use of the wrong future spot rate as one source of measurement error in testing the Fama (1984) relationships. Another source of bias is to fail in accounting for the bid-ask spread in the recorded market data. They found, however, that the bid-ask spread bias was negligible when testing for the Fama equations.

Table 1 presents the summary statistics for the whole period of the excess return, $s_{t+1} - f_t$, the depreciation rates, $s_{t+1} - s_t$ and forward premiums, $f_t - s_t$.[12] The values for the mean and variance statistics are on a percent per month basis since the forward spot rates are in logs and multiplied by 100. Panel A of Table 1 shows that excess returns are different from zero. Panel B of Table 1 exhibits the statistics of depreciation rate from the estimation period. The mean of depreciation of the Japanese yen is positive against the U.S. dollar and British pound and marginally positive for the French franc whereas for the rest of currencies the depreciation is negative. Note from Panel A and B that excess return variances, $s_{t+1} - f_t$, are marginally smaller than the variances of the depreciation rates, $s_{t+1} - s_t$, for almost all the currencies. This indicates that in terms of variance of forecast errors, the current forward rate is a marginally better predictor of the future spot rate than the current spot rate. Panel C in Table 1 presents general statistics of the forward premiums, $f_t - s_t$. Note that if $i_t^* > i_t$, that is if interest rates in the foreign currency are higher than interest in Japanese yen, the forward premium becomes negative which indeed has been the case during the analysed period.. The reported kurtosis and skewness coefficients are both zero under the null. Normality of returns of excess returns, $s_{t+1} - f_t$, the depreciation rates, $s_{t+1} - s_t$ and forward premiums, $f_t - s_t$, are rejected for all currencies.

Table 2 shows autocorrelations and partial autocorrelations functions of excess returns as defined in equation (3). Traditional Box and Jenkins (1976) procedures of identification can be applied to identify a correct time series model for excess returns. The autocorrelations and partial autocorrelations are consistent with an AR(1) process. Recall that this AR(1) model also represents the combination of the risk premium plus noise processes. Using a summation theorem for moving-average processes in Ansley *et al.* (1977) we can conclude that the excess return is consistent with a AR(1) model for the risk premia.

Maximum-likelihood estimates of the state-space models for risk premia are presented in Table 3. The results in Table 3 are based on the entire sample. First, in all cases the variance of the premium term is greater than the variance of the noise term.

[12] Note that by definition the excess return equals the difference between future depreciation $s_{t+1} - s_t$ and forward premium $f_t - s_t$, i.e. $s_{t+1} - f = (s_{t+1} - s_t) - (f_t - s_t)$

Note that the risk premiums, rp_t, are positively correlated with the unexpected change of the future spot rates, v_t. Intuitively, that means that the greater the risk premium, the greater the unexpected depreciation. The relative hyperparameter values, given as *q-ratios*, show the signal to noise ratio. All currencies present low signal to noise ratios. In the sample, the British pound has the biggest risk premium mean. When we multiply by 12 to make the figure comparable to interest rates computed per year the annualised risk premium for the British pound is 5.16%. Risk premiums calculated in this way give an indication of the average levels of time varying risk premia that are possible in the foreign forward exchange market.

The value denoted by $r(1)$ gives the residual autocorrelation at lag 1. In the same way, the Durbin Watson statistic gives an indication of the degree of first order serial correlation in the residuals. Both statistics show no sign of residual serial correlation giving strong indication that the proposed model is adequately capturing the dynamic structure of all currency series.

4.1. The Evolution of Foreign Currency Risk Premium

The main purpose of this paper is not only to estimate risk premium series in the foreign forward currency market but also to study their evolution through time so that we can visualise the convergence process of the projected monetary union taking place. By analysing the developments of the risk premia series obtained through Kalman filtering methodology we can investigate the speed and the direction of the convergence process.

Figure 1 shows the rolling window correlations of the German mark risk premium series with other currencies' risk premium series. The size of the window is fixed to 250 trading days. The moving correlation of the risk premium series converge to perfect correlation towards the end of the sample for those currencies participating in the final stage of the Monetary Union. On May 3rd of 1998 Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain joined the Euro. It is interesting to see from Figure 1 that there is a clear process of comovement with the German mark risk premium well before that date. Spain, Italy and Finland manifest an increasingly higher comovement with Germany since the beginning of 1997 but prior to that date their risk premium correlation behaves in a somewhat erratic fashion. Foreign exchange markets perceived during 1997 an increasing likelihood of these countries participating in the final stage of EMU. The case of France is an interesting one. Figure 1 shows that the degree of comovement of the French risk premium with that of Germany was never below the 92% mark. However, it is not until the end of 1997 when the rate of comovement becomes almost 100%. The Netherlands present an almost perfect correlation with German risk premia right from the start of the sample and Belgium joins this pair around the beginning of 1995.

The visualisation of the comovement of risk premium series for the currencies that finally entered the currency union also indicates that in effect there was already an almost perfect comovement among these currencies well before the starting date of EMU. In some cases, like the Dutch guilder and Belgium franc, this almost perfect comovement with the German mark was evident since 1992 for the guilder and late 1994 for the Belgium franc. Assuming a 250 days rolling window and benchmark correlation at the level of 98-99%, it is also possible to pinpoint the approximate dates when the remaining participating currencies joined the German mark, Dutch guilder and Belgium franc group of currencies: for the French franc this can be considered to have occurred at around April 1997, for the Spanish peseta at around July 1997, for the Finnish markka at around December 1997 and for the Italian lira in early January 1998. [13]

The British pound presents a quite unstable correlation with the German mark in the range of 60% and 90% over the analysed period, and a sharply decreasing correlation just at the end of the period. The US dollar risk premium, in turn, also shows a volatile correlation pattern with that of the German mark with a somewhat higher but still volatile correlation just at the end of the period.

The Irish currency traditionally linked to the British pound presents a divergent pattern to that of Britain in terms of risk premium correlations within the preceding two years before start of phase three of EMU. In this sense, the data tends to support the view that the market started to see the Irish pound as a different entity, closer

[13] This in effect means that over the prior 250 days the level of comovement has been very high as to produce a correlation between the German mark and the currency under consideration of 98% or above.

to the risk premia behaviour of continental European currencies.[14] However, unlike other participating currencies, the Irish pound did not achieve the pattern of almost perfect comovement described above for other participating currencies at least not until the end of the considered period of analysis.[15]

Finally, the Swedish krona risk premium correlation with that of the German mark is an interesting case to discuss as Sweden opted in December 1997 not to introduce the single currency from the start of EMU. The data tends to suggest that the level of comovement was increasing from the end of 1996 up to the end of 1997 when it reached the 90% correlation mark. However, when the political decision to not enter EMU was finally known the upward trend in the co movement of risk premium stopped, commencing a decreasing trend, although it maintained a relatively high level further on.[16]

Figure 1 is also able to show some of the major events that occurred in the period on the road to monetary union such as monetary storms during 1993 and devaluation in March of 1995 of the Spanish peseta and Portuguese escudo.[17] The ability of risk premia series to identify these major events in the form of a decrease in the level of correlation is noteworthy and reassuring.

---

[14] Rolling window correlations of the UK pound and US dollar risk premium with the other currencies used in the analysis were also computed and are available on request. In particular, the UK pound correlations with other EMS currencies show a very significant decrease at the end of the analysed period and this decrease is even more pronounced with the Irish pound.

