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The spot–forward relationship revisited: an ERM perspective

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Abstract

We re-examine the relationship between spot and forward exchange rates using Hansen's stability tests for co-integrating equations. Two numeraire currencies are used: the DM as the ERM's *n*th currency and the US$ as a 'control'. The striking feature is that while the spot–forward relationship displays broad stability against the dollar, precisely the opposite is true against the DM. We investigate whether this result can be interpreted as evidence that the ERM target zones lacked credibility. Using the general-to-specific modelling framework, we develop dynamic relationships that can be readily used to interpret the source of the Hansen instability. Our results also have implications for the appropriate way to test the unbiasedness of the forward exchange rate. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Spot–forward; Target zones; Dynamic modelling

JEL classification: F30; F41

1. Introduction

The speculative 'efficiency' hypothesis asserts that the foreign exchange forward discount is an unbiased predictor of future spot depreciation. Given that covered interest parity is virtually an arbitrage identity, this hypothesis is equivalent to uncovered interest parity. The notion that the international interest differential is

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equal to expect future spot depreciation is widely used in many open economy macro models. An example is the theory of target zones of Krugman (1991), particularly as interpreted by Svensson (1991) and Bertola and Svensson (1993). Indeed, Svensson uses uncovered interest parity to provide his 'simplest test' of target zone credibility.

The first contribution of this paper is to provide a critique of standard methods for representing and testing the speculative efficiency hypothesis. The Granger Representation Theorem provides us with a methodology for specifying the short-run dynamics of co-integrating relationships such as that typically exists between spot and forward exchange rates. The speculative efficiency hypothesis is shown to be an improbable specification and this is confirmed by empirical testing. More significantly, the analysis provides us with a straightforward guide to a valid estimation and testing framework.

The second contribution of the paper is to apply Hansen's stability tests for co-integrating regressions to the spot–forward relationship for EMS exchange rate mechanism participating countries. Two numeraire currencies are used – the DM and the US$. The countries selected are those that participated in the ERM. The results are vivid. The spot–forward relationships against the dollar are broadly stable. The DM relationships are chronically unstable. One interpretation is that indicates a lack of target zone credibility. However, it is not the only one.

The final contribution of the paper is to devise and implement a framework for identifying, when the instability of the spot–forward relationships is attributable to a lack of credibility of the ERM target zones. It confirms that some realignment was largely unanticipated, but other realignment can be interpreted as credibility failures.

The plan of the paper is as follows: in Section 2, we provide a critique of methods of representing, estimating and testing speculative efficiency. We also introduce the Hansen stability tests. Section 3 reports the empirical analysis. This includes the outcome of applying the Hansen stability tests. The different sources of instability are also assessed by estimating valid dynamic error correction mechanisms. Section 4 offers some concluding remarks.

2. The spot–forward relationship and econometric methods

2.1. Background

The traditional vehicle for testing the unbiasedness of the forward exchange rate is

$$\Delta s_t = \beta_0 + \beta_1(f_{t-1} - s_{t-1}) + u_t, \tag{1}$$

where s_t denotes the log of the spot exchange rate, and f_t is the log of the forward rate. Under the joint hypothesis of rational expectations ($\Delta s_t = E(\Delta s_t) + v_t$) and a zero risk premium, the forward premium should provide an unbiased estimate of the expected change in the exchange rate. That is, in an estimated version of Eq.

(1), $\hat{\beta}_0$ is expected to be zero, and $\hat{\beta}_1$ is expected to be unity. Numerous tests of this relationship have found that for US$ bilateral rates the forward premium is a biased predictor, and this has often been attributed to a time-varying risk premium (see Fama, 1984), or to some form of expectational failure (see Bilson, 1981). The existence of one or both of these effects introduces a non-zero correlation between the forward premium and error term in Eq. (1), thereby biasing the estimate of β_1 downwards. Barnhart et al. (1999) have demonstrated that this downward bias also exists in other equations used to estimate unbiasedness, such as error correction models and levels-based co-integration tests which do not account for simultaneous equation bias.

In this paper, we examine the unbiasedness of a number of Dollar and DM-based currencies. Our sample period corresponds to the ERM experiment with target zone exchange rates. The choice of this period is deliberate. For example, in a fully credible target zone, a test of Eq. (1) would be expected to produce a confirmation of unbiasedness, since the risk premium should be zero (or very small) and the credibility itself should rule out expectational failures (see Svensson, 1991). However, as is now well-known, the ERM did not constitute a credible target zone, at least not for the full period, and so the expectation is that in estimating Eq. (1) for an ERM-based currency, a result similar to that found for US$ bilaterals would be produced. But is this in fact the case? This is one of the issues we address in our empirical section. To avoid the potential simultaneity problems associated with testing unbiasedness, we use robust estimators. Furthermore, the econometric methods used offer an alternative and novel way of testing, the credibility of a target zone. We believe that our method is simpler than Svensson's drift adjustment method of testing credibility since it is a one-step single equation method.

As noted above, numerous researchers have exploited relationship (1) in a variety of econometric tests (see Engel, 1996 for a survey). However, in general, it is not a valid testing vehicle. There is, as we have noted, the potential problem of simultaneous equation bias, but, additionally, Eq. (1) can only be employed using stationary methods, if both the dependent and independent variables possess the same order of integration. There is a little doubt that spot exchange rates are I(1), except in extreme hyperinflation situations: it follows that their first differences, Δs_t are I(0), and indeed are typically white noise. The order of integration of the forward premium is more problematic. As Bekaert (1996) reminds us, it is a highly positively autocorrelated, but Baillie and Bollerslev (1994) argue that the forward premium is fractionally integrated with an order of integration greater than 1/2. The implication of Baillie and Bollerslev's view is that Eq. (1) is invalid, because the variance of the forward premium is not defined.

2.2. Single equation dynamics

Consider the levels equivalent to Eq. (1)

$$s_{t+k} = \beta_0 + \beta_1 f_t + v_{t+k}. \tag{2}$$

If the forward premium is, in fact, stationary, then this implies that the spot and forward rates in Eq. (2) are cointegrated (v_{t+k} is stationary), and that β_1 is specifically unity. However, this is merely accentuates the difficulty of using Eq. (1), since the Granger Representation Theorem (Engle and Granger, 1987) shows that a cointegrated relationship, such as Eq. (2), has a vector error correction representation (VECM). This consists of two and not one dynamic equations, one of, which indeed has Δs_t on the left-hand side as in Eq. (2), above. The second dynamic equation, of course, has Δf_t as the left-hand side variable. Eq. (3) illustrates the VECM

$$\begin{aligned}\Delta s_t &= \alpha_s(s_{t-1} - \beta_1 f_{t-1} - \beta_0) + \sum_{i=1}^{k-1} b_{si}\Delta s_{t-i} + \sum_{i=1}^{k-1} c_{si}\Delta f_{t-i} + \varepsilon_{st},\\ \Delta f_t &= \alpha_f(s_{t-1} - \beta_1 f_{t-1} - \beta_0) + \sum_{i=1}^{k-1} b_{fi}\Delta s_{t-i} + \sum_{i=1}^{k-1} c_{fi}\Delta f_{t-i} + \varepsilon_{ft},\end{aligned} \tag{3}$$

where α_s and α_f are the error correction adjustment parameters in the spot and forward equations, respectively, b_{si}, c_{si}, b_{fi} and c_{fi}, $i = 1,\ldots,(k-1)$ are other short-run adjustment parameters, ε_{st} and ε_{ft} are white noise error terms and k is the lag-length of the unrestricted vector autoregression from which the VECM is derived.

Johansen (1992) demonstrates that it is invalid to estimate the dynamic equations of a VECM, separately. He points out that, in general, there are efficiency losses from single equation estimation in cointegrated systems. In addition, Phillips (1991) proves that the use of the single-equation techniques in cointegrated systems imparts second-order asymptotic bias and nuisance parameter dependencies.

The important exception occurs when one of the variables is weakly exogenous (see Johansen, 1992). Moore (1994) applies Johansen's result to Eq. (2) and outlines the startlingly restrictive conditions under which Eq. (1) is a valid representation of the error correction mechanism in Eq. (3). The argument is straightforward and proceeds as follows:

If Δs_t is the dependent variable for single-equation estimation as in Eq. (1), then Johansen (1992) implies that it is the forward rate that must be weakly exogenous, i.e., $\alpha_f = 0$. Given this condition, it is easy to show from Johansen (1992) that efficient estimates are obtained from

$$\Delta s_t = b_0\Delta f_t + \alpha_s(s_{t-1} - \beta_1 f_{t-1} - \beta_0) + \sum_{i=1}^{k-1} b_i\Delta s_{t-i} + \sum_{i=1}^{k-1} c_i\Delta f_{t-i} + \varepsilon_t, \tag{4}$$

where b_0, b_i and c_i, $i = 1,\ldots,(k-1)$, are compound parameters. Letting $\begin{bmatrix}\sigma_{ss} & \sigma_{sf}\\ \sigma_{fs} & \sigma_{ff}\end{bmatrix}$ be the variance covariance matrix of $(\varepsilon_{st}\ \varepsilon_{ft})$, the parameters of Eq. (4) are related to those of Eq. (3) as follows: $b_0 = \sigma_{sf}\sigma_{sf}^{-1}$, $b_i = b_{si} - \sigma_{sf}\sigma_{ff}^{-1}b_{fi}$, $c_i = c_{si} - \sigma_{sf}\sigma_{ff}^{-1}c_{fi}$. Finally, the noise term $\varepsilon_t = \varepsilon_{st} - \sigma_{sf}\sigma_{ff}^{-1}\varepsilon_{ft}$.

