Inflation differentials and excess returns in the European Monetary System

P.J.G. Vlaar [a], F.C. Palm [b],*

[a] *De Nederlandsche Bank, PO Box 98, 1000 AB Amsterdam, The Netherlands*
[b] *University of Limburg, PO Box 616, 6200 MD Maastricht, The Netherlands*

Abstract

The dynamics of weekly excess returns of an investment in a foreign currency against that in the D-Mark are studied for four EMS currencies. For most of the period 1979–1990, the interest differentials within the EMS have been higher than the realized depreciations relative to the D-Mark. Two explanations for the existence of excess returns are found. The first is uncertainty, measured by the conditional standard deviation, which is influenced to a large extent by the inflation differential. The second source is the continuously changing perceived realignment risk, which causes the returns to be negatively correlated and induces a positive relationship between the returns and the position of the spot rate in the fluctuation band. © 1997 Elsevier Science B.V.

JEL classification: G14; F31

Keywords: Excess returns; Peso problem; Endogenous jumps

1. Introduction

The motivation for this study originates from the literature on modeling risk premia in foreign exchange markets in general (see, for example, Hodrick, 1987 for a survey) and from an analysis summarized in Section 3 which shows that substantial excess returns could have been made on an investment in the weak EMS currencies. For most of the period 1979–1990, the interest differentials were larger than the realized depreciations against the D-Mark. Moreover, it was shown that the excess returns increased if predictions of a previously developed exchange rate model were used to select the weeks in which one should invest.

In the light of this evidence on the existence of excess returns, we decided to model the series on excess returns (deviations from the uncovered interest parity)

---

* Corresponding author.

themselves, and to look for an economic explanation for their existence. Since it is possible that the interest rate differential compensates for some of the features of the exchange rate volatility, modeling excess returns directly might give interesting additional insights in the mechanism of price formation and the efficiency of the foreign exchange market. From a macroeconomic point of view, these insights are important as the excess returns are often accompanied by high domestic interest rates compared to German ones. High rates, required for the stability of the exchange rate in the absence of capital controls, might very well result in a slowdown of economic activity.

Using survey data on exchange rate expectations, Cavaglia et al. (1994) found that the forward risk premium, defined as the difference between the forward rate and the expected future spot rate, is significantly related to the inflation differential with Germany. Under the assumption of rational expectations and market efficiency, the conditional expectation of the excess returns is equal to the risk premium. Therefore, the inflation differential will also be given an important role in explaining excess returns in this paper.

When modeling returns within a target zone, care has to be taken of the 'Peso problem' (Krasker, 1980). As long as a weak currency is not devalued, a high interest rate on this currency may suggest a large risk premium. This premium may, however, be completely eroded if that currency is devalued. In our model these effects are modeled separately. The positive effect of weakness (measured by the inflation differential with Germany) on the excess return (via the higher interest rate) is modeled by a volatility measure in the mean equation. The negative effects of weakness on excess returns of possibly large losses due to large depreciations are modeled by means of stochastic jumps, where the jump probability depends on the inflation differential. An increase in the inflation differential leads to an increased probability of a draw from the normal in a compound normal distribution with the lower mean (an expected loss) and the higher variance (more volatility). A model with endogenous jumps was introduced in Vlaar (1992).

Other features of the model are the inclusion of a moving average term and the position of the spot rate in the fluctuation band as explanatory variables of expected excess returns. Both variables result from the fact that market participants do not always correctly assess the probability of a devaluation. Finally, the persistence of volatility in the excess returns is modeled by a GARCH specification (Bollerslev, 1986).

The structure of this paper is as follows. Section 2 gives some background on modeling of risk premia. To motivate the analysis, results on excess returns of different strategies of investing in foreign currencies are given in Section 3. Section 4 describes the data on excess returns. Section 5 provides the details of the model. Section 6 contains the empirical results and Section 7 concludes.

2. Modeling risk premia

If investors are risk neutral and have rational expectations, the market's forecast of the future spot exchange rate is reflected in the interest differential. However,

many researchers[1] have found that the forward premium, which under the assumption of covered interest parity is identical to the interest differential, is a biased predictor of the future exchange rate change. One way to rationalize this finding is to allow for risk aversion. If agents are risk averse, the interest differential not only reflects the expected change in the exchange rate, but also a risk premium. Considerable effort has been spent on the modeling of risk premia, but the successes have been rare.[2]

A major problem with the identification of risk premia is the two-sideness of the foreign exchange market. Since agents in two countries have objectives denominated in different currencies, it is no longer appropriate to use a model with just one type of 'representative agent'. In the literature, the representative agent model is usually restored by assuming absolute purchasing power parity (PPP) and by defining risk as the unexpected price change in one of two countries.[3] However, both absolute PPP and risk measures, defined in terms of the number of goods one can buy, are not of direct interest to the speculator in a foreign exchange market. A German investor might be searching for the highest return, denominated in D-Marks, not measured, for instance, in terms of the number of American cars he can buy. At the same time an American investor is maximizing his dollar return. Since for both investors it is risky to invest in the other currency, it is not clear who is willing to pay for the premium, and whether this will be the same party all the time.

If investors are indeed risk averse, it is not at all clear that there should be a one-to-one relationship between expected depreciations and interest rates in the first place. The reason for this loose relationship is the possible existence of risk on both sides of the market. Expected returns will only be exploited if they outweigh the minimal required risk premium. As a consequence, a range of outcomes for the current spot rate is possible given the interest rate differential and the expected future spot rate, even if all market participants have the same expectations and risk profiles:

$$E_t(s_{t+1}) + i_t^* - i_t - rp_t \leq s_t \leq E_t(s_{t+1}) + i_t^* - i_t + rp_t^*.$$

Here, s_t is the log exchange rate expressed in domestic currency per foreign currency, i_t denotes the domestic one period interest rate, rp_t is the risk premium one requires to invest in the foreign currency, and an asterisk indicates a variable for the foreign country. Within the European Monetary System, this problem of two-sidedness is probably less severe, since the risk of a devaluation within the EMS has been asymmetric most of the time. For practical purposes, the probability that the D-Mark is devalued in terms of one of the other currencies can be considered zero. As a consequence, the depreciation risk for investments in the D-Mark is bounded by the exchange rate target zone. Under these circumstances, even non-German investors might very well prefer D-Marks to their domestic currency (so that rp_t can be negative) since the risk of holding D-Marks is small, and the gains

---

[1] See, for instance, the survey articles by Froot (1990) or MacDonald and Taylor (1992).
[2] See, for instance, Giavazzi and Giovannini (1989), Giovannini (1990) and the survey by Hodrick (1987).
[3] For an application of this framework on target zone exchange rates, see Svensson (1992).

that can be made if their currency is devalued can be substantial. Therefore, it seems reasonable to assume that the risk premium is given only to the investors who are willing to invest in the weak (non-German) currency. This premium is paid by those who have to lend in the weak currency, since, in order to assure that the current spot rate stays within the fluctuation band, the interest rate on this currency will be higher than that on the D-Mark.