[15] It is to be reminded that the Irish pound was subject to a high degree of uncertainty about the entry rate to EMU (see for example Honohan (1997)). By March 14 1998, a revaluation of the currency of 3% took place. Although, on the 3rd of May of 1998 the exchanges rates were irrevocably fixed to the Euro, the level of comovement during the 250 days prior to the exchange fixing date show this high but imperfect correlation for the Irish pound and the German mark.

[16] While much of the Swedish establishment was in favour of EMU, economic experts and public opinion was divided. The Riksdag decision in December 1997 left open the door for a later Swedish participation in the monetary union recommending stability oriented economic policy (see Gottfries 2002 for a more detailed account of events). In any case, the Swedish krona has moved in broad terms in step with the Euro since its inception.

[17] The year 1992 is not shown since we use 250 days past observations to compute the rolling window correlations.

4.2. The Directional (A)symmetry of Convergent Risk Premia

The analysis in Figure 1 presented evidence on the convergence process that took place in Europe during the 1992-1998 periods. However, this analysis gives little indication on whether this convergence process was an asymmetric or symmetric one, i.e. whether European currencies risk premium converged to the German currency risk premium or that German risk premium and other European currency risk premiums moved towards each other. Indeed, the apparent convergence of European currencies risk premium to the German risk premium shown in Figure 1 may be unfounded. It is very possible that what was really happening was that the German risk premium was converging towards the risk premium of other participating currencies. To shed light on this matter we propose a bivariate causality model to test whether the past distance between the German risk premium and currency's X risk premium affect future variations of currency's X risk premium. Formally we estimate the following model

$$\Delta rp_t(X) = \sum_{i=1}^{m} \phi_{1i}\, \Delta rp_{t-i}(X) + \sum_{i=1}^{m} \theta_{1i} \left[rp(X) - rp(DEM) \right]_{t-i} + \varepsilon_t\,, \qquad (12)$$

$$\Delta rp_t(DEM) = \sum_{i=1}^{m} \phi_{2i}\, \Delta rp_{t-i}(DEM) + \sum_{i=1}^{m} \theta_{2i} \left[rp(X) - rp(DEM) \right]_{t-i} + \xi_t\,, \qquad (13)$$

where $rp_t(X)$ denotes the risk premium in time t of currency X and Δ is the first difference operator.

This model in first differences presents the short-term dynamic characteristics of the convergence process. Changes in the risk premium of currency X depends on past changes of its own risk premium and on the *convergence component* given by the parameter θ that captures the m-lagged distance between its risk premium and the German risk premium. A simple F-test can be used to determine whether the m-lagged values of the risk premium distance contribute significantly to the explanatory power of both regressions in equations (12) and (13).[18] If the risk premium distance or convergence component does contribute significantly we can reject the null hypothesis that the "*convergence component*", $[rp(X) - rp(DEM)]_{t-1}$, does not affect changes in risk premium. Note that we run this test for both equations. To conclude that the convergence component affect changes in the risk premium of currency *X*, we must reject the hypothesis "convergence towards German risk premium does not affect changes in currency *X* risk premium" and accept the hypothesis "convergence towards *X* currency risk premium does not affect changes in German risk premium". Note that the numbers of lags *m* in equations (12) and (13) is arbitrary and boils down to a question of judgment. In this paper, we run the tests for a few different values of *m* to make sure that the results are not sensitive to the choice of this parameter. Also, note that this is a very simple test and many authors have pointed out several weaknesses. One possible difficulty is that a third variable *Z* might in fact be causing changes in currency *X* risk premium but might also be contemporaneously correlated with the convergence component in equations (12) and (13).[19] In fact, when we say that a particular variable causes another within this hypothesis context we are actually meaning precedence and higher information content of that variable and not causality in the more common sense of the term. Another possible difficulty is that non-stationary variables enter the regression equations affecting the proper interpretation of the *p*-values associated to the *F*-tests (Banerjee, Dolado, Mestre, 1998). Non-stationary conditions in the risk premium series were rejected for all currencies allowing for the use of the *p*-statistic of the proposed test.

Figure 2 shows the result of 300 days rolling window F-tests for equations (12) and (13). They show the associated *p*-values of the *F*-tests. The tests are calculated for a value of *m* equal to 1 so the models capture the very short-term dynamics of the behaviour of changes in risk premium. Low *p*-values indicate that we can reject

---

[18] The test involves the estimation of an unrestricted regression as in equations (12) and (13) and a restricted regression without the risk premium distance variable. The *F*-statistic is $F = (N-k)\dfrac{(ESS_R - ESS_{UR})}{q(ESS_{UR})}$, where ESS_R and ESS_{UR} are the sums of squared residuals in the restricted and unrestricted regressions respectively, *N* is the number of observations, *k* is the number of estimated parameters in the unrestricted regression and *q* is the number of parameter restrictions. The statistic is distributes as $F(q, N\text{-}k)$.

[19] See for example Jacobi *et al*. (1979), Granger (1988) and Zellner (1988) for a critical examination of causality tests.

the null hypothesis that the "convergence component", $\left[rp(X) - rp(DEM)\right]_{t-1}$, does not affect changes in risk premium. On the contrary, higher p-values, say more than 5%, indicate that we cannot reject the null hypothesis.

The virtue of Figure 2 is that it allows to examine the changing behaviour of causation during the 1992-1998 periods. Let's take for example the French franc case in Figure 2. There is a strong support for the view of German risk premium levels affecting the French risk premium but not vice versa. Indeed the p-values of the F-test for the French franc regression are below the 5% mark for almost the entire second half of the sample starting approximately at the end of 1995 and corresponding p-values for the German regression are high for practically the entire sample. Before December 1995 p-values are around the 20% level for the French regression but with two major shifts upwards, one around the 1992-93 periods and the second in the spring of 1995. The years 1992 and 1993 were an eventful period in the EMS.[20] These events are associated with periods of decreasing rates of policy coordination and declining perception in the markets of the accomplishment of a future monetary union. In this sense, periods of uncertainty mean for the French franc lower intensity in the effort of convergence towards the German mark.

In the case of the Dutch and German relationship depicted in Figure 2, none of the currencies seem to be affected by the convergence component. This means that both currencies have achieved a high degree of integration with a perceived risk premium evolution that is seen as equal. The rest of currencies participating in the EMS show a clear pattern of asymmetry in relation to the German mark with the exception of the Irish pound. In the case of the Irish pound, it is an indication that perhaps a third factor plays a role (e.g. the British pound) and that in terms of risk premium Ireland had not converged yet which is corroborated by the visualisation of the rolling window correlations analysed in the previous section.

The British pound shows a different pattern. For the British pound we can not reject the null of no causation at the beginning of the sample but this relation changes into one of causation from the end of 1996. Conversely, the German mark goes from a position of being explained by the convergence component in the middle of the sample to a position of no rejection of the null at the end of the period.

[20] See the appendix A for a chronology of events in the EMS during the 1992-1998 period.

Now, it is interesting to examine the relationship between the U.S. and German currencies. Hassapis *et al.* (1999) have suggested that U.S. monetary policy may influence German monetary policy and in turn other national central banks' policy. Indeed, Figure 2 shows that for the most part of the sample these currencies have an effect on each other. This gives support to the view that the relative position of the German mark with the US dollar is important for both currencies. In this case, we cannot talk about integration as in the Dutch and German case since the degree of comovement of the U.S. and German currencies is much less than for the Dutch-German case. In view of this result we cannot exclude the possibility of the U.S. playing an indirect role in the EMS through the German-U.S. significant relationship.[21]

5. Conclusions

This paper was set to investigate the relationship of European and non-European currencies risk premium in the context of the European Monetary Union (EMU). Using estimated currency risk premium series we introduce a new way of looking at currency and monetary integration. We analyse the behaviour of risk premium based on Kalman filter estimates during the eventful seven years period immediately preceding the actual monetary integration occurred on the first of January of 1999 (i.e. 1992-1998). The analysis is conducted from the point of view of a currency external to the European currencies involved in the EMU, the Japanese yen.