Eq. (1) is, in fact, a special case of Eq. (4). To see this, it is the first useful to rearrange Eq. (4) as follows

$$\Delta s_t = -\alpha_s\beta_0 - \alpha_s(f_{t-1} - s_{t-1}) + b_0\Delta f_t + \alpha_s(1-\beta_1)f_{t-1} + \sum_{i=1}^{k-1} b_i \Delta s_{t-i} + \sum_{i=1}^{k-1} c_i \Delta f_{t-i} + \varepsilon_t. \quad (5)$$

An examination of Eq. (5) shows that it degenerates into Eq. (1), when $b_0 = 0$, $\beta_1 = 1$, $b_i = 0$, $c_i = 0$, $i = 1,\ldots,(k-1)$. $b_0 = 0$ means that the contemporaneous cross-equation covariance σ_{sf} in the vector autoregression of the spot and forward rate must be zero. The zero restrictions on the parameters, b_i and c_i mean that the length of the VAR must be unity.

The above remarks on the usefulness of the traditional vehicle in Eq. (1), is summarised in Corollary 1 of Moore (1994). For Eq. (1) to be valid:

1. The spot and forward rate must be cointegrated;
2. The slope of the co-integrating vector (β_1 in Eq. (2)) must equal unity;
3. The forward rate must be weakly exogenous. In a limited sense, the derivative market must drive the underlying market!
4. The cross-equation residual covariance in the VECM must be zero;
5. The lag length of the VECM must be precisely one.

Conditions (a) and (b) are obvious from the above discussion and are the focus of the remainder of this section. By far, the most important of the remaining three conditions is (c). We show in Section 3 of this paper that one of the two variables analysed in the paper is typically weakly exogenous. Unfortunately, for the proponents of the traditional vehicle in Eq. (1), it is the wrong variable – the spot rate – in the majority of cases! However, the notion that the spot market usually drives the forward market should hardly surprise us. We conclude that the widely held finding, that the estimated coefficient on the forward premium in Eq. (1) is more often close to minus one than plus one, is a function of the estimation method used rather than a measure of time-varying risk premia or expectational errors (see, for example, MacDonald, 1990).[2]

2.3. Stability tests

In testing for co-integration, we take an unusual approach. A cursory glance at the data shows that spot and forward rate levels move together over the long run. Consequently, conventional co-integration tests are unable to distinguish the data from a cointegrated process.[3] However, the EMS data may not be cointegrated in the way in which we would normally understand this. When the spot and forward rates diverge, they do not simply rely on endogenous adjustment. Instead, the authorities re-imposed equilibrium through realignments. Realignments were analogous to regime shifts. As Gregory and Hansen (1996) shows standard unit root tests (using the null of integration or no co-integration) have low power

[2] This is also the conclusion of Barnhart et al. (1999), though for different reasons.

[3] We have carried out the relevant tests and the results are available on request.

against this alternative because the distributional theory to evaluate the residual-based tests is not the same. Evans (1991) makes a related point.

Instead, we use the estimator proposed by Hansen (1992) and Phillips and Hansen (1990) [HPH]. This is a single-equation estimator and relies on non-parametric corrections for residual heterogeneity. Its main use here is to provide a test of parameter stability. We provide a brief description of this method, in the context of the spot–forward relationship, in order to motivate our stability tests.

Assume that the deterministic vector consists solely of a constant term. In terms of Eq. (2), if s and f are cointegrated, the error term, v_{t+k} should be an I(0) process. If, however, s and f are not cointegrated then v_{t+k} is I(1) and we may think of it as consisting of a random walk component, D, and a stationary term, η (i.e., $v_{t+k} = D + \eta_{t+k}$). Under these conditions, we may rewrite Eq. (2) as

$$s_{t+k} = \mu + \beta_1 f_t + \eta_{t+k}, \tag{6}$$

where $\mu = \beta_0 + D$. Hence, the alternative hypothesis of no co-integration is equivalent to the intercept term in Eq. (6) following a random walk. The tests considered below are designed to test this alternative and variants, thereof. Hansen (1992) proposes three approaches to test for the stability of the relationship, namely the L_c, MeanF and SupF statistics. All three of these test statistics share the same null hypothesis, but all three have different alternative hypothesis.[4] Therefore, the choice of a particular test will depend on a particular application. In particular, the L_c statistic is an LM test for the alternative hypothesis that the μ coefficient in Eq. (6) follows a random walk and therefore may be interpreted as a test of the null of co-integration against the alternative of no co-integration. Although the SupF and MeanF are not exactly geared to testing for the alternative of random walk coefficients, they have, nevertheless, asymptotic power against this alternative as well. Hansen (1992) warns, however, that rejection of the null does not imply the particular alternative, the test was designed to detect. The *only* statistically justified conclusion is that the standard model of co-integration, including its implicit assumption of long-run stability of the co-integrating relationship, is rejected by the data.

The intuition behind the three tests are as follows. As a preliminary, Hansen develops an F test, which could be described as a non-stationary analogue to the familiar Chow test of stationary inference. It is, however, much more than this because, in effect the F test is calculated at every point in the sample with the exception of a number of observations at the beginning and end of the sample. Therefore, this amounts to a comprehensive sub-sample analysis that can be described as the non-stationary analogue to the Brown-Durbin-Evans tests in stationary inference. Unfortunately, the F test can only be validly used on its own if the date of the structural break is known in advance for reasons that are held as a prior. This is, of course, unusual. Since, we do not have this information in the current application, we do not rely on the F test, directly. Two out of the three

[4] See Hansen (1992) for an accessible discussion of the development of these tests.

Hansen tests, which we use here, are derived from the sequence of F tests. The SupF and MeanF tests enable us to use the F tests without a specific prior in a way that systematises common practice. The SupF test takes the *worst* test result of the sample and compares it to an analytical critical value. Not surprisingly, this is higher than the critical value for an F test for a known break. Hansen suggests that SupF has power at testing for an abrupt break in the relationship. By contrast, the MeanF test takes the commonsense approach of taking the unweighted arithmetic average of the sequence of F tests. The analytical critical value for this is less than (i.e. more demanding) the critical value for a known break. Hansen suggests that MeanF has power at testing for a gradual change in the relationship over time. Finally, the L_c test is not derived from the sequence of F tests, but like the MeanF test also tests for a gradual change in the relationship over time. In particular, the L_c test is appropriate if the likelihood of parameter variation is relatively constant throughout the sample.

In summary, then, we are arguing that there may be problems with the traditional vehicle used for testing the unbiasedness of the forward exchange rate. These problems concern the appropriate way of addressing non-stationarity and, in particular, the implications may have the specification of the equation traditionally used to test for unbiasedness. Additionally, the traditional vehicle is not robust to the existence of a non-zero covariance between the regressor and the error term (see also, Barnhart et al., 1999) and may produce a biased estimate of β_1. The main testing method used in this paper – that of HPH – is robust to the above problems and has the additional advantage that it gives an alternative description of the credibility of a target zone to the confidence interval methods proposed by Svensson (1991).

3. Empirical analysis

3.1. Data sources and unit root tests

The source for all data used in this study was Datastream. The span of our data sample runs from August 1, 1978 to December 1994. Although the ERM began in March 1979 and effectively ended in August 1993, the data span enable us to 'drop' observations at both ends of the data as required by the HPH framework. The maximum number of available observations is 197. The exchange rates used are all end-of-period values, defined as the home currency price of a unit of foreign exchange and are originally sourced from International Financial Statistics (IFS), line ae. The forward rates have a 1-month maturity and have been carefully matched to the spot rates, so that there should be no issue of spurious alignment. In order to make our results comparable with much of the extant literature, we have used monthly observations. There is, however, a more important reason for limiting ourselves to monthly data. It is well-known (see, for example, Hodrick, 1987) that the observation period is shorter than the maturity period for forward contracts, the forward premium has a non-invertible moving average element in its time series properties. Moore and Copeland (1995) shows that this problem critically affects non-stationary inference. Monthly data gives us the highest data frequency that we can use without encountering this problem.