3. EMS exchange rate modeling

The basis for the exchange rate models is the one developed by Vlaar and Palm (1993), where it was shown that weekly EMS exchange rate changes could be modeled by means of a combined MA(1)–GARCH(1,1) jump specification. The MA part models the stabilizing effects of the intervention policy. The GARCH part models the persistence in volatility, whereas the jump specification models the large movements due to large devaluations and changes within the band due to changes in the expected devaluation probability (sudden panic induced by various kinds of economic or political news).

In Vlaar (1992), the model was extended in two directions. First, a parity reversion term was included to ensure that the spot rate would stay within the fluctuation band most of the time. Second, the probability of a jump was made time-varying. Since the jumps are often related to anticipated and/or realized realignments, they were made a function of economic fundamentals that influence the devaluation probability, i.e. the inflation differential with Germany and the trade balance surplus.[4] The resulting model for the change of the logarithm of the exchange rate (s_t) reads as:

$$\Delta s_t = \mu + \phi(s-c)_{t-1} + \lambda_t \theta + \phi D_{t-1} \epsilon_{t-1} + \epsilon_t, \tag{1}$$

where μ is the intercept, c_{t-1} is the logarithm of the central parity, and D_{t-1} is a dummy variable that takes the value 0 if the currency was devalued in period $t-1$ and 1 otherwise. It is included since changes that result from realignments differ from the usual changes within the band. $\lambda_t \theta$ denotes the contribution of the jumps to the exchange rate change. θ is the mean jump size, and λ_t denotes the probability of a jump, which is defined as:

$$\lambda_t = 1 - (1 + \exp(\lambda_0 + \lambda_{infd} infd_{t-8} + \lambda_{tb} tb_{t-8}))^{-1}. \tag{2}$$

Here $infd_{t-8}$ denotes the inflation differential between the country considered and Germany, and tb_{t-8} is the trade balance surplus of this country. A priori one would expect that the probability of a jump depends on the accumulated inflation differential and trade balance surplus. Estimation results for models in which λ_t depends on accumulated inflation differential since the last realignment and trade

---

[4] Several other variables were investigated as well, but were found to be insignificant. Among these were the accumulated inflation differential, the position of the spot rate in the fluctuation band and the interest rate differential with Germany.

balance surplus were not satisfactory. Therefore, we decided to use Eq. (2) through-out this paper. The distribution of the disturbance ϵ_t is given by the following mixture of two normal distributions:

$$\epsilon_t \sim (1-\lambda_t)N(-\lambda_t\theta, h_t^2) + \lambda_t N((1-\lambda_t)\theta, h_t^2 + \delta^2). \tag{3}$$

Conditional on the absence of a jump, an event which has probability $1-\lambda_t$, ϵ_t is normally distributed with expectation $-\lambda_t\theta$ and variance h_t^2, otherwise the expecta-tion is increased by the mean jump size θ and the variance is increased by the variance of the jump size δ^2. To model the persistence in volatility, h_t^2 is given a GARCH(1,1) specification (see Bollerslev, 1986):

$$h_t^2 = \alpha_0 + \alpha_1\epsilon_{t-1}^2 + \beta h_{t-1}^2. \tag{4}$$

This model was estimated and used in forecasting. The sample period runs from April 1979 to December 1990 (613 weeks), and the forecast period from January 1991 to September 23 1992 (91 weeks). The data were taken from Datastream and are middle rate notations from the London Eurocurrency market. For the Belgian franc interest rate, data are only available from 1981 onwards. The last week of the forecast period is the week before the Italian lira left the EMS. The model appeared to predict exchange rate changes (also out-of-sample) in the foreign exchange market with a reasonable degree of accuracy. More importantly for the present study, as the findings in Table 1 show, the excess returns associated with several investment strategies based on Eqs. (1)–(4) are substantial both for the estimation period and the forecast period. The excess returns are computed as the difference between the foreign and German 1 week interest rate (on a weekly basis) minus the realized depreciation of that currency over the investment week, i.e. $R_t \equiv i_{t-1} - i_{t-1}^{GER} - \Delta s_t$, where R_t, i_t, i_t^{GER} and s_t denote the excess returns, the foreign and the German interest rates and the logarithm of the spot rate, respectively.

For the sample period, investing every period in the weak currency (strategy 1) yields a significantly positive return for the French franc and the Italian lira. The excess returns possibly reflect a 'Peso like' risk premium (Krasker, 1980) which compensates investors for a small probability of a large devaluation. For the forecast period, significant positive excess returns are no longer present. For the Italian lira, the mean excess return is negative. The recent large depreciations of the lira were not compensated by comparably high interest differentials. The decline in excess returns for the other currencies is probably due to increased credibility of the Exchange Rate Mechanism (ERM). For the second strategy, which is based on the idea that exchange rates behave like random walks, the mean excess return is larger than for the first strategy. In efficient markets, higher excess returns result from increased risk. Indeed the standard deviations associated with this strategy are slightly higher.

The next three strategies make use of the model predictions. Mean returns are generally significantly higher than for rules 1 and 2, both within and out-of-sample. Moreover, the standard deviations are mostly smaller than for rule 2, although it should be noted that the sample variance might not be the best measure of volatility

Table 1
Excess returns on investment strategies

Strategy	Within sample				Out-of-sample			
	BF	DG	FF	IL	BF	DG	FF	IL
(1)	1.24	0.16	1.97**	3.59***	0.15	0.08	−0.08	−3.45
	25.63	12.83	23.54	30.19	17.48	4.21	10.40	42.98
	521	613	613	613	91	91	91	91
(2)	1.27	1.11**	2.09**	3.67***	2.77	1.29	0.37	−3.45
	25.69	11.91	23.63	30.27	17.79	5.17	10.45	42.98
	518	453	603	609	26	24	79	91
(3)	5.29***	2.26***	3.32***	5.12***	17.92***	2.35***	0.27	−6.28
	18.60	13.39	24.80	29.40	14.70	4.60	9.27	55.89
	329	322	467	521	17	29	64	52
(4)	6.10***	2.39***	3.35***	5.49***	19.74***	2.90***	0.28	−11.18
	18.35	13.93	25.87	29.53	15.62	4.60	8.63	69.04
	292	278	405	461	14	20	45	33
(5)	4.59***	2.39***	3.72***	5.19***	19.74***	2.90***	0.28	2.45
	15.63	13.93	20.72	28.87	15.62	4.60	8.63	12.80
	227	278	400	460	14	20	45	29

For each strategy three numbers are given. The first is the excess return R_t, averaged over investment weeks (measured in percentage points on an annual basis). The second is the standard deviation of the excess returns; the third is the number of weeks in which one is investing.

For each currency the following five strategies are investigated: (1) invest in all periods; (2) invest only when the interest rate differential is positive; (3) invest when the expected return (interest differential − expected depreciation) is positive; (4) invest when the expected return divided by the conditional standard deviation >5%; (5) invest when the expected return divided by the conditional standard deviation >5% and the probability of a devaluation <10%.