Foreign currency risk premium series obtained through the Kalman filter approach provide a sense of the degree of uncertainty associated with a particular currency. In the context of monetary integration, if two currencies were seen as essentially the same currency, new arrival of information would cause a move in the same direction and magnitude for both currencies, in other words, their risk premium profile would be the same. The methodology is based on the simple principle of considering the estimated risk premium as the right indicator for the risk profile of the currencies analysed. The analysis, therefore, implies that market participants act rationally and that they demand an equilibrium premium paid for taking more risk when holding

[21] A more elaborated approach would be necessary to quantify the extent of influence of the US dollar on participating currencies and indeed on the overall currency integration process, through for example the introduction of trivariate or multivariate system of equations. This is not attempted in this occasion and it is left open for further research.

foreign deposits. We use this principle to first show the evolution of convergence of the risk premium of different currencies relative to the German mark risk premium, seen as the anchor currency, and second to test the level of asymmetry of the convergence between the German and other European currencies.

We are able to show through the use of univariate representations of the risk premium, obtained through Kalman filtering technology, the paths and speed towards convergence of the European currencies participating in EMU. As regards the level of asymmetry in the convergence process, it is possible to show through rolling window bivariate causality tests, a clear pattern of asymmetry of the different participating currencies in relation to the German mark. This asymmetry does not hold for the Dutch guilder, which was seen as proxy for the German mark almost for the entire analysed period. The analysis also shows that we cannot exclude the possibility of the U.S. playing an indirect role in the EMS through a significant relationship between the German mark and U.S. dollar.

The methodology presented in the paper may be used as an alternative way for looking at the evolution in the formation of currency unions by examining the role of possible anchor currency candidates. This proposal could be useful in the context of financial market stability in situations preceding monetary policy integration or in situations where new currencies opt to join a monetary union, e.g. new EU entrants joining the Euro. Possible extensions to the paper could be the analysis of the source of risk premium by identifying, for example, country specific risks and common or systematic risks of countries participating in monetary unions, the examination of regime-switching models to identify changes in coordination in national monetary policies and the methodological treatment and analysis of the role of third party currencies (e.g. the US dollar).

References

Anderson, B.D.O. and Moore, J.B. (1979): Optimal Filtering. Englewood Cliffs. Prentice Hall.

Ansley, C.F. and Allen, W. and Wrobleski, W. (1977): On the Structure of Moving Average Processes. *Journal of Econometrics* 6, 121-134.

Artus, P. and Avouyi-Dovi, S. and Bleuze, E. and Lecointre, F. (1991): Transmission of US Monetary Policy to Europe and Asymmetry in the European Monetary System. *European Economic Review* 35, 1369-1384.

Banerjee, A., Dolado, J.J. and Mestre, R., (1998): Error Correction Mechanism Tests for Cointegration in a Single-Equation Framework. *Journal of Time Series Analysis* 19, n. 3, 267-283.

Bekaert, G. and Hodrick, R.J. (1993): On Biases in the Measurement of Foreign Exchange Risk Premiums. *Journal of International Money and Finance* 12, 115-138.

Bossaerts, P. and Hillion, P. (1991): Market Microstructure Effects of Government Intervention in the Foreign Exchange Market. *Review of Financial Studies* 4, 513-541.

Box, G.E.P. and Jenkins, G.M. (1976): Time Series Analysis: Forecasting and Control. Revised Edition. San Francisco. Holden Day.

Buiter, W.H. and Corsetti, G. and Pesenti, P.A. (1998): Financial Markets and European Monetary Cooperation. The Lesson of the 1992-93 Exchange Rate Mechanism Crises. *Cambridge University Press*.

Cheung, Y-W. (1993): Exchange Rate Risk Premiums. *Journal of International Money and Finance* 12, 182-194.

Evans, C.L. and Kuttner, K.N. (1999): Can VARs Describe Monetary Policy. Unpublished Manuscript. *Federal Reserve Bank of New York.*

Fama, E. (1984): Forward and Spot Exchange Rates. *Journal of Monetary Economics* 14 (November), 319-338.

Frankel, J.A. (1982): In Search of the Exchange Risk Premium: A Six-Currency Test Assuming Mean-Variance Optimization. *Journal of International Money and Finance* 1 (April), 255-274.

Giavazzi, F. and Pagano, M. (1988): The Advantage of Tying One's Hands: EMS Discipline and Central Bank Credibility. *European Economic Review* 32 (June), 1055-1082.

Gottfries, N. (2002) Why Sweden is not in EMU. *Swedish Institute*.

Granger, C.W.J. (1969): Investigating Causal Relations by Econometric Models and Cross Sprectal Methods. *Econometrica* 37, 424-438.

Granger, C.W.J. (1988): Some Recent Developments in a Concept of Causality. *Journal of Econometrics* 39, 199-211.

Grossman, G.M. and Rogoff, K. (1995): Introduction. *Handbook of International Economics*. Vol. 3. Amsterdam. North Holland.

Hansen, L.P. and Hodrick, R.J. (1980): Forward Exchange Rates as Optimal Predictors of Future Spot Rates: An Econometric Analysis. *Journal of Political Economy* 88 (October), 829-853.

Harvey, A.C. (1986): Analysis of Generalization of a Multivariate Exponential Smoothing Model. *Management Science* 32, 374-380.

Harvey, A.C. (1993): Time Series Models. 2nd Edition. *Harvester WheatSheaf.* Great Britain.

Hassapis, C. and Pittis, N. and Prodromidis, K. (1999): Unit Roots and Granger Causality in the EMS Interest Rates: the German Dominance Hypothesis Revisited. *Journal of International Money and Finance* 18, 47-73.

Hodrick, R.J. and Srivastava, S. (1986): The Covariation of Risk Premiums and Expected Future Spot Exchange Rates. *Journal of International Money and Finance* 5, 5-22.

Honohan, P. (1998): The Tortuous Path to EMU Entry: Irish Policy Issues for Interest Rates and Exchange Rates. Unpublished manuscript.

Hsieh, D. (1984): Tests of Rational Expectations and No Risk Premium in Forward Exchange Markets. *Journal of International Economics* 17, 173-184.

Jacobi, E. and Leamer, E. and Ward, M.P. (1979): The Difficulties with Testing for Causation. *Economic Inquiry* 17, 401-413.

Kalman, R.E. (1960): A New Approach to Linear Filtering and Prediction Problems. *Journal of Basic Engineering*. Transactions ASME. Serie D 82, 35-45.

Katsimbris, G.M. and Miller, S.M. (1993): Interest Rate Linkages within the European Monetary System: Further Analysis. *Journal of Money, Credit and Banking, Vol. 25, No. 4 (1993), 771-779.*

Lewis, K. K. (1995): Puzzles in International Financial Markets. In Grossman, G. and Rogoff, K. eds., *Handbook of International Economics*. Vol.3. Amsterdam. North Holland.

MacDonald, R. and Taylor, M.P. (1991): Exchanges Rates, Policy Convergence and the European Monetary System. *Review of Economics and Statistics* (August), 553-558.