As noted in Section 2, we examine two sets of EMS-based bilateral currencies, the one set is based on the US$ and the other on the German mark. Apart from these two currencies, the other currencies are the Belgian franc, the British pound, the Danish krone, the Dutch guilder, the French franc, the Irish punt, the Italian lira, the Portuguese escudo, and the Spanish peseta.

Before implementing our econometric tests, we constructed the standard Augmented Dickey Fuller statistics for both the levels and differences of all the spot and forward exchange rates. The overwhelming impression obtained from these results is that all of the spot and forward rates are I(1) processes.[5]

Table 1
Stability test statistics: US$ bilateral exchange rates[a]

	LC	MF	SF
Belgium	0.979	6.984	18.589
	(<0.01)	(<0.01)	(<0.01)
Denmark	0.123	0.945	4.521
	(>0.20)	(>0.20)	(>0.20)
France	0.188	1.673	14.785
	(>0.20)	(>0.20)	(0.02)
Germany	0.303	2.489	7.249
	(0.15)	(>0.20)	(>0.20)
Ireland	0.142	1.703	28.240
	(>0.20)	(>0.20)	(<0.01)
Italy	0.127	1.225	14.492
	(>0.20)	(>0.20)	(0.03)
Netherlands	0.295	2.389	8.257
	(0.15)	(>0.20)	(>0.20)
Portugal	0.200	2.085	11.078
	(>0.20)	(>0.20)	(0.14)
Spain	0.171	3.132	40.071
	(>0.20)	(0.15)	(<0.01)
UK	0.287	2.744	9.406
	(0.16)	(>0.20)	(0.19)

[a] *Notes:* LC, MF and SF, denotes, respectively, the estimated *Lc*, MeanF and SupF statistics. The numbers in parentheses for the last three columns are *p*-values. *p*-values less than 1% are shown as <0.01 while those greater than 20% are shown as >0.20. The country label against each row refers to that country's spot and forward rates against the US$.

[5] Results available on request.

Table 2
Stability test statistics: German mark bilateral exchange rates[a]

	LC	MF	SF
Belgium	0.287	27.715	72.695
	(0.16)	(<0.01)	(<0.01)
Denmark	0.174	3.274	14.09
	(>0.20)	(0.14)	(0.03)
France	0.837	11.486	21.31
	(<0.01)	(<0.01)	(<0.01)
Ireland	1.140	26.111	330.46
	(<0.01)	(<0.01)	(<0.01)
Italy	0.833	16.962	136.86
	(<0.01)	(<0.01)	(<0.01)
Netherlands	2.015	118.86	226.81
	(<0.01)	(<0.01)	(<0.01)
Portugal	3.857	191.99	1179.97
	(<0.01)	(<0.01)	(<0.01)
Spain	14.502	790.97	2154.13
	(<0.01)	(<0.01)	(<0.01)
UK	35.344	2148.82	4628.88
	(<0.01)	(<0.01)	(<0.01)

[a] *Notes:* See Table 2 with the obvious exception that the last sentence should read 'The country label against each row refers to that country's spot and forward rates against the DM'.

3.2. Test results

In Tables 1 and 2, the stability tests are reported in the columns headed LC, MF and SF.[6] The numbers in parentheses under the three Hansen test statistics are p-values.

The results in Table 1 indicate a remarkable degree of stability for the spot–forward relations based on the US$. A low p-value represents a rejection of stability: for simplicity, estimated p-values below 1% are reported as "<0.01". Thus, at the 1% significance level, only 1 out of 10 countries have significant L_c or MeanF statistics (the exception is Belgium) and the SupF test does not reject stability in 7 out of 10 cases. Some of the estimated p-values are very high and for simplicity, P-values in excess of 20% are reported as ">0.20".

[6] In computing the results reported in Tables 2 and 3, we have followed Hansen (1992) and estimated the covariance parameters using a quadratic spectral kernel, with residuals pre-whitened using a VAR(1) process. Following Andrews (1990), we have used an automatic bandwidth. This is constructed as follows: First, we fitted a VAR(1) to the p-dimensional vector of residuals$\hat{v}_t$. Labeling the VAR residuals as the vectore_t, let $(\hat{\rho}_a, \hat{\sigma}_a^2)$ denote the first-order autoregressive and innovation variance for the ath element ofe_t. Next, we constructed$\hat{\gamma}_t$as $\hat{\gamma} = \dfrac{\Sigma_{a=1}^{p} \dfrac{4\hat{\rho}_a^2 \hat{\sigma}_a^2}{(1-\hat{\rho}_a)^8}}{\Sigma_{a=1}^{p} \dfrac{\hat{\sigma}_a^2}{(1-\hat{\rho})^4}}$. Finally, the automatic bandwidth is calculated as $1.32221(n\hat{\gamma})^{1/5}$, where n is the sample size.

In Table 2, the results of our currency pairings with the German mark are reported. The sample size was related to the period of each country's membership of the ERM. For most countries, this ends in August 1993 with the exceptions of Italy and Britain, where the last observation ends in September 1992. Spain, Portugal and Britain also had much later starting dates (June 1989, September 1989 and October 1990, respectively). In contrast with the US bilaterals the L_c, MeanF and SupF tests indicate a startling degree of instability. In terms of the former two statistics, which may be thought of as testing for gradual change in the relationship, the L_c rejects stability in 7 out of 9 instances, whilst the MeanF rejects in eight out of nine cases. The SupF test, which may be thought of as testing for abrupt changes in the relationship rejects in eight out of nine cases. Only Denmark fails to produce any rejection of instability. This is notable given Denmark's less than full commitment to European integration during the sample period.

In Figs. 1–9, we diagrammatically report the sequence of F statistics,[7] along with some critical values, in connection with the DM-based spot–forward regressions reported in Table 2. The continuous jagged line represents the sequence of F tests, one each for every point in the sample. The three parallel lines are all 5% critical

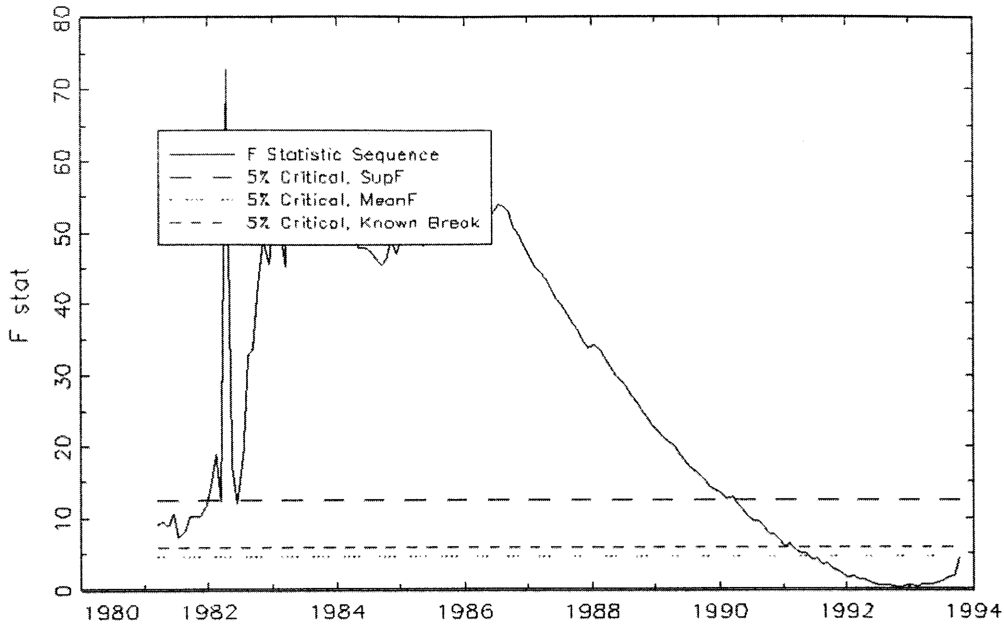

Fig. 1.

[7] The MeanF statistics, which are reported in the tables, are difficult to read from the graphs. In many figures, the sequence of F statistics shoots over the 5% MeanF critical value while the reported MeanF statistics are not significant at all. This is possible, because the MeanF is simply the average of the F test sequence.