*, **, *** indicate significance at the 10, 5 and 1% levels, respectively.

in the presence of a Peso problem. The exception is the out-of-sample excess return for the Italian lira, for which the depreciations in September 1992 were much larger than forecast by the model. The last investment rule explicitly penalizes for devaluation risk, measured as the probability mass above the upper fluctuation margin. The condition is rarely binding. The results improve for the currencies for which the timing of devaluations was rightly predicted or enforced by the market, e.g. the French franc within sample and the Italian lira out-of-sample, but worsen for those currencies for which the timing of devaluations was not clearly foreseen, e.g. the Belgian franc within sample.

The excess returns associated with the use of the above model are in line with but substantially higher than those obtained by Koedijk et al. (1993) and Koedijk and Kool (1993). In a study of model-based investment strategies, they found that, for various subperiods of the EMS, a strategy of borrowing in low interest currencies and investing in high interest currencies would have been profitable for the Belgian franc, the French franc and the Italian lira, especially since 1983. In these papers, the investment decision was only based on devaluation risk.

Investment rule 5 points towards possible arbitrage opportunities in the EMS.

Using a model that relies only on information available to the market at the time of the expectation formation, it appears to be possible to single out weeks in which the mean return is higher and the variance is lower than the overall average. This means that the market is either not efficient or too risk averse to exploit expected opportunities for excess returns. Whatever the reasons were, the mere existence of these opportunities would make the foundations of models based on the assumption of absence of arbitrage opportunities highly questionable. In the following sections, the excess returns will be modeled and explained in terms of market volatility related to inflation differentials between different currencies.

4. The data

We investigate the excess returns R_t on an investment in a weak EMS currency relative to a risk-free investment in the D-Mark. Both interest rates and exchange rates series were taken from Datastream and are middle rate notations from the London Eurocurrency market. Fig. 1 shows the weekly excess returns and the devaluations (indicated by the diamonds) of the Belgian franc, the Dutch guilder, the French franc and the Italian lira for the period April 1979 to September 1992. The series for the Belgian franc start later since interest rates for the franc on the Eurocurrency market were not available before 1981. The Irish punt and Danish kroner are not included at all for the same reason. Several interesting features emerge from these figures. First of all, realignments can lead to very large speculative losses, especially if these devaluations were not foreseen by the market. The most obvious examples are the February 1982 devaluation of the Belgian franc and the September 1992 devaluation of the Italian lira. However, when a devaluation was predicted by the market, its effect on the returns is much less dramatic. The returns might even be highly positive (the French franc in 1983). Second, the volatility of the series has declined over the years, especially for the Dutch guilder. Third, these graphs do not show clear arbitrage opportunities. On average small positive excess returns are followed by (large) negative returns and vice versa.

In Table 2 some summary statistics are given for the excess returns. For all currencies the mean excess return is positive. This is in accordance with the existence of a positive risk premium for the weak currencies. The magnitude of the mean excess return for a particular currency is positively related to the number of devaluations experienced by that currency. As the low values of the first-order autocorrelation show, there is no evidence for the existence of a unit root. Serial correlation in both the raw and the squared data is only significantly present for the Dutch guilder. However, these statistics are quite sensitive to the occurrence of large outliers. Large (negative) outliers also lead to very significant excess kurtosis and negative skewness.

5. The model

To motivate the model, assume that the objective of the monetary authorities is to achieve a low inflation rate and a low unemployment level. The most important
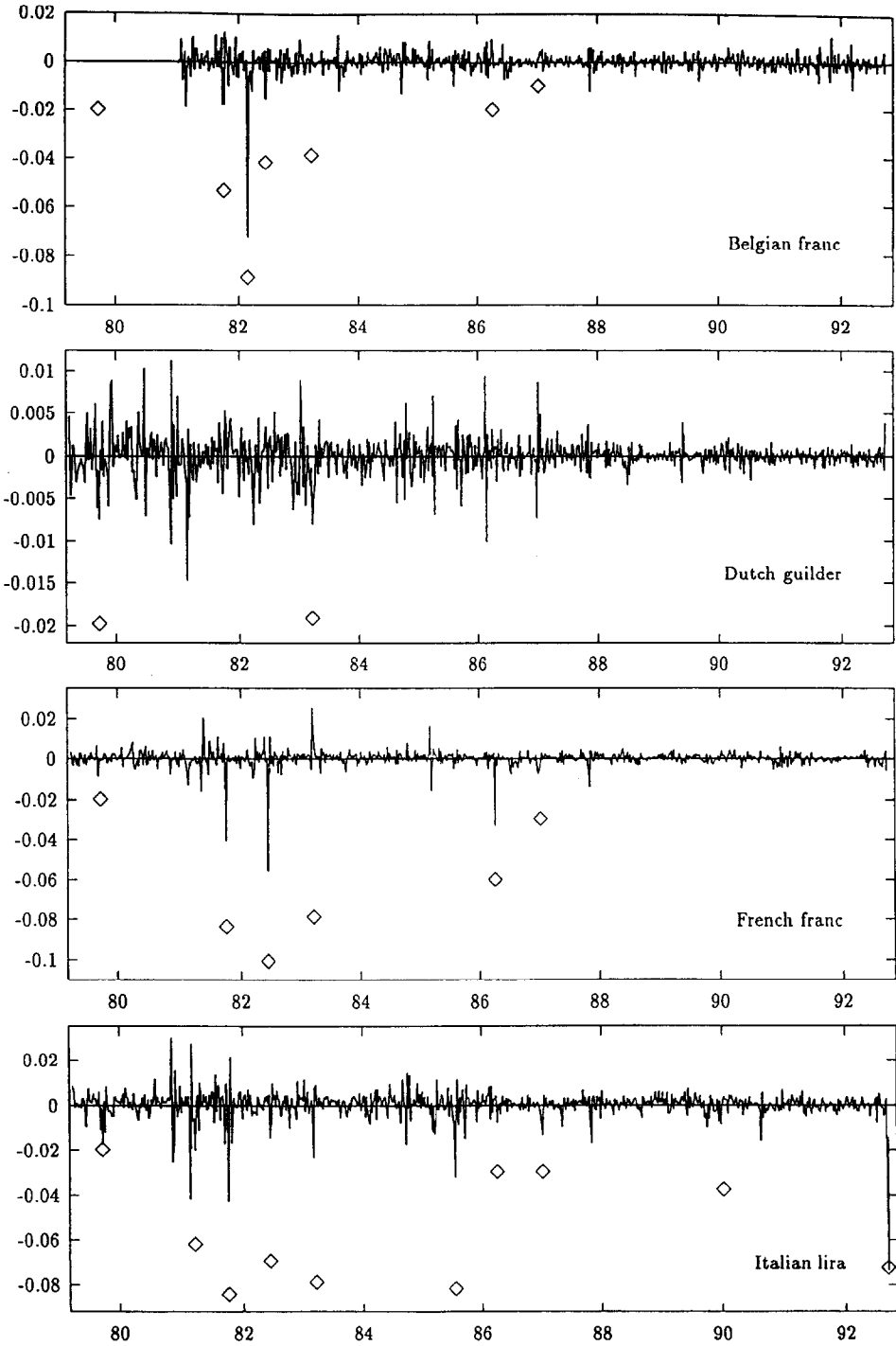
Fig. 1. Weekly excess returns and devaluations relative to the German mark.