Roll, R. and Solnik, B. (1977): A Pure Foreign Exchange Asset Pricing Model. *Journal of International Economics* (May), 161-179.

Smeets, H.D. (1990): Does German Dominate the EMS? *Journal of Common Market Studies* 29, 37-52.

Von Hagen, J. and Frantianni, M. (1990): German Dominance in the EMS: Evidence from Interest Rates. *Journal of International Money and Finance* 9, 358-375.

Weber, A.A. (1991): Reputation and Credibility in the EMS. *Economic Policy* 12, 58-102.

Wolff, C.C.P. (1987): Forward Foreign Exchange Rates, Expected Spot Rates, and Premia: A Signal Extraction Approach. *Journal of Finance* 42 (2), 395-406.

Zellner, A. (1988): Causality and Causal Laws in Economics. *Journal of Econometrics* 39, 7-21.

Appendix A: The chronology of events[22].

The European Monetary System (EMS) was created in March 1979 with the purpose to promote monetary stability and closer economic cooperation in the countries of the European Community. The Exchange Rate Mechanism (ERM) was at the core of the system. With the advent of the Euro the ERM was revised. The ERM was designed to keep currencies trading in a range around a central rate. After the crises in 1993, the bands were widened to 15% for all except the DEM and NLG, which maintained 2.25% bands. At the end of 1996, the grid included 12 European Union currencies. Britain's pound, Sweden's krona and Greece's drachma remained outside. A following chronology describes the main events leading up to the formation of the planned single currency.

	1992
February 7	Maastricht Treaty signed by EU finance and foreign ministers.
April 6	Portuguese escudo enters ERM with 6% bands.
June 2	Danes vote no to the Maastricht Treaty, with 50.7% against, awakening market doubts about EMU and launching months of ERM turmoil.
June 3	France announces autumn referendum on Maastricht.
July 16	Bundesbank announces discount rate rise to record 8.75%.
June 19	Ireland votes in favour of Maastricht, with 68.7% in favour.
September 3	UK treasury borrows 16 billion ECU to defend the pound within ERM.
September 4	Italy raises official rates by 1.75 points to defend lira.
September 5	EU finance ministers stress they have no plans for ERM realignment.
September 8	Finland severs markka's link to ECU. Sweden raises interest rates.
September 10	British Prime Minister John Major rules out devaluation within ERM.
September 13	First major realignment of the ERM since January 1987; behind-the-scenes deal trades lira devaluation to 802.49 per mark for Deutsche interest rate cuts.
September 14	Bundesbank announces modest rate cuts; market sells pound and lira.
September 16	"Black Wednesday." Markets force pound, lira and peseta below ERM floors. Central banks intervene. Britain announces unprecedented two-stage rise in base rate from 10% to 15%, then suspends pound from ERM and cuts base rate to 12%. Sweden hikes overnight rate to 500%.
September 17	After a six-hour meeting, EU's monetary committee suspends lira from ERM. Peseta devalued by 5%. Britain cuts base rate to 10%.
September 20	French voters approve Maastricht treaty, with 51.05% in favour.
September 23	France and Germany launch counter-offensive against currency speculation. Exchange controls imposed temporarily in Ireland, Spain and Portugal.
November 19	Sweden abandons efforts to peg krona to the ECU, renewing turmoil.
November 22	Peseta, escudo devalued. Markets attack Irish pound, Danish krona, and French franc.
December 12	EU summit in Edinburgh reaffirms commitment to Maastricht treaty.

	1993
January 1	EU single market begins; Ireland, Spain, Portugal lift exchange controls.
January 7	Ireland raises overnight interest rates to 100%.
January 30	Ireland devalues the pound by 10%, biggest single ERM devaluation.
February 1	Central Bank intervention deflects market attention from Danish krona.
April	Bank of France starts suggesting franc might share mark's anchor role in ERM.
April 19	EU finance ministers unveil 35 billion ECU plan to create jobs.
May 13	Peseta and escudo devalued.
May 18	Danish vote in favour of Maastricht treaty at second referendum.
June 21	French intervention rate below Deutsche discount rate, first time in 23 years.
June21/22	EU summit in Copenhagen calls for quick cuts in European interest rates.
July 12	Bundesbank intervenes to buy French francs.
July 29	Bundesbank ignores market speculation it will cut its discount rate to save the ERM, shaves half a point off less important Lombard rate instead.
July 30	Central banks fail to stop repeated French franc dips below ERM floor.
August 1	Emergency meeting of finance ministers and central bankers. After 12 hours of talks, early in the morning of August 2 they widen bands for all ERM currencies except the mark and guilder to 15%. Mark and guilder maintain 2.25% range.
November 1	German constitutional court rules in favour of Maastricht Treaty.

[22] *Source* Reuters plc.

Appendix A: (continued)

	1994
January 1	Stage Two of EMU starts; European Monetary Institute (EMI) founded in Frankfurt.
September 6	Germany's ruling CDU party suggests core countries launch EMU in 1999.
October17	Germany's Chancellor Kohl wins fourth term.

	1995
January 1	Austria, Finland and Sweden join EU.
January 8	Austrian schilling joins the ERM with 15% fluctuation bands.
March 6	Peseta, escudo devalued.
May 8	Jacques Chirac elected French president.
December 15	EU leaders confirm January 1, 1999, as start date for single currency.

	1996
October 14	Finland joins the ERM with 15% fluctuation bands.
November 24	European finance ministers and central bankers compromise on lira-entry to ERM at 990 per mark after heated debate, with Germany pushing for stronger lira.

	1997
April 15	EMI issues annual report expressing concern that many EU states had not managed to rein in national deficits enough to launch euro as planned in 1999.
June 1	French left win snap two-round election. Socialist leader Lionel Jospin, who had previously voiced concerns about the social effects of tight fiscal policy, forms new government and subsequently endorses EMU.
July	Asian economic crisis begins in earnest with devaluation of the Thai baht. Financial turmoil in Asian countries rages throughout the second half of 1997. EU officials repeatedly say that apart from dampening overall economic growth the crisis poses no threat to the European economy or to EMU.
September 26	Britain becomes subject of intense speculation as the Financial Times newspaper reports the government plans to announce sterling is likely to join EMU early after 1999 euro launch. The report quotes an unnamed minister, and government offices call it speculation but British stock and bond markets surge.
October 27	British Chancellor of the Exchequer Gordon Brown tells parliament Britain will not join a single currency before next election, due by 2002, but he says Britain in principle approves of EMU and that if it works it will be of benefit for sterling to join.

	1998
March 14	European authorities approve Greek drachma entry into ERM and simultaneous revaluation of Irish pound. Greek drachma enters ERM with 15% fluctuation bands. The Irish Pound is revalued by 3%.
March 25	European Commission recommends 11 members for EMU after evaluating economic performance in 1997. On same day, EMI says all EMU candidates must do more to consolidate public finances.
March 27	Bundesbank says it has serious concerns about Italy and Belgium achieving fiscal sustainability but that 1999 launch of euro remains justifiable in stability terms.
May 2-3	European leaders due to hold summit. Expectations are that they will select Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain to join the euro.

Table 1. Summary statistics of forward and spot exchange rates.