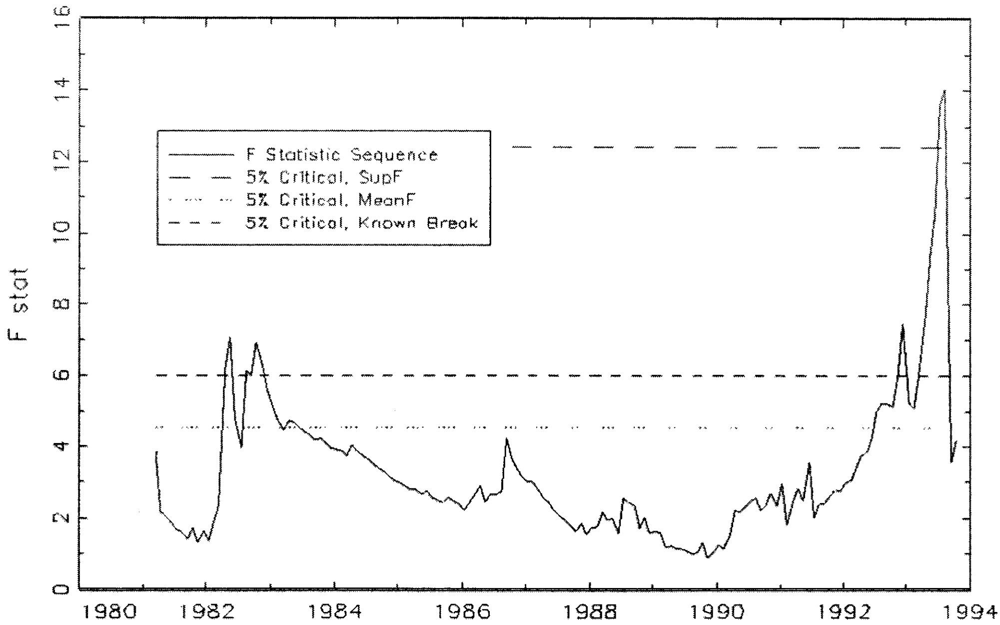

Fig. 2.

values, one for each of three different tests. The highest is for the SupF test, while the lowest is for the MeanF test. Though we do not use it, the middle line represents the critical value for a single F test, where we have a prior about the date of the structural break. The L_c test is not represented on the graphs, because it does not readily fit into the F testing framework. Note that the three parallel lines, representing the critical values, are 'bunched' down at the bottom of the graph. This confirms the instability of the DM-based regressions although the figures shed further light on the extent of the instability.

One of the remarkable feature of these graphs is the extent of the instability for two of the key ERM currencies, namely the Belgian franc and Netherlands guilder. In terms of the latter currency, for example, the F statistics are above even the SupF 5% critical value throughout the sample. Note especially the very large vertical upward movements in the Guilder at the time of 1983 and 1986 realignments. Further, the period in which the ERM was supposedly at its most stable (certainly in terms of spot rate behaviour) for the Guilder is one that still exhibits significant instability, although to be fair the significance of the instability is falling throughout the period. The falling instability is also evident in the French case at least until the final crisis.

A final perspective from Figs. 1–9 concerns the pattern of instability relating to the upheavals of the ERM in the 1992–1993 period. A striking feature is that the buildup of instability is evident from the early 1990's for Italy, Ireland, Denmark, Spain and Britain. Portugal is a notable exception and only begins to show serious instability in the run-up to the realignment of May 1993. In the British and Italian cases, the graphs dramatically illustrate the restoration of stability that occurred with their exit in September 1992 (the final observation for those two countries). The Irish devaluation of February 1993 is clearly evident, as are the Spanish realignments of late 1992. The inadequacy of the Spanish realignments is vividly illustrated in the recurrence of the instability of the peseta in early 1993. In general, then, these figures offer a similar perspective to the 95% and 100% confidence interval pictures presented in Svensson (1993).

The interpretation placed on the above-noted instability is worth commenting on further. In particular, the kind of instability reflected in the HPH graphics could be picking up either anticipated or unanticipated crises.[8] The former is not consistent with a credible target zone, whereas the latter is. For example, in the former case, agents anticipate a change in the band, but the zone stays intact for a while. During this time a classic 'peso' problem will exist, whereby the forward rate fails to predict the spot rate. Such a period would generate a coefficient different from unity on f_t, followed by a coefficient of unity after the realignment (assuming the new zone is credible). Our tests will reveal this as instability of the spot–forward relationship and the correct interpretation would be that such instability was consistent with a non-credible target zone. If, in contrast to the above account, the realignment were largely unanticipated, then the resulting misalignment of the forward rates would

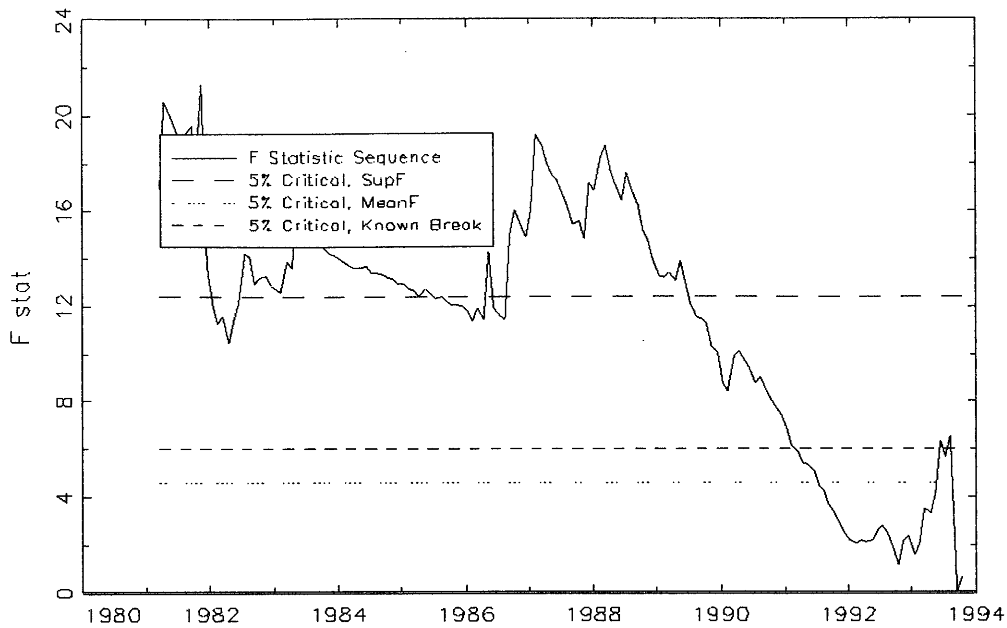

Fig. 3.

[8] We are grateful to an anonymous referee for making this point.

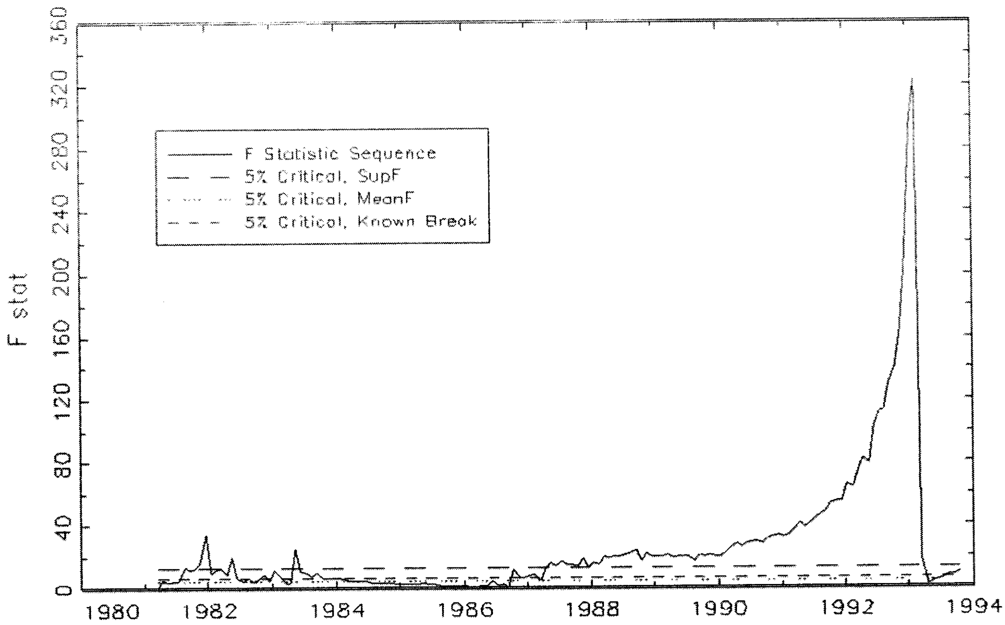

Fig. 4.

again produce instability although this should not be interpreted as evidence of a non-credible target zone. Hence, a health warning should be attached to Figs. 1–9. On their own, they simply tell us that there was instability at certain times in our sample period, they do not explain the source of this instability. However, we believe that the dynamic error correction models considered in Section 3.4 shed light on the sources of the instability.

In Table 3, we present tests for weak exogeneity, namely tests for the significance of the ECM adjustment parameters – α_s and α_f – in our estimates of Eq. (3). These results indicate that for all, but two cases, the spot rate is found to be weakly exogenous.[9] This, in turn, means that the underlying market is driving the derivative market. Sensible, though this may sound, it means that in all but two cases, the traditional vehicle for analysing the spot–forward relationship – Eq. (1) – should not be estimated. The summary of Moore (1994), provided in Section 2 immediately after Eq. (5), makes it clear that it requires weak exogeneity of the forward rate. In the two cases where this holds – France and Portugal – we can test the other restrictions required for Eq. (1) to be valid.