Table 2
Summary statistics for weekly excess returns

Statistics	BF	DG	FF	IL
Mean ($\times 10^4$)	2.32	0.56	3.54	5.42
Standard deviation ($\times 10^4$)	47.26	23.22	42.87	61.90
ρ_e (1)	−0.11*	−0.16**	0.00	−0.08
LB_e^A (25)	34.79*	41.84**	36.22*	27.61
LB_{e^2} (25)	7.26	176.20***	3.77	8.79
Skewness	−6.19***	−0.24***	−4.67***	−3.40***
Excess kurtosis	89.69***	6.32***	58.93***	37.43***

Data consist of 704 weekly observations from April 4 1979 to September 23 1992, except for the Belgian franc for which the starting date is January 7 1981.
ρ_e (1) is the first-order autocorrelation; LB_e^A (25) is a Ljung–Box statistic, adjusted for ARCH-like heteroskedasticity: see Diebold (1987), and LB_e (25) is a Ljung–Box statistic for the first 25 autocorrelations in the squared data.
*,**,***Indicate significance at the 10, 5 and 1% levels, respectively.

instruments available to the monetary authorities are the parities and the level of the interest rates. A credible peg to the D-Mark enables the monetary authorities to pursue an anti-inflationary policy, since this peg is only sustainable if domestic inflation rates converge to German levels. Such an external target might be more effective than an announced monetary target, since the penalty for breaking this target (political loss of face) is higher than for not achieving the monetary target (see Giavazzi and Pagano, 1988). As long as the inflation levels have not fully converged, however, the exchange rate peg leads to a real appreciation relative to the D-Mark. The loss of competitiveness might result in a slowdown in economic activity and, as a consequence, a rise in unemployment.

If the peg is not perceived to be fully credible yet, the slowdown of economic activity might even be worsened by the high interest rates the market will demand for investments in the weak currency. Under these conditions a devaluation might seem appropriate, but it would seriously jeopardize the inflation objectives. It would lead to additional imported inflation and reduce the market's belief in the announced targets. Moreover, in the long run, a devaluation is likely to result in higher interest rates (which might lead to higher unemployment) and a higher risk premium due to the loss of credibility.[5] Under these circumstances, it might be difficult for the market to forsee the measures taken by monetary authorities. Since the speculative loss can be considerable if a (large) devaluation is not foreseen by the market, the uncertainty of the market participants about future devaluations is very important. Uncertainty will be the driving force behind our model. Large losses, either resulting from depreciations within the band or from unforeseen devaluations are modeled by means of stochastic jumps. The statistical meaning of a jump is a draw from a

---

[5] Obstfeld (1991) shows that the mere existence of the realignment possibility already destabilizes the exchange rate system, even if the authorities pledge they will only use this escape clause in extreme circumstances. This is primarily due to the fact that the contingents under which they will devalue are often not observable, or may change over time.

normal distribution with a negative mean (an expected loss) and a high variance (much volatility). Since the jumps are related to parity realignments, we assume their intensity to be a function of fundamentals determining the realignment probability. In this paper, only the inflation differential with Germany will be considered,[6] thereby adapting Eq. (2) by imposing the restriction $\lambda_{tb} = 0$. The empirical results for the model in which λ_t depends on the accumulated inflation differential since the last realignment were not significant. Therefore, they are not reported.

It should be noted that λ_t is not the same as the probability of a realignment at time t. Jumps might also occur in anticipation of realignments, speculative attacks or sudden panic due to some political or economical 'news'. Moreover, if the variance of the jump size is very high compared to its mean, the number of 'jumps' exceeds the number of large depreciations (the jumps change the distribution, they cannot be identified separately).

In each period, market participants will assess the probability of a realignment in the next period. The higher this perceived probability is, the higher will be the interest rate demanded on that currency. Market expectations about a parity adjustment will be based on, among other things, the decisions taken by the monetary authorities. The authorities will therefore try to keep the exchange rate well within the fluctuation band,[7] since a spot rate at the top of the band could be interpreted by the market as an indication for an upcoming devaluation.[8] Only if the costs, in terms of high interest rates, of keeping the spot rate in the middle of the band become too high, the exchange rate will approach the weak margin. Therefore, a high position of the spot exchange rate in the fluctuation band is likely to be accompanied by a high interest differential with Germany. This means that as long as no devaluation has been decided on, a high position in the fluctuation band leads to a large excess return. Moreover, again under the assumption of no devaluation, it is likely that returns are negatively autocorrelated. A speculative loss, that is an unforeseen depreciation (due to a rise in the expected realignment probability for the upcoming week), is accompanied by a rise in the interest rate, whereas at the same time in the absence of a realignment, the maximum depreciation is bounded by the fluctuation band. These effects might, however, be completely compensated by devaluations. If the timing of realignments was always correctly foreseen by the market, it would not be clear whether the position in the band is informative about the future return. Finally, risk averse investors require a higher risk premium, that is an increase of the expected excess return, in the presence of increased risk. This will be modeled by including the conditional standard deviation of the excess return in the mean equation of our model.

---

[6] This is in accordance with Cavaglia et al. (1994), where it was shown that the inflation differential significantly influences the risk premium. The specification is also in accordance with the results of Rose and Svensson (1994), who found the inflation differential to be the only economic fundamental determining the market expectation of a realignment.

[7] Until the Basle–Nyborg agreement in September 1987, this was the official policy of the French monetary authorities.

[8] Chen and Giovannini (1993) found the realignment expectation to be positively related to the current position in the band.

From these considerations the following equation for the excess return is put forward:

$$R_t = \mu + \gamma SD_{t-1} + \phi(s-c)_{t-1} + \lambda_t \theta + \psi D_{t-1}\epsilon_{t-1} + \epsilon_t, \qquad (5)$$

which is similar to the equation for Δs_t in Eq. (1) and where SD_{t-1} denotes the conditional standard deviation of R_t given information up to period $t-1$. It is given by the square root of the variance, conditional on the inflation differential in Eq. (6). The distribution of the disturbance ϵ_t is the same as the one for the exchange rates, given in Eq. (3). From the distribution of the error term it follows that:

$$E(\epsilon_t^2) = (1 - \lambda_t)[(-\lambda_t\theta)^2 + h_t^2] + \lambda_t[((1-\lambda_t)\theta)^2 + h_t^2 + \delta^2]$$

$$= h_t^2 + \lambda_t(\delta^2 + (1-\lambda_t)\theta^2). \qquad (6)$$

The dummy variable D_{t-1} takes the value 0 after a devaluation and 1 otherwise. It is included since losses that result from parity changes are not expected to be compensated the next week. $\lambda_t\theta$ measures the contribution of the 'jumps' to the expected return.

Eq. (5) can also be interpreted as a specification explaining the risk premium defined as $rp_t \equiv i_{t-1} - i_{t-1}^{GER} - E_{t-1}s_t + s_{t-1}$ with $E_{t-1}s_t$ denoting the expectation of s_t conditional on the information available at period $t-1$. Therefore, we have $rp_t = R_t - \epsilon_t$. To the extent that the inflation differential reflects the degree of uncertainty in foreign exchange markets, it is expected to be a major determinant of the risk premia. If the inflation differential rises, the probability of a draw from the normal distribution with lower mean (on average a loss) and higher variance (more volatility) rises. Finally, the persistence in volatility is modeled by means of a GARCH(1,1) specification as in Eq. (4).