Panel A.	Statistic: Excess Returns $(s_{t+1} - f_t)$				
Currency	Mean	Variance	Skewness	Kurtosis	ρ_1
dem	0.2827	0.1035	-0.2486	0.0896	0.9601
usd	0.3884	0.1142	-0.3449	0.6788	0.9586
gbp	0.4353	0.1695	-1.1831	2.7604	0.9668
esp	0.1970	0.1534	-0.7924	1.8878	0.9651
nlg	0.2673	0.1032	-0.2352	0.0964	0.9604
iep	0.3368	0.1422	-0.8822	1.7928	0.9625
itl	0.2522	0.1991	-1.1866	3.1790	0.9693
fim	0.2027	0.1667	-1.4311	4.4348	0.9611
frf	0.3738	0.1102	-0.1929	0.1015	0.9616
sek	0.2325	0.1841	-0.6813	0.8676	0.9641
bef	0.3061	0.1045	-0.3041	0.1661	0.9590

Panel B.	Statistic: Depreciation Rate $(s_{t+1} - s_t)$				
Currency	Mean	Variance	Skewness	Kurtosis	ρ_1
dem	-0.0148	0.1043	-0.2562	0.0835	0.9604
usd	0.1455	0.1105	-0.3948	0.8263	0.9572
gbp	0.0223	0.1672	-1.2219	2.9213	0.9663
esp	-0.4107	0.1568	-0.8251	1.9064	0.9660
nlg	-0.0142	0.1039	-0.2442	0.0917	0.9606
iep	-0.1004	0.1433	-0.9077	1.9059	0.9629
itl	-0.3952	0.2012	-1.2604	3.5006	0.9695
fim	-0.1633	0.1709	-1.5057	4.8259	0.9622
frf	0.0024	0.1115	-0.2217	0.0906	0.9622
sek	-0.2812	0.1864	-0.7164	0.9090	0.9647
bef	-0.0174	0.1048	-0.3208	0.1384	0.9592

Panel C.	Statistic: Forward Premium $(f_t - s_t)$				
Currency	Mean	Variance	Skewness	Kurtosis	ρ_1
dem	-0.2975	5.90E-05	-0.8677	-0.4491	0.9819
usd	-0.2428	4.28E-04	0.4555	-1.4800	0.9963
gbp	-0.4129	1.52E-04	0.2095	-1.3046	0.9848
esp	-0.6078	3.74E-04	-1.1452	2.4806	0.9748
nlg	-0.2815	5.45E-05	-1.0880	0.1939	0.9835
iep	-0.4372	1.75E-04	-2.3454	10.5910	0.9779
itl	-0.6474	3.08E-04	-1.7502	5.9591	0.9722
fim	-0.3660	4.05E-04	-1.9635	3.9227	0.9921
frf	-0.3714	2.00E-04	-1.4703	2.7169	0.9793
sek	-0.5138	6.99E-04	-6.4025	57.9611	0.9654
bef	-0.3235	1.10E-04	-1.7023	4.3085	0.9833

Note: The forward and spot rates are in logs and the values for mean and variance are on a percent per month basis and multiplied by 100.

Table 2. The sample autocorrelation and partial autocorrelation functions of the excess returns (er_t).

Autocorrelation

Lag	usd	dem	gbp	esp	nlg	iep	itl	fim	frf	sek	bef
1	0.958	0.960	0.966	0.965	0.960	0.962	0.969	0.961	0.961	0.964	0.959
2	0.920	0.920	0.933	0.929	0.920	0.925	0.937	0.922	0.922	0.924	0.917
3	0.884	0.885	0.899	0.898	0.885	0.890	0.909	0.890	0.888	0.891	0.881
4	0.848	0.850	0.865	0.867	0.850	0.857	0.880	0.859	0.854	0.858	0.846
5	0.816	0.813	0.831	0.830	0.815	0.824	0.848	0.825	0.817	0.825	0.810
6	0.778	0.775	0.793	0.791	0.776	0.786	0.813	0.791	0.778	0.790	0.773
7	0.740	0.732	0.754	0.749	0.734	0.745	0.777	0.749	0.736	0.755	0.731
8	0.707	0.692	0.717	0.713	0.693	0.706	0.743	0.708	0.696	0.723	0.692
9	0.674	0.653	0.678	0.676	0.653	0.667	0.709	0.669	0.656	0.693	0.654
10	0.637	0.611	0.639	0.637	0.612	0.629	0.676	0.630	0.615	0.664	0.613

Partial autocorrelation

Lag	usd	dem	gbp	esp	nlg	iep	itl	fim	frf	sek	bef
1	0.958	0.960	0.966	0.965	0.960	0.962	0.969	0.961	0.961	0.964	0.959
2	0.016	-0.018	-0.012	-0.031	-0.018	-0.007	-0.035	-0.013	-0.034	-0.069	-0.031
3	0.006	0.039	-0.036	0.050	0.035	0.003	0.042	0.057	0.054	0.066	0.050
4	-0.003	-0.020	-0.024	-0.023	-0.015	0.001	-0.028	0.002	-0.020	-0.009	-0.002
5	0.018	-0.027	-0.009	-0.086	-0.029	-0.004	-0.060	-0.049	-0.050	-0.024	-0.027
6	-0.094	-0.051	-0.067	-0.051	-0.053	-0.087	-0.055	-0.019	-0.048	-0.038	-0.039
7	-0.005	-0.070	-0.057	-0.079	-0.071	-0.070	-0.062	-0.126	-0.073	-0.025	-0.075
8	0.026	-0.000	0.019	0.050	-0.003	0.001	0.020	-0.007	0.000	0.034	0.008
9	-0.023	-0.022	-0.040	-0.026	-0.022	-0.025	-0.006	-0.018	-0.021	-0.010	-0.019
10	-0.059	-0.039	-0.045	-0.030	-0.043	-0.009	-0.009	-0.029	-0.031	0.005	-0.055

Table 3. Maximum likelihood estimates of the risk premium model.

	usd	dem	gbp	esp	nlg	iep	itl	fim	frf	sek	bef
ϕ	0.9604	0.9612	0.9673	0.9651	0.9614	0.9630	0.9692	0.9614	0.9627	0.9641	0.9601
Mean(rp_t)	0.0038	0.0028	0.0043	0.0019	0.0026	0.0033	0.0025	0.0020	0.0037	0.0023	0.0030
Mean(v_t)^a	0.0124	0.2910	0.3580	0.1530	0.2660	0.3470	0.1470	0.1710	0.3960	0.2000	0.3500
Var(rp_t)	0.0011	0.0009	0.0016	0.0014	0.0009	0.0013	0.0019	0.0015	0.0010	0.0017	0.0009
Var(v_t)^a	0.0073	1.4300	1.9100	1.8600	1.4100	1.8500	2.1300	2.2800	1.4600	2.3400	1.4900
q-ratio	0.0001	0.0146	0.0074	0.0127	0.0117	0.0137	0.0112	0.0144	0.0140	0.0134	0.0151
$R(1)$	0.0004	0.0175	0.0109	0.0294	0.0170	0.0068	0.0034	0.0117	0.0328	0.0675	0.0292
DW	1.9980	1.9620	1.9770	1.9390	1.9630	1.9840	1.9300	1.9750	1.9310	1.8630	1.9380
$p.e.v.^a$	9.2029	7.9259	10.910	10.410	7.8521	10.310	11.920	12.540	8.1329	12.860	8.2281
$\rho_{RP,v}$	0.1991	0.1870	0.1797	0.1783	0.1865	0.1821	0.1684	0.1798	0.1853	0.1832	0.1892
Annual (rp_t)	0.0458	0.0336	0.0516	0.0228	0.0312	0.0396	0.0300	0.0240	0.0444	0.0276	0.0360

Note: The estimated autoregressive $AR(1)$ coefficient is ϕ. $^{a)}$ indicates that numbers are scaled up by 10^5. The basic measure of the goodness of fit is *p.e.v* (prediction error variance) defined as the variance of the one-step ahead prediction errors in the steady state. The $R(1)$ is the residual autocorrelation at lag 1, distributed approximately as N(0,1/T). DW is the Durbin-Watson statistic, distributed approximately as N(2/T). The relative hyperparameter, known here as the *signal to noise ratio* is given as the *q-ratio*. $\rho_{rp,v}$ is the sample correlation of the risk premium (rp_t) and the unexpected rate of depreciation (v_t) respectively .