This is a strong result. To check that it is not peculiar to the ERM or to German bilateral exchange rates, we also tested for weak exogeneity for US$ bilateral exchange rates and these are reported in Table 4. We used data for the full sample

[9] The weak exogeneity tests are conventional applications of stationary inference. They are valid because the error correction terms are stationary when conditioned on the realignment dummies.

period and found that these results provide even stronger evidence for weak exogeneity of the spot rate. In particular, we are unable to find a single case of forward rate weak exogeneity, and there is evidence of spot rate weak exogeneity in all but two cases.

We believe that this finding in itself is interesting since it implies that in examining spot–forward relationships in a single-equation context, the change in the forward rate should be the dependent variable in the majority of cases. Now, we use the information on weak exogeneity to produce dynamic error correction equations for the German bilateral exchange rates. This, in turn, will be used to cast light on the source of the instability in the DM-based results as revealed by the HPH stability tests.

3.3. Dynamic error correction equations

In Section 3.2, we noted a sharp contrast for DM-based currencies relative to those based on the US$. In Section 3.3, we attempt to explain these findings using insights from the target zone literature. Our research agenda proceeds in the following way. Three sources of the above-noted instability are examined.

First, the target zone model pre-supposes that the system analysed is fully credible. It is well known, however, that for much of the time, the ERM was not a credible system and this was exemplified most clearly in the fact that there were so many realignments during its existence. From all of the many realignment dates during the ERM period, we have selected only the 'important' realignments for

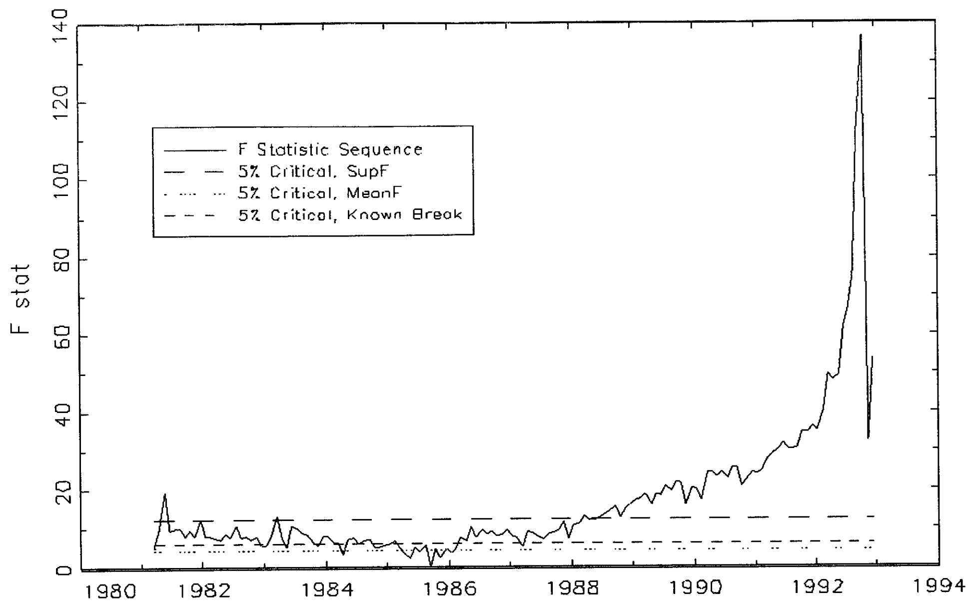

Fig. 5.

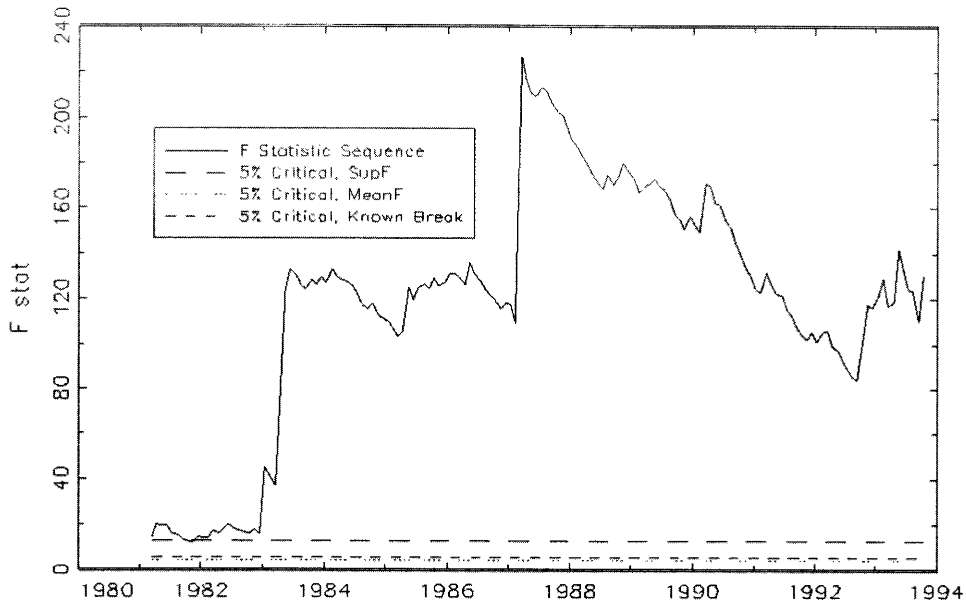

Fig. 6.

each country. We interpreted 'important' based on the size of the change in the central rate for each country. In addition, we included the most significant realignments for the DM in every country. Again, this was based on the size of the change in the central rate for Germany. There was one exception to this. Ireland experienced major realignments in November as well as September 1992. Since leads and lags, for each realignment was included in the general equation, this would have led to perfect multicollinearity in the Irish equation. Consequently, the larger of the two realignments – November 1992 – was selected based on the size of the change in the central rate. This parsimony in the choice of realignment dates also reflects the fact that not all realignments affect all countries. Also, it achieves the more practical objective that including all realignment dates in our equations would produce a chronic loss of degrees of freedom.[10]

Secondly, the differing liquidity characteristics of the markets under consideration may be important. In particular, the vast majority of foreign exchange market intervention occurs in the spot market, thereby, ensuring that this market is relatively liquid. By contrast, little intervention occurs in the forward market, making it relatively illiquid and important distortions and instabilities may be introduced for the DM-based bilateral exchange rates as compared to the dollar bilateral exchange rates for the same currencies. If a target zone system is credible, then a key prediction of the model is that intervention need only occur at the

[10] Full details of the selected realignments are available on request.

margin. However, Dominguez and Kenen (1992) have demonstrated that the kind of intervention employed by European central banks during the ERM period was standard leaning against the wind, or intra-marginal, intervention. Thus, the nature of the ERM meant that intervention was particularly systematic for DM-based rates (especially, around realignment points). By contrast, the Federal Reserve was not constrained to operate within specific exchange rate bands and its intervention was less systematic and could be regarded as simply providing a smoothing function. We would expect, therefore, that foreign exchange market intervention for the German bilateral exchange rates could have had a distortionary effect on the spot–forward relationship.

The final factor we introduce to our testing method is potential non-linearities that may exist in the ERM data because of the existence of the bands. We do not experiment with non-linear forms for the equations, but rather proceed in a somewhat ad hoc manner by experimenting with non-linear transformations of the independent variables.

The kind of equation we estimate for the forward rate (and also the spot rate where relevant), therefore, has the following general form:

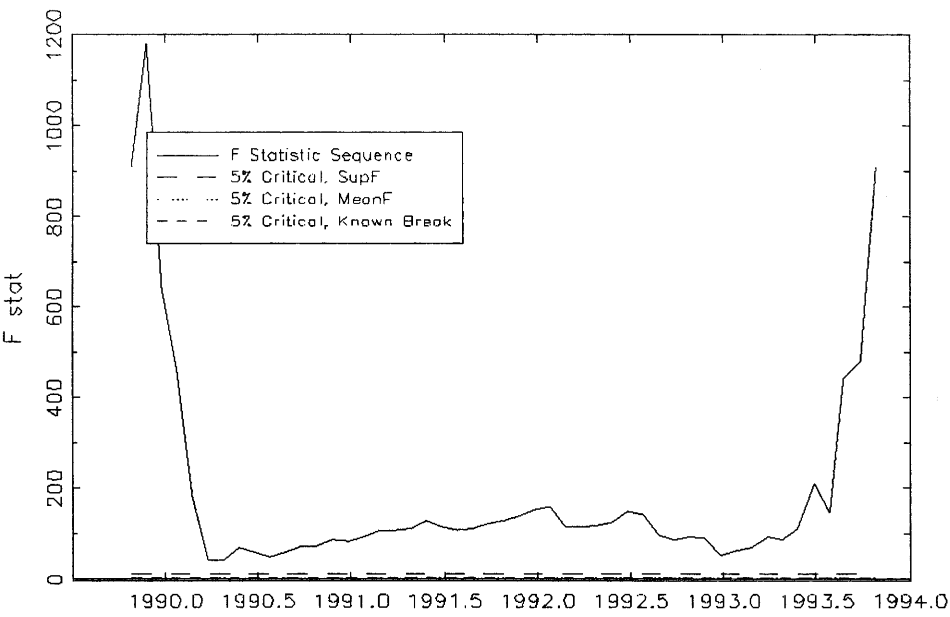

Fig. 7.