The differences with the model for the exchange rate changes given in Section 3 are that SD_{t-1} does not enter into the equation for the mean of Δs_t in Eq. (1), whereas the trade balance surplus enters as an additional explanatory variable into the specification of the jump intensity in Eq. (2). This variable has been deleted for the excess return models to avoid multicollinearity. Given that an MA(1)–GARCH(1,1)-Bernoulli-jump model has been found to perform quite well in explaining the exchange rate dynamics, we expect that the model in Eqs. (2)–(6), with $\lambda_{tb} = 0$, will also be appropriate to explain excess returns.

Finally, the expected jump size θ could be made a function of fundamentals, such as the inflation differential, as well, but this extension did not yield a significant statistical result. Estimation results for the model in which λ_t depends on the accumulated inflation differentials were not satisfactory either.

6. Empirical results

In Table 3, the maximum likelihood results are shown. The effect of volatility (γ), measured as the conditional standard deviation (SD_{t-1}) is highly significant for three out of four currencies. As expected, volatility increases the mean excess return. Only

Table 3
Empirical results for weekly excess returns

The model

$$R_t = \mu + \gamma SD_{t-1} + \phi(s-c)_{t-1} + \lambda_t \theta + \psi D_{t-1}\epsilon_{t-1} + \epsilon_t$$
$$\lambda_t = 1 - (1 + \exp(\lambda_0 + \lambda_{infd} infd_{t-8}))^{-1}$$
$$\epsilon_t \sim (1-\lambda_t)N(-\lambda_t\theta, h_t^2) + \lambda_t N((1-\lambda_t)\theta, h_t^2 + \delta^2)$$
$$h_t^2 = \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \beta h_{t-1}^2$$

Parameters	BF	DG	FF	IL
μ ($\times 10^4$)	−5.46*	−0.53	−2.65	−11.34*
	(−1.72)	(−0.47)	(−0.57)	(−1.68)
γ	0.18**	0.10	0.22*	0.43***
	(2.38)	(1.44)	(1.91)	(3.45)
ψ ($\times 10^2$)	3.83***	3.47	1.59	0.84
	(3.75)	(1.57)	(1.44)	(1.55)
ψ	−0.30***	−0.27***	−0.10***	−0.12***
	(−5.46)	(−5.98)	(−2.77)	(−2.80)
λ_0	−4.32***	−2.65***	−4.90***	−3.77***
	(−5.79)	(−5.55)	(−7.35)	(−7.74)
λ_{infd}	36.80***	56.58	41.52***	14.65***
	(2.69)	(1.46)	(3.79)	(3.98)
θ ($\times 10^2$)	−0.62	−0.14*	−0.49	−0.92***
	(−0.95)	(−1.75)	(−1.30)	(−2.75)
δ^2 ($\times 10^4$)	4.21	0.19***	2.60**	2.79**
	(1.01)	(2.37)	(1.77)	(1.69)
α_0 ($\times 10^6$)	1.99**	0.05*	3.70***	3.60***
	(2.17)	(1.50)	(7.20)	(3.45)
α_1	0.21**	0.18***	0.13***	0.15**
	(2.24)	(2.68)	(2.38)	(2.10)
β	0.51***	0.76***	0.06	0.40***
	(3.45)	(8.72)	(0.90)	(3.27)
Statistics				
χ^2 (29)	36.04	37.39	33.64	50.94***
LB_e (25)	24.23	35.01*	27.42	35.30
LB_{e^2} (25)	30.87	19.76	22.28	10.97
Skewness	0.03	0.03	−0.09	−0.10
Excess kurtosis	0.39**	0.15	0.17	0.35*

The data consist of 704 weekly observations from April 4 1979 to September 23 1992, except for the Belgian franc for which the starting date is January 7 1981.
χ^2 (29) is an adjusted Pearson goodness-of-fit test performed on a classification in 30 cells. LB_{e^2} (25), skewness and excess kurtosis are computed on normalized residuals: see Vlaar (1993).
Heteroskedasticity-consistent t-values are in parentheses.
*, **, *** indicate significance at the 10, 5 and 1% levels, respectively.

for the Dutch guilder is the coefficient not significant, a finding which reflects the small magnitude of the inflation differential, which is a major determinant of the conditional variance, during the whole sample period.

Inflation also has the expected effect (λ_{infd} is positive) for all currencies. Again, it is not significant for the Dutch guilder. For all currencies, the probability of a jump increases with the inflation differential. Since the mean jump size (θ) is negative (although not always significant), this means that a relatively high inflation differential increases the probability of a big loss. The variance of the jump size (δ^2), however, is very big compared to its mean, so that the effect on volatility is also very important. As the volatility increases with inflation, the risk of a big loss is at least partly compensated by an increase of the expected excess returns due to a rise in *SD*.

A position in the band above the central parity increases the expected return, as the estimates of ϕ are positive. This effect is only significant for the Belgian franc. One would expect a positive sign if the devaluations were not all perfectly foreseen by the market. The significant negative moving average parameter (ψ) is also in accordance with our expectations. In particular, for the French franc, this result is quite remarkable since the first order autocorrelation of the excess returns was positive. The positive correlation of R_t is probably due to two successive negative outliers. By including jumps in the specification, the model allows for the occurrence of outliers and the influence of these outliers is reduced: see Vlaar and Palm (1993). The magnitude of the MA parameters is very much in line with those for the exchange rates themselves: see Vlaar (1992). This means that the interest differentials do not compensate for the negative correlation in the exchange rate changes.

The GARCH(1,1) specification is appropriate in modeling the conditional heteroskedasticity, although an ARCH(1) specification would do just as well for the French franc. Again, these results are similar to those for the exchange rates in Vlaar (1992). Conditional heteroskedasticity is present in all series, although the LB_{e^2} statistic was only significant for the Dutch guilder (see Table 2). The conditional heteroskedasticity would not be detected if jumps were not included.

Turning to the model diagnostics, we see that the model performs reasonably well. The χ^2 (29) statistic is an adjusted Pearson χ^2 goodness-of-fit test statistic performed on a classification in 30 cells: see Vlaar (1993).[9] Only for the Italian lira is there strong evidence against the model (at the 1% level). As the goodness-of-fit test also requires independent observations, a rejection of the null might be due to dependence in the data, which might be remedied by a modification in the MA–GARCH specification. Therefore, we also computed Ljung–Box statistics. As this test assumes a normal distribution, we first normalized the residuals: see Vlaar (1993). Given the probability of getting a smaller value than the one observed, the corresponding standard normal residual is computed by means of the inverse of the standard normal cumulative distribution function. The dependence in the data appears to be modeled appropriately using the MA(1)–GARCH(1,1) specification.

---

[9] The adjustment concerns the classifying mechanism. Since the (standardized) residuals of a combined jump–GARCH model are not identically distributed, which is required for the Pearson test, we classify them according to the value of the cumulative distribution function. That is to say, for each residual we compute the probability of getting a smaller value than the one observed. These probabilities should be identically uniformly distributed between zero and one.