Figure 1. The rolling (250 days) correlation of the German mark risk premium with other currencies' risk premium.

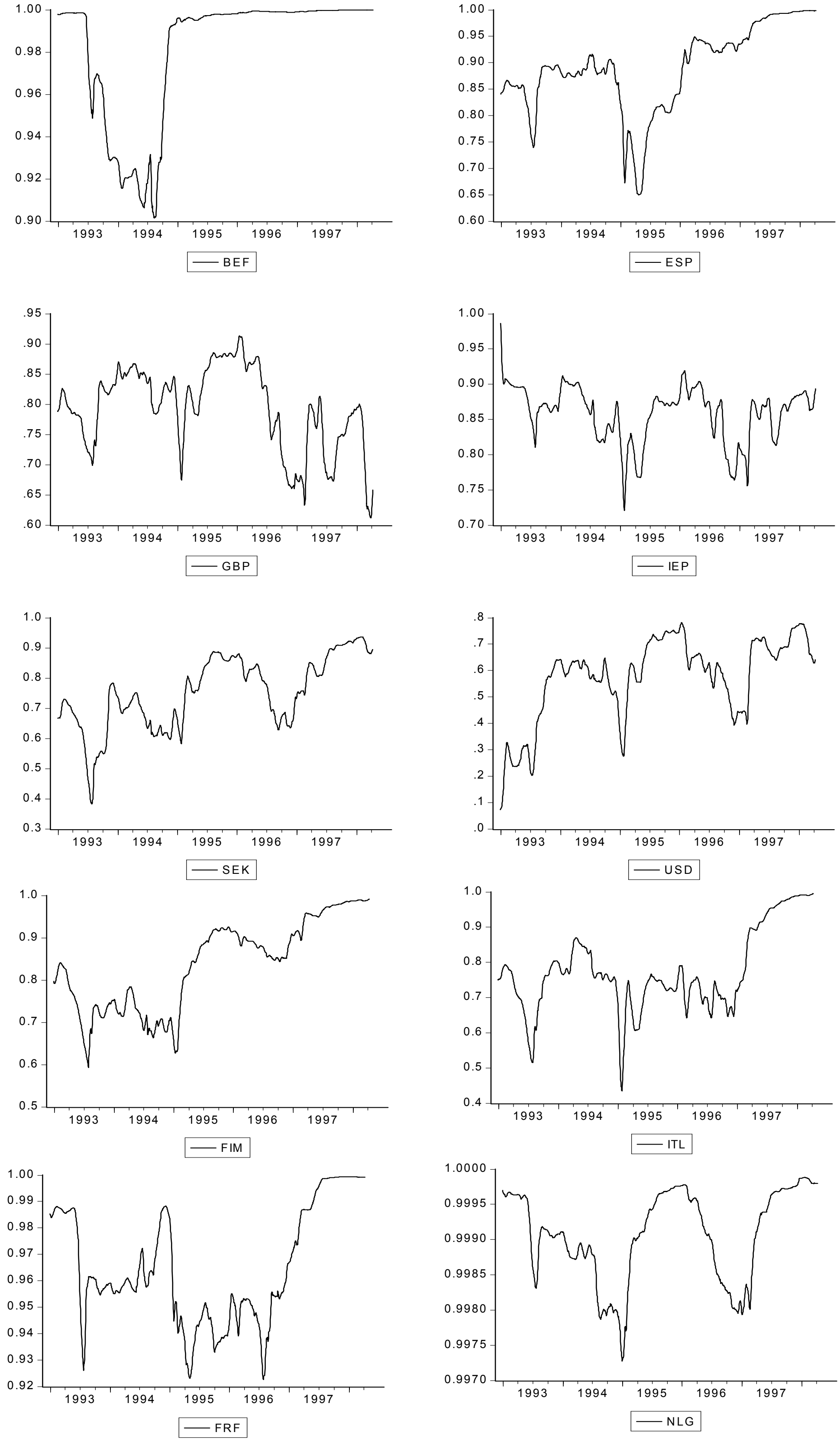
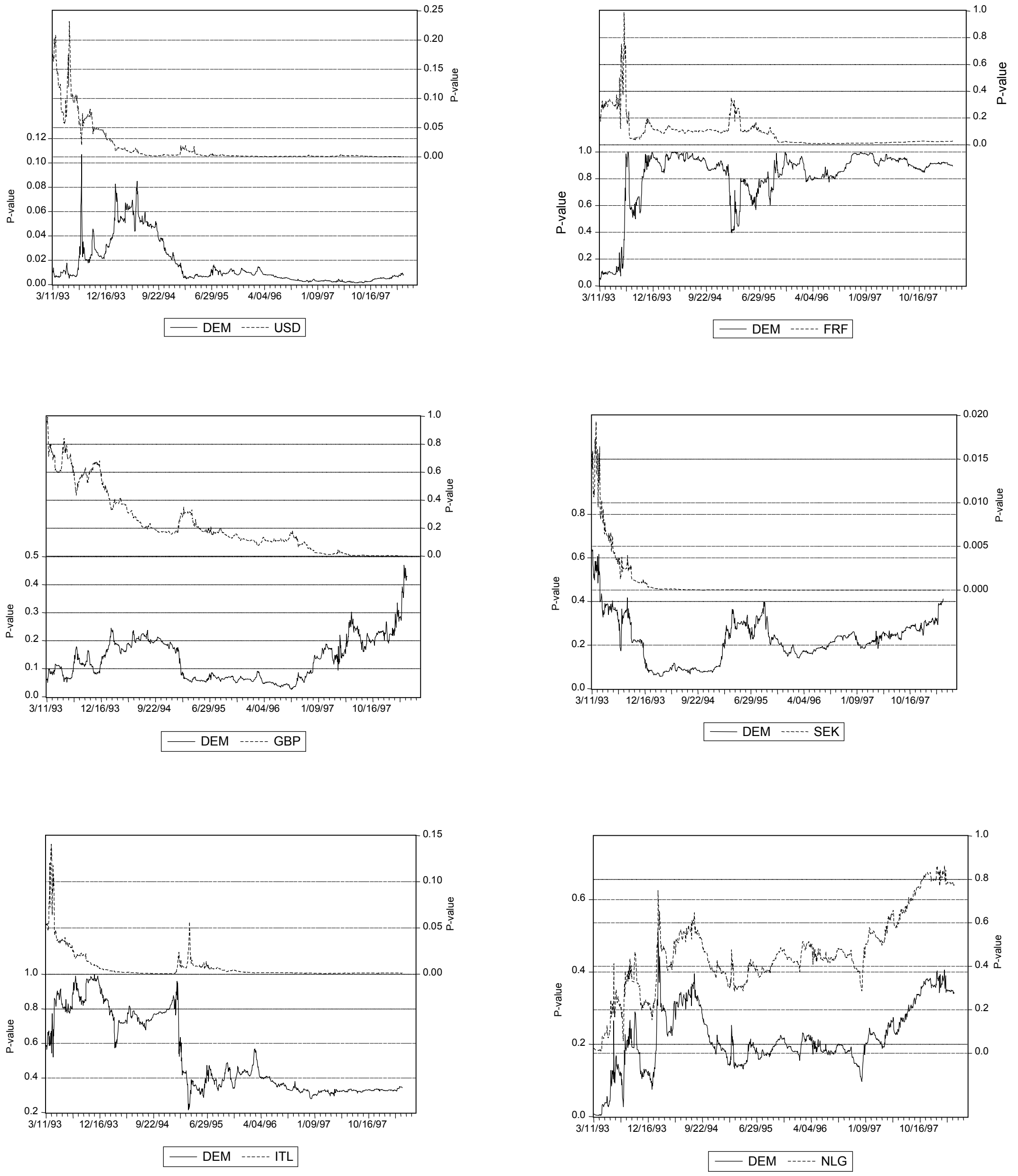
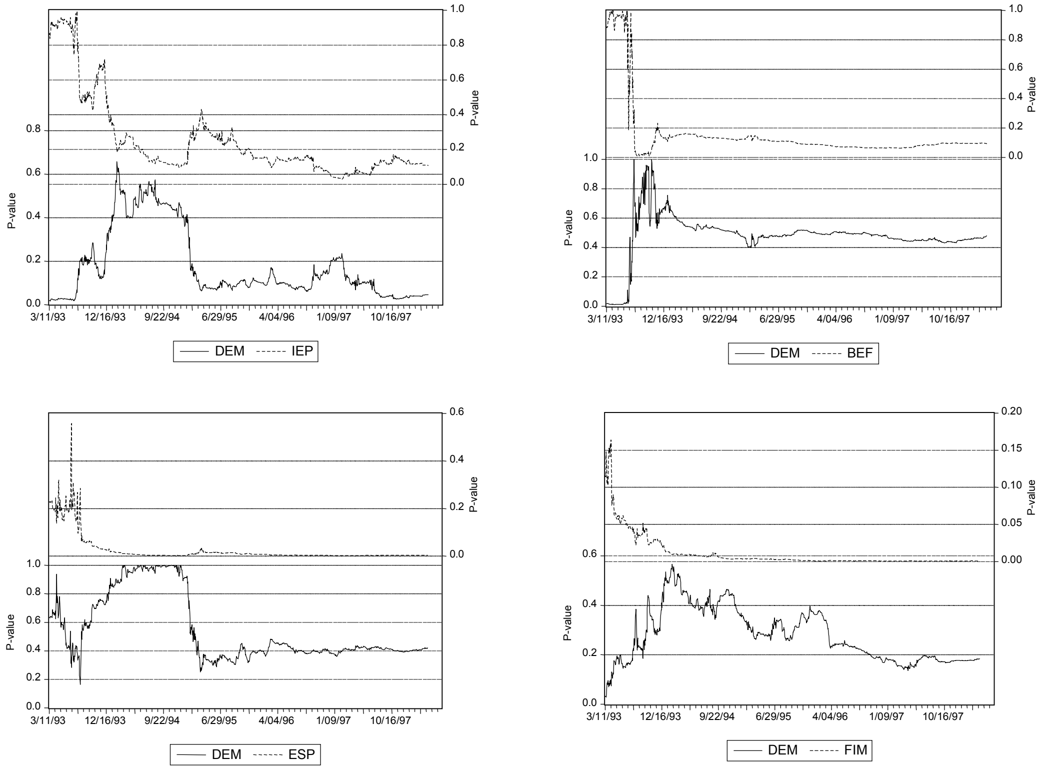