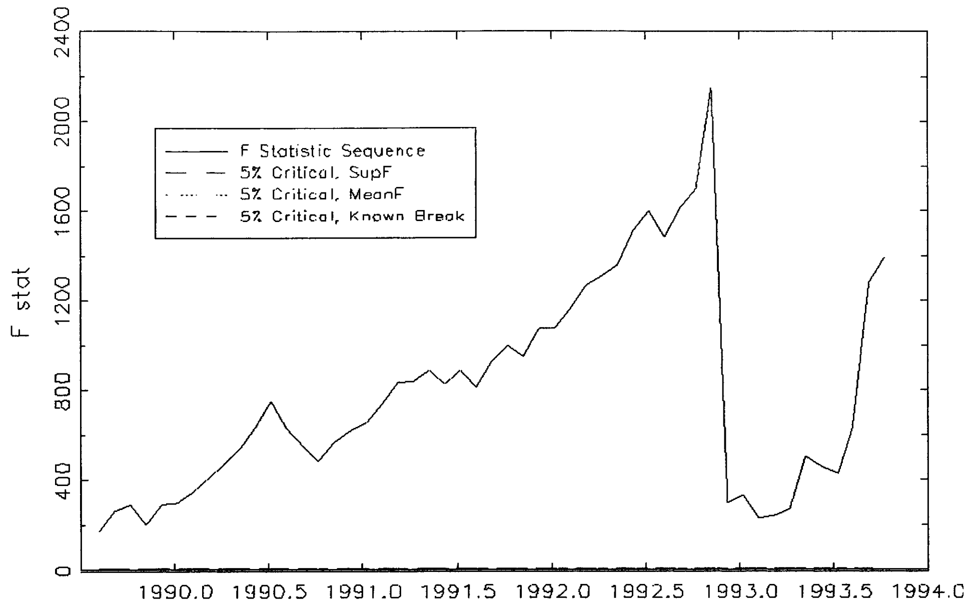

Fig. 8.

$$\Delta f_t = \alpha_f \mathrm{ecm}_{t-1} + \sum_{i=1}^{n} \gamma_i \Delta f_{t-i} + \sum_{i=0}^{n} \delta_i \Delta s_{t-i} + \sum_{i=0}^{n} \theta_i \Delta \mathrm{res}_{t-i} + \sum_{i=0}^{n} \psi_i \mathrm{non}_{t-i}$$
$$+ \sum_{j} \sum_{i=-1}^{+1} \varphi_i \mathrm{dum}_{j,t-i} + \varepsilon_t, \qquad (7)$$

where, of variables not already defined, 'ecm' denotes the error correction term, 'res' denotes total foreign exchange reserves,[11] the change in which is our proxy for intervention, 'dum' denotes a dummy, and 'non' denotes a non-linear term. In addition γ_i, δ_i, θ_i, ψ_i, φ_i, and, of course, α_f are parameters.

Using the general equations, we tested down in the conventional manner until parsimonious dynamic ECM equations were obtained. These are reported in Table 5, along with a full set of diagnostic tests, for Belgium, Britain, Denmark, Ireland, Italy, The Netherlands and Spain. The parsimonious equations have a standard pattern with only small differences between equations. Thus, in addition to lagged values of the forward rate and spot exchange rate changes, it is the realignment dummies that play an essential role in the equations. Reserve changes enter only significantly into the equations for Denmark and Spain. The equation for the Irish punt is the only one that non-linear terms entered significantly and these are interactive terms between lagged reserve changes and lagged realignments. All of the equations have ECM terms that enter with a negative coefficient and all of these

[11] Of course, reserves are not a strictly accurate measure of intervention since they change for non-intervention reasons such as reserve revaluations, direct government foreign borrowing, etc.

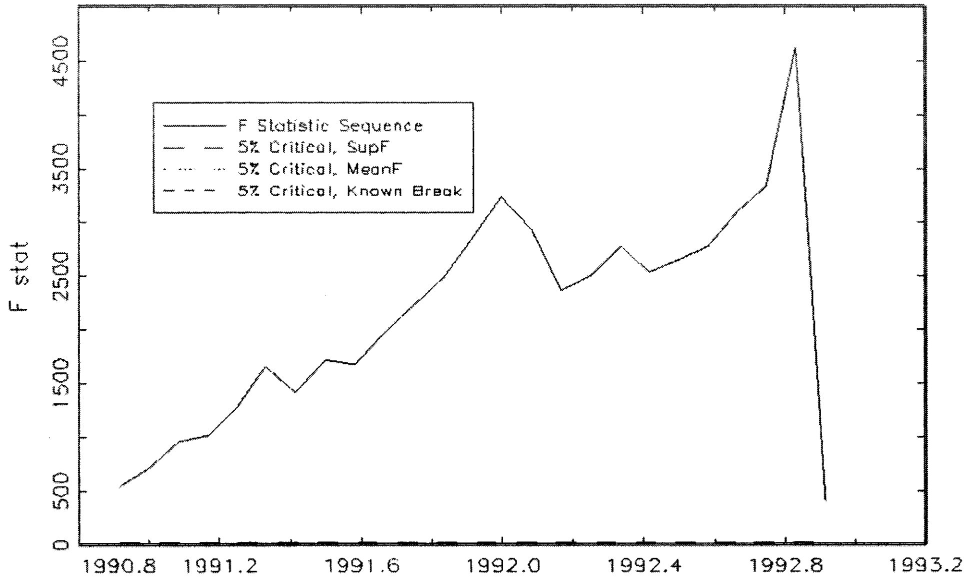

Fig. 9.

Table 3
Tests for weak exogeneity: German bilateral exchange rates[a]

	$\alpha_s = 0$	$\alpha_f = 0$	Result[b]
Belgium	1.18	4.70**	SWE
UK	1.53	30.52**	SWE
Denmark	1.34	2.71**	SWE
France	4.95**	0.95	FWE
Ireland	0.81	3.17**	SWE
Italy	0.89	5.76**	SWE
Netherlands	0.00	2.66**	SWE
Portugal	4.15**	2.53*	FWE
Spain	0.00	4.43**	SWE

[a] *Notes:* These are t-statistics, which are tests of the significance of the error correction term in the spot (α_s) and forward (α_f), rate equations, respectively.

[b] This column indicates if it is the spot rate (SWE) or the forward rate (FWE) which is weakly exogenous. It is, of course, possible that both variables are weakly exogenous, but this was not observed in the data. It is also possible that neither variable is weakly exogenous. Neither of these possibilities arises for the spot–forward relationships examined in this table, but see Table 4.

* Significance at the 5% level.

** Significance at the 1% level.

Table 4
Tests for weak exogeneity: US$ bilateral exchange rates[a]

	$\alpha_s = 0$	$\alpha_f = 0$	Result[b]
Belgium	2.02*	2.82**	SWE
UK	1.35	2.66**	SWE
Denmark	0.1	4.19**	SWE
France	0.94	3.79**	SWE
Germany	1.04	2.52*	SWE
Ireland	0.64	8.09**	SWE
Italy	2.06*	4.87**	SWE
Netherlands	2.40*	2.31*	NEITHER
Portugal	2.78**	2.91**	NEITHER
Spain	1.35	6.21**	SWE

[a] *Notes:* These are t-statistics, which are tests of the significance of the error correction term in the spot (α_s) and forward (α_f) rate equations, respectively.

[b] This column indicates if it is the spot rate (SWE) or the forward rate (FWE) which is weakly exogenous. In two cases – Portugal and the Netherlands – neither variable is weakly exogenous.

* Significance at the 5% level.

** Significance at the 1% level.

terms are statistically significant, thereby confirming the discussion above.[12] Most significantly, however, all of the equations pass the Chow stability test: these modelling methods seem to have been successful, therefore, in removing the instabilities detected by the HPH tests.

For the two countries which have the forward rate as weakly exogenous – France and Portugal – the general equation is specified in the same way as in the above and the parsimonious equations derived in the conventional manner for the change in the forward rate. These results are reported in Table 6. Both equations pass the battery of diagnostic tests including the crucial stability test. We also report a test for whether the general model for these two currencies can be reduced to the traditional Eq. (1). Both test statistics ($\chi^2(7)$ for France and $\chi^2(11)$ for Portugal) are significant at the 1% level indicating that Eq. (1) is not a valid reduction of the equations reported in Table 6. This would seem to contain an important message for researchers who estimate Eq. (1) without pre-testing the general dynamic structure.