Only for the Dutch guilder and the Italian lira is the Ljung-Box test significant at the 10% level. When based on the squared residuals, the Ljung–Box statistic is not significant at the conventional levels.

Finally, the resulting skewness and excess kurtosis in the normalized residuals are computed. Although both skewness and excess kurtosis are substantially reduced, there is still some excess kurtosis left for the Belgian franc and Italian lira. These results are completely due to the very negative returns during the devaluations of February 1982 (for the Belgian franc) and September 1992 (the Italian lira): see Fig. 1.

Since it is not clear at first sight whether the effect of inflation on expected excess returns is dominated by volatility (via γSD) or by the negative jumps (via $\lambda\theta$), we calculated the expected returns and variances, conditional on the inflation differential. For these calculations it was assumed that the spot rate was in the middle of the fluctuation band, and that the lagged error term was zero. The resulting expected return is:

$$E(R) = \mu + \gamma SD + \lambda\theta. \tag{7}$$

From Eq. (6) for the conditional variance, and the GARCH Eq. (4), one obtains $E(h^2) = (\alpha_0 + \alpha_1 E(\epsilon^2))/(1 - \beta)$, which leads to the following variance specification, conditional on the inflation differential:

$$
\begin{aligned}
E(\epsilon^2) &= (\alpha_0 + \alpha_1 E(\epsilon^2))/(1 - \beta) + \lambda(\delta^2 + (1 - \lambda)\theta^2) \\
&= (\alpha_0 + (1 - \beta)\lambda(\delta^2 + (1 - \lambda)\theta^2))/(1 - \alpha_1 - \beta).
\end{aligned} \tag{8}
$$

The square root of this expression is used to compute SD in Eq. (7).

In Fig. 2, the expectation Eq. (7) and variance Eq. (8) are shown, expressed as a function of the inflation differential. On the horizontal axis, the inflation differential with Germany is shown. For each currency the range corresponds to the historical inflation differentials over the sample period.

The yearly inflation differentials with respect to Germany are given in Fig. 3. For the Belgian franc it varies between 5 and -2%. For the Dutch guilder the range is from 2 to -1.5 percentage points. For the French franc, the inflation differential has dropped from 8 to roughly -1% over the sample period, whereas the Italian lira experienced only positive inflation differentials which reached a maximum of some 15% in 1981.

For each currency the expected excess returns remain positive at zero and negative inflation differentials. This reflects the reputation of the D-Mark as a strong currency. If the inflation differential is not too high, the inflation effect through the volatility measure SD dominates the expected return. For higher inflation differentials, however, the effect through $\lambda\theta$ becomes more important. For the French franc and the Dutch guilder, the highest expected return is reached at an inflation differential of about 8 and 1%, respectively, after which the negative expected jump size dominates.

Notice that the determination of the premium strongly relies on the form of the specification of the model and the assumption that the true model has been known to the market. It is likely that in the early years of the EMS, market participants
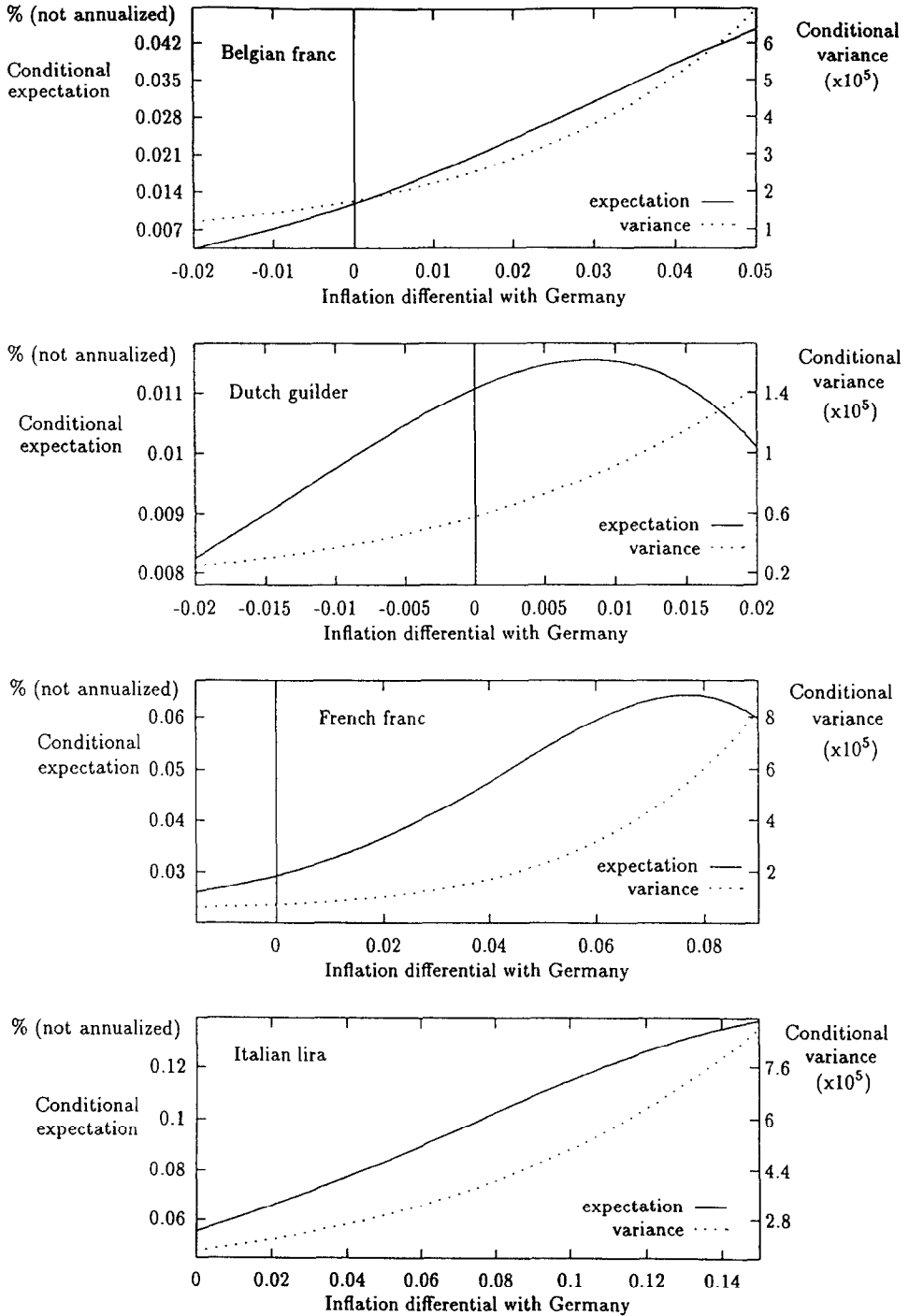
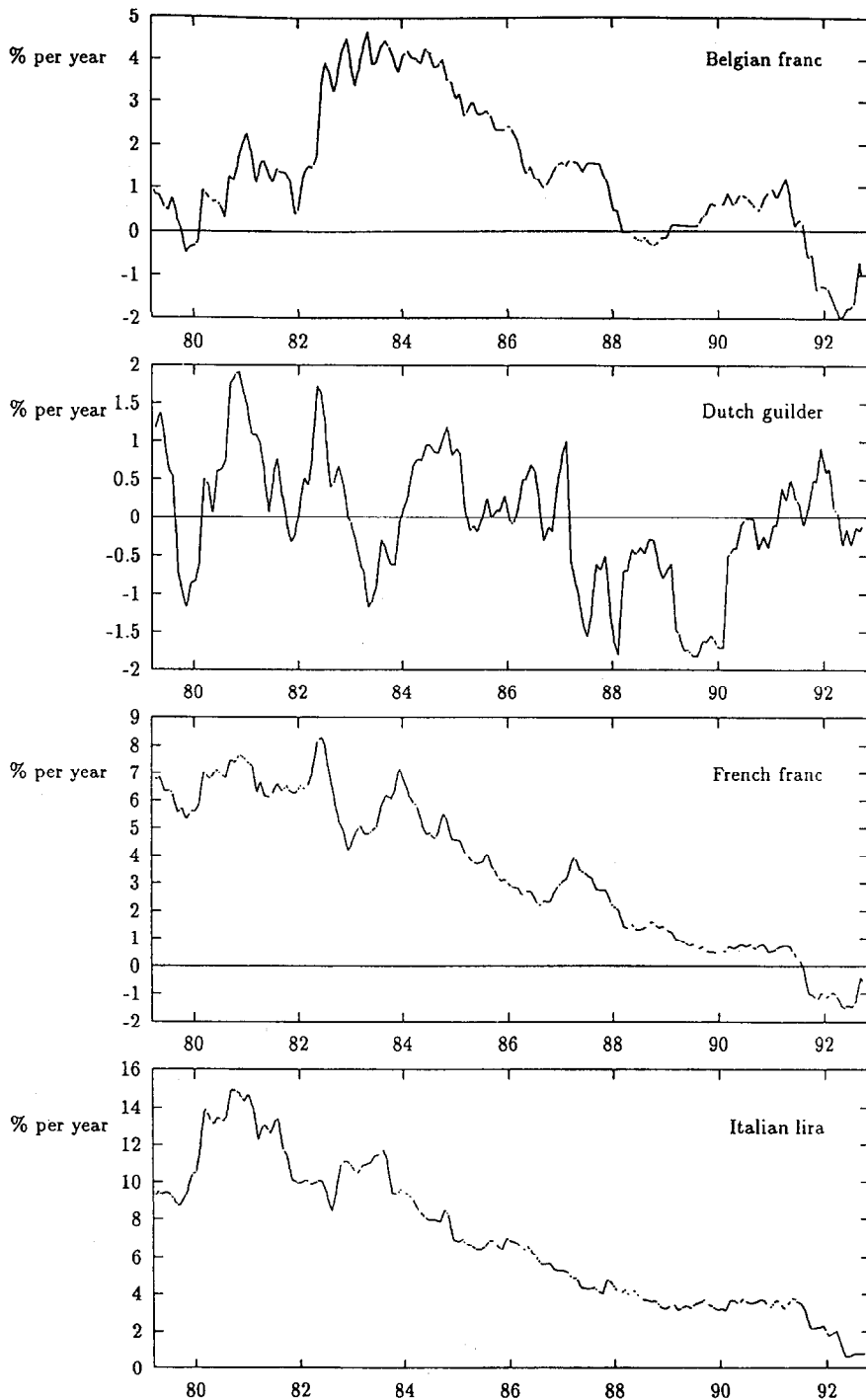Fig. 2. Conditional expectation and variance of excess return.