Figure 2. The rolling causality tests between the risk premium of German mark and other currencies risk premium[23].



[23] The graphs show the associated p-values of the F -tests of equations (12) and (13). The size of the rolling window is fixed to 300 trading days. Low p-values indicate that we can reject the null hypothesis that the "convergence component", $\left[rp(X) - rp(DEM)\right]_{t-1}$, does not cause changes in risk premium.

Figure 2. Continued. The rolling causality test between the risk premium of German mark and the other currencies risk premium[24].



[24] The graphs show the associated p-values of the F -tests of equations (12) and (13). The size of the rolling window is fixed to 300 trading days. Low p-values indicate that we can reject the null hypothesis that the ”convergence component”, $\left[rp(X) - rp(DEM)\right]_{t-1}$, does not cause changes in risk premium.

Appendix B: The Kalman filter recursive estimation procedure.

The Kalman filter recursions for t=0, 1, 2,…, N are given by the following expressions

$$E_t(rp_{t+1}) = \phi\, E_t(rp_t), \tag{1}$$

$$E_t(er_{t+1}) = \theta\, E_t(rp_{t+1}), \tag{2}$$

$$V_t(rp_{t+1}) = \phi\, V_t(rp_t)\,\phi' + Q, \tag{3}$$

$$D_t(er_{t+1}) = \theta\, V_t(rp_{t+1})\,\theta' + R, \tag{4}$$

$$E_{t+1}(rp_{t+1}) = E_t(rp_{t+1}) + V_t(rp_{t+1})\,\theta'\left[D_t(er_{t+1})\right]^{-1}\left[E_t(er_{t+1}) - \phi\, E_t(rp_{t+1})\right], \tag{5}$$

$$V_{t+1}(rp_{t+1}) = V_t(rp_{t+1}) - V_t(rp_{t+1})\,\theta'\left[D_t(er_{t+1})\right]^{-1}\theta\, V_t(rp_{t+1}). \tag{6}$$

The recursive procedure in equations (1) to (6) will calculate the optimal estimator of the state vector, rp_t, given all the information which is available at time t. Given the prior information for rp_0 and V_0, the Kalman filter produces the optimal estimator of the state as each new observation becomes available. When all T observations have been processed, the estimator $r\hat{p}_T$ contains all the information needed to make predictions of future observations. After filtering we can use smoothing techniques to take account of the information made available after time t. The smoothed estimator[25] is based on more information that the filtered estimator and therefore will have generally a smaller mean square error (MSE) than the filtered estimator without smoothing. In our paper we use the fixed interval-smoothing algorithm as introduced in Harvey (1993). This procedure involves a backward pass of the data through the Kalman filter from $t = T$ to $t = 1$. Finally, in our state space model in equations in the main text (9) and (10), the system matrices, Q and R will depend on a set of unknown parameters. These will be referred as the hyper parameters. In our particular case of an AR(1) model the hyper parameters are σ_v^2 and σ_u^2. Using the Kalman filter to construct the likelihood function can carry out maximum likelihood estimation of the

[25] Harvey (1993) introduces three different smoothing algorithms: the fixed point smoothing, the fixed-lag smoothing and fixed-interval smoothing.

hyperparameters. For our particular problem Harvey (1993) shows that the log-likelihood function[26] can be expressed as

$$\log L = -\frac{T}{2}(\log 2\pi) - \frac{T}{2}\log\left(\frac{1}{T}\right)\sum_{t=1}^{T} w_t^2 - \frac{1}{2}\sum_{t=1}^{N}\log f_t \, , \qquad (7)$$

where f_t is equal to $[V_{t-1}(rp_t)/\sigma_v^2 + 1]$ and w_t is equal to $[(er_t - E_{t-1}(er_t))]/(f_t)^{1/2}$. Note that both f_t and w_t can be computed using the Kalman filter introduced above. In the rest of the paper, maximum likelihood estimates of the premium models will be presented based on our model presented in equations (9) and (10).