[12] All equations in Tables 5 and 6 perform very well in terms of a standard battery of diagnostic tests. The tests are: (i) the likelihood ratio (LR) test which tests the specific equation against the general model. This is a chi-squared test with the degrees of freedom given by the number of restrictions; (ii) the Ljung-Box Q (LB) test which tests for up to twelfth-order serial correlation. This is distributed $\chi^2(12)$; (iii) an ARCH(1) test for heteroscedasticity (AR); this is, of course, distributed $\chi^1(1)$; (iv) the Chow (CH) test for parameter stability. The degrees of freedom of this F test are indicated in each case; (v) six observations were left at the end of each sample to perform a $\chi^2(6)$ test for predictive failure (PF); (vi) the Jarque-Bera $\chi^2(2)$ test for normality (NM). In the cases of Portugal and the Netherlands, the ARCH(1) test failed so that an additional result for heteroscedasticity is reported: this is a $\chi^2(1)$ test of the significance of squared fitted values in a regression on squared residuals (RS). On the basis of these tests, all of the equations exhibit high explanatory power, an absence of serial correlation and heteroscedasticity. Only the Jarque-Bera test produces unsatisfactory results. This is due to excess kurtosis, which is commonplace in many asset price distributions.

Table 5
Dynamic error correction equations and diagnostics: dependent variable, Δf[a]

(*i*) *Belgium* (*sample*: 1979:4-1992:12)							
$\Delta f_t =$	$-0.08(f_t-s_t)_{t-1}$	$-$ $0.37\Delta f_{t-1}$	$+$ $0.39\Delta s_{t-1}$	$+$ $0.11\Delta s_{t-2}$	$-$ $0.014\text{mar}81_t$	$+$ $0.014\text{mar}81_{t+1}$	
	(2.71)	(5392)	(10.84)	(3.24)		(3.34)	
	$-0.025\text{oct}81_t$	$+$ $0.016\text{oct}81_{t-1}$	$+$ $0.023\text{feb}82_t$	$-$ $0.018\text{feb}82_{t-1}$	$+$ $0.02\text{jun}82_{t-1}$	$+$ $0.031\text{jun}82_{t+1}-$	
	(5.36)	(3.07)		(3.26)	(4.22)	(5.66)	
	$0.015\text{mar}83_t$	$+$ $0.01\text{mar}83_{t-1}$					
		(2.26)					
(*ii*) R^2 = 0.79, LR(27) = 37.42(0.09), LB(12) = 15.42(0.22), AR(1) = 3.27(0.07), CH(14, 137) = 0.678(0.792), PF(6) = 2.02(0.92), NM(2) = 94.02(0.00)							
Britain (Sample: 1979: 12-1994:5)							
$\Delta f_t =$	$-0.13(f_t-0.99s_t+0.003)_{t-1}$	$-$ $0.18\Delta f_{t-1}$	$+$ $0.87\Delta s_{t-1}$	$+$ $0.18\Delta s_{t-2}$	$-$ $0.001\text{mar}81_t$		
	(3.23)	(2.44)	(21.31)	(2.51)	(3.98)		
$-$	$0.001\text{oct}81_t$	$+$ $0.001\text{apr}86_t$	$-$ $0.002\text{apr}86_{t-1}$	$-$ $0.001\text{sep}92_{t+1}$			
	(3.69)	(2.73)	(2.62)	(2.13)			
R^2 = 0.99, LR(32) = 45.55(0.06), LB(12) = 10.08(0.61), AR(1) = 1.64(0.20), CH(9,156) = 0.929(0.5), PF(6) = 1.43(0.96), NM(2) = 46.70(0.00)							
(iii) Denmark (sample: 1978:12–1994:5)							
$\Delta f_t =$	$-0.11(f_t-s_t)_{t-1}$	$-$ $0.25\Delta f_{t-1}$	$+$ $0.89\Delta s_{t-1}$	$+$ $0.27\Delta s_{t-2}$	$-$ $0.004\Delta res_{t-2}$	$+$ $0.010\text{nov}79_t$	
	(2.86)	(3.85)	(21.58)	(3.96)	(3.64)	(4.80)	
	$0.010\text{nov}79_{t-1}$	$+$ $0.003\text{nov}79_{t+1}$	$-$ $0.002\text{oct}81_{t-1}$	$-$ $0.002\text{feb}82_{t-1}$			
	(4.17)	(2.10)	(2.03)	(2.08)			
R^2 = 0.97, LR(29) = 34.97(0.21), LB(12) = 9.47(0.66), AR(1) = 0.47(0.49), CH(10,166) = 1.723(0.08), PF(6) = 0.31(1.00), NM(2) = 195.39(0.00)							
(iv) Ireland (sample 1979:4–1992:12)							
$\Delta f_t =$	$-0.17(f_t-0.9s_t)_{t-1}$	$-$ $0.37\Delta f_{t-1}$	$+$ $0.84\Delta s_{t-1}$	$-$ $0.20\Delta f_{t-2}$	$+$ $0.38\Delta s_{t-2}$	$+$ $0.22\Delta s_{t-3}$	$-$ $0.014\text{aug}86_t$
	(3.18)	(6.94)	(0.84)	(4.25)	(6.78)	(4.21)	(3.40)
	$0.007\text{aug}86_{t-1}$	$+$ $0.007\text{aug}86_{t+1}$	$-$ $0.009\text{nov}92_t$	$+$ $0.03\text{nov}92_{t-1}$	$+$ $0.01\text{feb}93_{t-1}$	$-$ $0.038\text{feb}93_{t+1}$	
	(3.39)	(2.78)	(6.19)		(10.98)	(13.72)	
	$+0.004\text{aug}93_{t-1}$	$+$ $0.047\text{drapr}86_t$	$+$ $0.047\text{draug}86_t$	$+$ $0.031\text{drnov}92_t$	$-$ $0.035\text{draug}93_t$		
	(3.83)	$-$ (3.67)	(3.71)	(7.74)	(3.25)		
R^2 = 0.99, LR(24) = 41.70(0.02), LB(12) = 14.31(0.28), AR(1) = 5.88(0.02), CH(19,147) = 0.41(0.99), PF(6) = 0.08(0.99), NM(2) = 17.95(0.00)							
(v) Italy (sample: 1978:10–1994:5)							
$\Delta f_t =$	$-0.46(f_t-0.98s_t)_{t-1}$	$-$ $0.55\Delta s_{t-1}$	$+$ 0.03	$-$ $0.008\text{jun}82_t$	$-$ $0.001\text{jun}82_{t+1}$	$-$ $0.014\text{mar}83_t$	
	(8.20)	(9.77)	(8.21)	(4.37)	(5.04)	(5.04)	
	$0.005\text{mar}83_{t-1}$ (2.86)	$+$ $0.008\text{mar}83_{t+}$	$+$ $0.006\text{apr}86_t-$	$-$ $0.007\text{apr}86_{t-1}$	$-$ $0.006\text{oct}81_{t-1}$	$0.01\text{oct}81_{t+1}$	
	(2.86)	(4.38)	(3.24)	(3.84)	(3.96)	(5.04)	
R^2 = 0.99, LR(24) = 21.38(0.62), LB(12) = 24.15(0.02), AR(1) = 0.19(0.88), CH(12,164) = 0.587(0.85), PF(6) = 1.33(0.97), NM(2) = 1828.6(0.00)							
(vi) Netherlands (sample: 1978:12–1994:5)							
$\Delta f_t =$	$-0.16(f_t-s_t)_{t-1}$	$-$ $0.05\Delta s_t$	$-$ $0.40\Delta f_{t-1}$	$+$ $0.83\Delta s_{t-1}$	$-$ $0.16\Delta f_{t-2}$	$+$ $0.42\Delta s_{t-2}$	
	(3.87)	(4.27)	(6.06)	(19.4)		(6.33)	
	$+0.176\Delta s_{t-3}$	$+$ 0.001apr86t	$-$ $0.001\text{apr}86_{t+1}$				
	(2.75)	(2.08)	(2.03)				
R^2 = 0.97, LR(20) = 28.81(0.92), LB(12) = 14.12(0.29), AR(1) = 3.42(0.06), CH(9,168) = 0.84(0.58), PF(6) = 0.19(1.00), NM(2) = 81.65(0.00)							
(vii) Spain (sample: 1978:11–1994:5)							
$\Delta f_t =$	$-0.15(f_t-0.99s_t+0.036)_{t-1}$	$-$ $0.22\Delta f_{t-1}$	$+$ $0.85\Delta s_{t-1}$	$+$ $0.22\Delta s_{t-2}$	$-$ $0.014\Delta res_{t-2}$	$+$ $0.015\text{sep}79_t$	
	(2.62)	(3.43)	(14.78)	(3.49)	(3.47)	(3.65)	
	$-0.210\text{sep}79_{t-1}$	$+$ $0.006\text{sep}79_{t+1}$	$+$ $0.015\text{mar}83_t$	$-$ $0.015\text{mar}83_{t+1}$			
	(7.12)	(2.00)	(4.70)	(4.61)			
R^2 = 0.98, LR(28) = 37.65(0.11), LB(12) = 20.08(0.05), AR(1) = 9.32(0.00), RS(1) = 0.14(0.70), CH(10,167) = 0.61(0.81), PF(6) = 0.27(1.00), NM(2) = 383.76(0.00)							

[a] *Notes:* The relationships reported in this Table are dynamic error correction equations. Variables and test statistics are defined in the text. Numbers in parenthesis under coefficient values are t-ratios. Numbers in parenthesis after the test statistics are P-values.