Fig. 3. Yearly inflation differential with Germany (lagged 8 weeks).

had to learn about its mechanisms. If, for example, they had known the size of the devaluations in advance, they would probably not have invested in the French franc in 1981–1982, or they would have demanded a higher interest rate (as they did in 1983, Fig. 1).

On the right-hand scale the variance, conditional on the inflation differential, is depicted. The variance is influenced to a large extent by the inflation differential. For the French franc for instance, the conditional variance is about 16 times higher for a inflation differential of 9% than for a situation with a zero inflation differential. Although the differences for the other currencies are less severe, considerable differences are found for all of them.

The estimated risk premia $\hat{rp}_t = R_t - \hat{\epsilon}_t$ are given in the graphs of Fig. 4. The risk premia are highly volatile reflecting the volatility of the exchange rates. They have been positive most of the time for the French franc and the Italian lira. For these currencies, the magnitude of the premium has been in the order of several percentage points on an annual basis for sustained periods. On several occasions, the risk premium even reached a level of over 50% on an annual basis. These extremely high premia are due to the high conditional variance (due to the GARCH effect) after realignments.

Finally, we note that alternative variants of the model have been estimated too. The model in which the inflation differential is included in the mean Eq. (5) also yielded less satisfactory results than the above model. Including the trade balance or the accumulated inflation differential since the last realignment in Eq. (2) did not lead to an improvement either. This is probably due to multicollinearity. A model in which the inflation differential enters into the mean Eq. (5) instead of the volatility measure SD yielded satisfactory results, but for theoretical reasons, the above model which links excess returns to volatility was preferred.

7. Conclusions

In this paper a model for the weekly excess returns on four EMS exchange rates against the D-Mark was presented. The structure of the model is similar to that used in previous analyses of the behavior of the exchange rates themselves (see Vlaar, 1992). However, the present model goes further as it explains excess returns through volatility. The model is a MA(1)–GARCH(1,1)-Bernoulli-normal jump process with a mean that depends on the position of the currency in the fluctuation band of the EMS and on volatility and with a jump intensity that depends on the inflation rate differential. This GARCH in mean-type model performs remarkably well compared to other GARCH in mean models used in finance.