[26] Note that the likelihood function is concentrated over σ_v^2 the variance of the noise term. The important characteristic of the likelihood function is that only the ratio of the variance of v_{t+1} to the variance of u_t matters for the calculation of premium terms, not the individual variances (Harvey 1993).

European Central Bank working paper series

For a complete list of Working Papers published by the ECB, please visit the ECB's website (http://www.ecb.int)

518 "Term structure and the sluggishness of retail bank interest rates in euro area countries" by G. de Bondt, B. Mojon and N. Valla, September 2005.

519 "Non-Keynesian effects of fiscal contraction in new Member States" by A. Rzońca and P. Ciżkowicz, September 2005.

520 "Delegated portfolio management: a survey of the theoretical literature" by L. Stracca, September 2005.

521 "Inflation persistence in structural macroeconomic models (RG10)" by R.-P. Berben, R. Mestre, T. Mitrakos, J. Morgan and N. G. Zonzilos, September 2005.

522 "Price setting behaviour in Spain: evidence from micro PPI data" by L. J. Álvarez, P. Burriel and I. Hernando, September 2005.

523 "How frequently do consumer prices change in Austria? Evidence from micro CPI data" by J. Baumgartner, E. Glatzer, F. Rumler and A. Stiglbauer, September 2005.

524 "Price setting in the euro area: some stylized facts from individual consumer price data" by E. Dhyne, L. J. Álvarez, H. Le Bihan, G. Veronese, D. Dias, J. Hoffmann, N. Jonker, P. Lünnemann, F. Rumler and J. Vilmunen, September 2005.

525 "Distilling co-movements from persistent macro and financial series" by K. Abadir and G. Talmain, September 2005.

526 "On some fiscal effects on mortgage debt growth in the EU" by G. Wolswijk, September 2005.

527 "Banking system stability: a cross-Atlantic perspective" by P. Hartmann, S. Straetmans and C. de Vries, September 2005.

528 "How successful are exchange rate communication and interventions? Evidence from time-series and event-study approaches" by M. Fratzscher, September 2005.

529 "Explaining exchange rate dynamics: the uncovered equity return parity condition" by L. Cappiello and R. A. De Santis, September 2005.

530 "Cross-dynamics of volatility term structures implied by foreign exchange options" by E. Krylova, J. Nikkinen and S. Vähämaa, September 2005.

531 "Market power, innovative activity and exchange rate pass-through in the euro area" by S. N. Brissimis and T. S. Kosma, October 2005.

532 "Intra- and extra-euro area import demand for manufactures" by R. Anderton, B. H. Baltagi, F. Skudelny and N. Sousa, October 2005.

533 "Discretionary policy, multiple equilibria, and monetary instruments" by A. Schabert, October 2005.

534 "Time-dependent or state-dependent price setting? Micro-evidence from German metal-working industries" by H. Stahl, October 2005.

535 "The pricing behaviour of firms in the euro area: new survey evidence" by S. Fabiani, M. Druant, I. Hernando, C. Kwapil, B. Landau, C. Loupias, F. Martins, T. Y. Mathä, R. Sabbatini, H. Stahl and A. C. J. Stokman, October 2005.

536 "Heterogeneity in consumer price stickiness: a microeconometric investigation" by D. Fougère, H. Le Bihan and P. Sevestre, October 2005.

537 "Global inflation" by M. Ciccarelli and B. Mojon, October 2005.

538 "The price setting behaviour of Spanish firms: evidence from survey data" by L. J. Álvarez and I. Hernando, October 2005.

539 "Inflation persistence and monetary policy design: an overview" by A. T. Levin and R. Moessner, November 2005.

540 "Optimal discretionary policy and uncertainty about inflation persistence" by R. Moessner, November 2005.

541 "Consumer price behaviour in Luxembourg: evidence from micro CPI data" by P. Lünnemann and T. Y. Mathä, November 2005.

542 "Liquidity and real equilibrium interest rates: a framework of analysis" by L. Stracca, November 2005.

543 "Lending booms in the new EU Member States: will euro adoption matter?" by M. Brzoza-Brzezina, November 2005.

544 "Forecasting the yield curve in a data-rich environment: a no-arbitrage factor-augmented VAR approach" by E. Mönch, November 2005.

545 "Trade integration of Central and Eastern European countries: lessons from a gravity model" by M. Bussière, J. Fidrmuc and B. Schnatz, November 2005.

546 "The natural real interest rate and the output gap in the euro area: a joint estimation" by J. Garnier and B.-R. Wilhelmsen, November 2005.

547 "Bank finance versus bond finance: what explains the differences between US and Europe?" by F. de Fiore and H. Uhlig, November 2005.

548 "The link between interest rates and exchange rates: do contractionary depreciations make a difference?" by M. Sánchez, November 2005.

549 "Eigenvalue filtering in VAR models with application to the Czech business cycle" by J. Beneš and D. Vávra, November 2005.

550 "Underwriter competition and gross spreads in the eurobond market" by M. G. Kollo, November 2005.

551 "Technological diversification" by M. Koren and S. Tenreyro, November 2005.

552 "European Union enlargement and equity markets in accession countries" by T. Dvorak and R. Podpiera, November 2005.

553 "Global bond portfolios and EMU" by P. R. Lane, November 2005.

554 "Equilibrium and inefficiency in fixed rate tenders" by C. Ewerhart, N. Cassola and N. Valla, November 2005.

555 “Near-rational exuberance” by J. Bullard, G. W. Evans and S. Honkapohja, November 2005.

556 “The role of real wage rigidity and labor market frictions for unemployment and inflation dynamics” by K. Christoffel and T. Linzert, November 2005.

557 “How should central banks communicate?” by M. Ehrmann and M. Fratzscher, November 2005.

558 “Ricardian fiscal regimes in the European Union” by A. Afonso, November 2005.

559 “When did unsystematic monetary policy have an effect on inflation?” by B. Mojon, December 2005.

560 “The determinants of ‘domestic’ original sin in emerging market economies” by A. Mehl and Julien Reynaud, December 2005.

561 “Price setting in German manufacturing: new evidence from new survey data” by H. Stahl, December 2005

562 “The price setting behaviour of Portuguese firms: evidence from survey data” by F. Martins, December 2005

563 “Sticky prices in the euro area: a summary of new micro evidence” by L. J. Álvarez, E. Dhyne, M. M. Hoeberichts, C. Kwapil, H. Le Bihan, P. Lünnemann, F. Martins, R. Sabbatini, H. Stahl, P. Vermeulen and J. Vilmunen, December 2005

564 “Forecasting the central bank’s inflation objective is a good rule of thumb” by M. Diron and B. Mojon, December 2005

565 “The timing of central bank communication” by M. Ehrmann and M. Fratzscher, December 2005

566 “Real versus financial frictions to capital investment” by N. Bayraktar, P. Sakellaris and P. Vermeulen, December 2005

567 “Is time ripe for a currency union in emerging East Asia? The role of monetary stabilisation” by M. Sánchez, December 2005

568 “Exploring the international linkages of the euro area: a global VAR analysis” by S. Dées, F. di Mauro, M. H. Pesaran and L. V. Smith, December 2005

569 “Towards European monetary integration: the evolution of currency risk premium as a measure for monetary convergence prior to the implementation of currency unions” by F. González and S. Launonen, December 2005