Table 6
Dynamic error correction equations and diagnostics: dependent variable, Δs[a]

(iv) France (sample: 1978:12–1994:5)													
$\Delta s_t =$	$-1(f_t - s_t)_{t-1}$	+	$0.97\Delta f_t$	+	$0.60\Delta f_{t-2}$	−	$0.54\Delta s_{t-3}$	+	$0.020\text{mar}81_t$	−	$0.024\text{mar}81_{t-1}$	−	$0.016\text{mar}83_t$
			(14.12)		(2.80)		(2.73)		(2.43)		(2.84)		(2.01)
	$-0.019\text{mar}83_{t+1}$	+	$0.040\text{aug}93_t$	−	$0.042\text{aug}93_{t-1}$	+	$0.01\text{oct}81_{t-1}$	+	$0.015\text{jun}82_{t-1}$	−	$0.02\text{jun}82_{t+1}$		
	(2.25)		(5.18)		(5.07)		(2.36)		(2.41)		(3.05)		
$R^2 = 0.58$, LR(20) = 34.90(0.02), LB(12) = 7.19(0.84), AR(1) = 0.00(0.95), CH(12,162) = 0.312(0.98), PF(6) = 0.98(0.98), NM(2) = 368.92(0.00), $X2(7) = 171.81(0.00)$													
(vii) Portugal (sample: 1979:2–1994:5)													
$\Delta s_t =$	$-1(s_t - f_t)_{t-1}$	−	$0.77\Delta s_{t-1}$	−	$0.71\Delta f_{t-2}$	−	$0.55\Delta f_{t-3}$	+	$0.59\Delta s_{t-3}$	+	$0.42\Delta s_{t-4}$	−	$0.126(\Delta f + \Delta s)_{t-5}$
			(11.82)		(3.24)		(2.53)		(2.86)		(2.10)		(2.54)
	$-0.041\text{apr}86t$	+	$0.041\text{apr}86_{t-1}$	+	$0.071\text{aug}93_t$	+	$0.08\text{aug}93_{t-1}$	+	$0.021\text{jun}82_{t-1}$	−	$0.009\text{jan}90_{t-1}$	−	$0.014\text{mar}81_{t+1}$
	(2.31)		(2.33)		(3.92)		(4.22)		(2.28)		(2.10)		(2.10)
	$-0.014\text{mar}81_{t+1}$	+	$0.025\text{oct}81_{t-1}$	+	$0.031\text{mar}83_{t+1}$	+	$0.015\text{sep}92_{t+1}$						
	(2.10)		(2.79)		(4.08)		(2.55)						
$R^2 = 0.56$, LR(30) = 30.31(0.45), LB(12) = 6.41(0.89), AR(1) = 7.00(0.01), RS(1) = 0.35(0.55), CH(16,152) = 0.17(1.00), PF(6) = 1.49(0.96), NM(2) = 103.08(0.00), $X2(11) = 156.14(0.00)$													

[a] *Notes:* See Table 5.

3.4. Sources of instability

What light do the significance of the realignment dummies in the equations reported in Tables 5 and 6 shed on the interpretation of the instability derived from the HPH results? Up to and including the effective collapse of the ERM in August 1993, there were altogether twenty-four realignments. Each country was only affected by a small number of these. In Table 7, the column headed 'Total' illustrates this point. For the Netherlands, only the April 1986 realignment affected the stability of its spot–forward relationship. By contrast, one-third of all realignments was important in Portugal's case.

The column headed 'Anticipated' is crucial to identifying the sources of instability in the ERM. It shows the number of significant realignments that were anticipated. A significant led dummy ($t + 1$) indicates an anticipated realignment, whereas a significant lagged or current dummy is consistent with an unanticipated realignment. With this interpretation, note that both types of dummy are significant in our equations and, in particular, the $t + 1$ dummy appears in each of the dynamic ECM's, indicating that a lack of credibility was, in fact, an issue for each currency on at least one of the realignment dates. It is equally clear that for some countries, such as France and Belgium, realignments were more often unanticipated. For those countries, the instability of the spot–forward relationship was not primarily due to a lack of credibility.

Furthermore, we note that some realignments were sometimes partly anticipated and partly unanticipated. For example, for Belgium, the June'82 crisis appears to have both unanticipated and anticipated components. The anatomy of the March 1981 crisis also emerges clearly for the Belgian case. The $t + 1$ dummy is significant showing that a realignment was anticipated. When the realignment actually came, Belgium surprised the market by moving in line with the DM. This is shown by the fact that the current dummy has an equal and opposite sign to the lead dummy for March 1981. The instability was caused first by a lack of credibility and then doubly by a surprising display of credibility.

Of course, some realignments were completely unanticipated. The final collapse in August 1993 seems to have taken the markets in France, Ireland and Portugal by

Table 7
Significant realignments

Country	Total	Anticipated
Belgium	5	2
Britain	4	1
Denmark	3	1
Ireland	4	2
Italy	4	3
The Netherlands	1	1
Spain	2	2
France	5	2
Portugal	8	4

surprise. More controversially, 'Black Wednesday' in September 1992 emerges as a credibility problem in Britain and Portugal. This is contrary to the analysis in, for example, Eichengreen and Wyplosz (1993). However, the explanation lies in our use of monthly data. The crisis emerged without apparent warning in August 1992 with the speculative attack on the Finnish Markka. By the end of that month, the date of our lead dummy, the credibility of the ERM was in serious doubt.

One of the most striking findings is that lagged realignment dummies are significant in all, but one of the dynamic error correction equations (The Netherlands is the exception). We also give this a credibility interpretation albeit a different one from the case of anticipated realignments. Following surprise realignments, agents appeared to take some time to become convinced of the durability of the new bands. Consequently, the adjustment of the forward rate to the new band is not implemented instantly. This caution is wholly reasonable as some of the realignments were quickly followed by further realignments (e.g., two in September 1992 and another in November 1992).

It is also interesting to note how realignments were affecting some countries even before they joined the ERM. This suggests these countries were tracking the ERM, the obvious examples being Spain, September 1979 and, both Britain and Portugal in April 1986. In sum, we believe that our dynamic ECM's provide a richly suggestive menu of sources of instability.

4. Concluding comments

In general, uncovered interest rate parity does not hold. This is because the forward exchange rate is usually not weakly exogenous. Any theory, which is based on this parity condition, is unreliable. Few theoretical conclusions can be drawn out of departures from uncovered interest parity. In particular, some of the credibility tests provided by the exchange rate target zone literature are poorly founded.

Nevertheless, the spot–forward relationship can be usefully employed to assess the stability of a target zone, so long as the techniques employed are valid. We re-examine the relationship for ERM-participating currencies using Hansen's stability tests for co-integrating equations. Two numeraire currencies are used: the DM as the ERM's nth currency and the US$ as a 'control'. The interesting feature is that while the spot–forward relationship displays broad stability against the dollar, precisely the opposite is true against the DM.[13] Because, the Hansen tests lend themselves to graphical treatment, this conclusion is illustrated vividly.

Mere instability in the spot–forward relationship for the ERM does not, of itself, imply a lack of credibility. We outline different interpretations of the result. To gain a further perspective on the credibility issue, we use a general-to-specific modelling framework to produce an error correction model for the spot–forward relationship for each DM/ERM currency pair. This allows for spot interventions as well as realignments and succeeds in identifying a satisfactory stable relationship in each case. Most relevantly, it enables us to assess when an ERM realignment episode was indicative of a lack of credibility.

[13] This result contrasts with that of Flood and Rose (1995) who find, using traditional methods, that the forward rate bias is less pronounced for currencies participating in the ERM of the EMS.

We find significant evidence of a lack of credibility of the ERM target zones. Our result re-emphasise that a target zone policy does not involve intervention in the forward market is unlikely to succeed. They also point sharply to the conclusion that the spot–forward relationship cannot be adequately examined outside the context of policy.

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