Two major sources for the excess returns are found. The first is uncertainty, measured by the conditional standard deviation of the excess returns, which is influenced to a large extent by the inflation differential. The second source for excess returns is the continuously changing perceived realignment risk. These changes cause
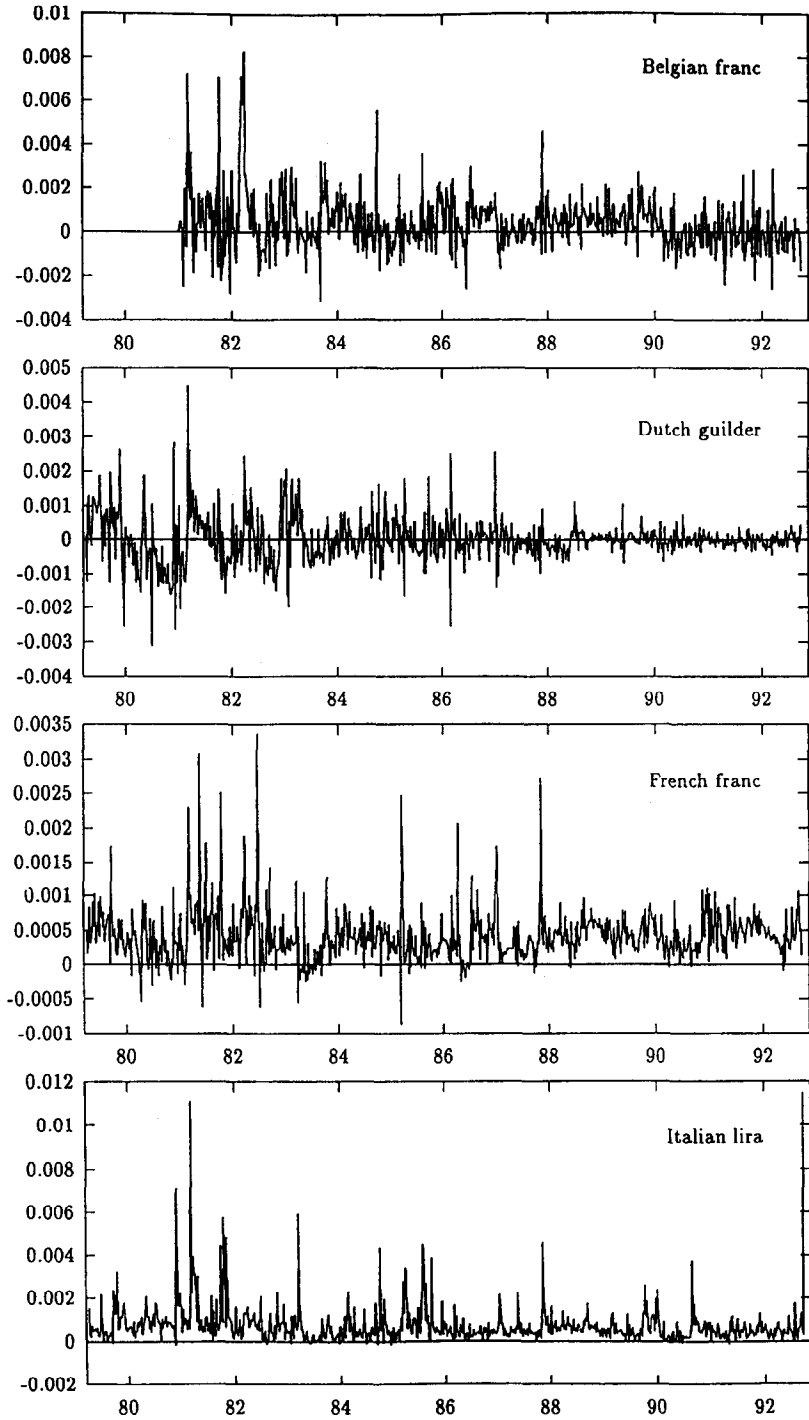
Fig. 4. Expected weekly excess returns.

the excess returns to be negatively correlated and induce a positive relationship between the position of spot rate in the fluctuation band and the expected excess returns. However, this does not necessarily mean that the market is inefficient. It merely points towards the fact that the market does not always correctly predict the timing of devaluations, which is hardly surprising. Abnormal returns generally arose when the timing or size of a parity realignment was not correctly assessed by the market. The model describes the empirical regularities in excess returns quite well. It incorporates the linear relationship between expected returns and volatility and the nonlinear relationship between excess returns and the inflation differential, a major economic fundamental, in a very satisfactory manner. It performs remarkably well in explaining, at least in part, the observed excess returns in terms of increased volatility and increased inflation differentials, a finding which is very much in line with the efficient market hypothesis.

Estimates of the risk premium based on the model show that premia are substantial and highly volatile, reflecting the changing uncertainty present in the EMS. These findings are at variance with those of Svensson (1992) and Beetsma (1992), who find that the foreign exchange risk premium for an imperfectly credible exchange rate band with devaluation risk is, respectively, of moderate or of small and constant size. From a macroeconomic point of view, understanding the interest rates associated with large risk premia can lead to an economic slowdown.

Although risk premia are not completely explained by economic fundamentals, our results show that this can at least be partly achieved. Compared with earlier results for free-float currencies, this result is encouraging. The differences are probably due to the fact that EMS currencies always move in the direction of the fundamentals (if they move), whereas free-float currencies might be more frequently subject to speculative bubbles which conceal the relationship between risk premia and fundamentals.

References

Beetsma, R., 1992. Imperfect Credibility of the Band and Risk Premia in the European Monetary System. CentER Discussion Paper 9254, Tilburg University.

Bollerslev, T., 1986. Generalized autoregressive conditional heteroskedasticity. Journal of Econometrics 31, 307–327.

Cavaglia, S.M.F.G., Koedijk, K.G., Vlaar, P.J.G., 1994. Exchange rate expectations and risk premia in the European Monetary System: 1985–1991. Open Economies Review 5, 347–360.

Chen, Z., Giovannini, A., 1993. The determinants of realignment expectations under the EMS: some empirical regularities. NBER Working Paper 4291.

Diebold, F.X., 1987. Testing for serial correlation in the presence of ARCH. Proceedings from the American Statistical Association, Business and Economics Section, pp. 323–328.

Froot, K., 1990. Short rates and expected asset returns. NBER Working Paper 3247.

Giavazzi, F., Giovannini, A., 1989. Limited Exchange Rate Flexibility. MIT Press, Cambridge, MA.

Giavazzi, F., Pagano, M., 1988. The advantage of tying one's hands: EMS discipline and central bank credibility. European Economic Review 32, 1055–1082.

Giovannini, A., 1990. European monetary reform, progress and prospects. Brooking Papers on Economic Activity 2, 217–291.

Hodrick, R.J., 1987. The Empirical Evidence on the Efficiency of Forward and Futures Foreign Exchange Markets. Harwoord Academic Publishers, Chur, Switzerland.

Koedijk, K.G., Kool, C.J.M., 1993. Betting on the EMS. Open Economies Review 4, 151–173.

Koedijk, K.G., Stork, P.A., de Vries, C.G., 1993. An EMS target zone model in discrete time. Limburg Institute of Financial Economies, Working Paper 93-02.

Krasker, W.S., 1980. The 'Peso problem' in testing the efficiency of forward exchange markets. Journal of Monetary Economics 6, 269–276.

MacDonald, R., Taylor, M.P., 1992. Exchange rate economics. IMF Staff Papers 39, 1–57.

Obstfeld, M., 1991. Destabilizing effects of exchange-rate escape clauses. NBER Working Paper 3603.

Rose, A.K., Svensson, L.E.O., 1994. European exchange rate credibility before the fall. European Economic Review 38, 1185–1216.

Svensson, L.E.O., 1992. The foreign exchange risk premium in a target zone with devaluation risk. Journal of International Economics 33, 21–40.

Vlaar, P.J.G., 1992. Target zones and realignment risk: an integrated approach. Research Memorandum 92-050, University of Limburg.

Vlaar, P.J.G., 1993. Simple diagnostic tests for likelihood functions with an application to daily US dollar rates. Research Memorandum 93-004, University of Limburg.

Vlaar, P.J.G., Palm, F.C., 1993. The message in weekly exchange rates in the European Monetary System: mean reversion, conditional heteroskedasticity and jumps. Journal of Business and Economic Statistics 11, 351–360.