Bank of England

Discussion Papers

Technical Series

No 36

Sterling's relationship with the dollar and the deutschemark: 1976–89

by

A G Haldane

and

S G Hall

December 1990

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The object of this *Technical Series* of Discussion Papers is to give wider circulation to econometric research work predominantly in connection with revising and updating the various Bank models, and to invite comment upon it; and any comments should be sent to the authors at the address given below.

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The authors would also like to thank the Bulletin Group for editorial assistance in producing this paper.

Issued by the Economics Division, Bank of England, EC2R 8AH to which requests for individual copies and mailing list facilities should be addressed; envelopes should be marked for the attention of the Bulletin Group. *(Telephone: 071-601-4030)*

ISBN 0 903315 30 0

ISSN 0263-6123

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Abstract

This paper uses a new methodology to evaluate the linkages between bilateral exchange rates, based upon a time-varying parameter model which can be estimated using the Kalman filter. This technique solves many of the statistical problems which may otherwise arise if Ordinary Least Squares is used to estimate temporal correlations between currencies. In particular, the use of a stochastic constant, which partials out all potentially omitted variables, ensures that, by construction, the error processes of the estimated relationships are stationary. Additionally, the time-varying parameter model allows for completely endogenous estimation of the timing of possible regime shifts within these exchange rate relationships.

The new technique is applied to the relationship between the dollar-sterling, DM-sterling and DM-dollar bilateral exchange rates, using daily data between 1976 and 1989. The results presented, in keeping with the findings of previous empirical studies, suggest an unambiguous weakening of sterling's linkage with the dollar, since the mid-1970s. In addition, the paper suggests that these currency linkages have been subject to periodic gyrations corresponding to notable exchange rate regime shifts. This finding fixes a slightly different interpretation upon the timing of the weakening of sterling's relationship with the dollar to the one proposed by previous studies.

Sterling's relationship with the dollar and the deutschemark: 1976–89

1. Introduction

A number of authors have highlighted a so-called **Dollar-Deutschemark polarisation** within the European Community [see, for example, Giavazzi and Giovannini (1985), Padoa-Schioppa (1985), Giavazzi and Giovannini (1990)]; that is, the historical coincidence of periods of dollar strength with Deutschemark (DM) weakness *vis-à-vis* European currencies. The inception of the European Monetary System (EMS) in March 1979 is widely believed to have contributed to a weakening of this polarisation, significantly reducing the sensitivity of EMS bilateral rates to dollar perturbations [see Giavazzi and Giovannini (1990)]. Indeed, this observation has been interpreted by some as explaining, at least in part, Germany's original interest in participating in the system; namely, as a means of insulating the West German economy from the potentially destabilising influence of dollar shocks [Ludlow (1982)].

The weakening of the Dollar-DM polarisation as it relates to the Exchange Rate Mechanism (ERM) members is largely explicable in terms of co-ordinated central bank intervention, the evolution of a single EC market in goods, services and perhaps most importantly capital, and increasing EMS credibility in respect of exchange rate stabilisation.

A more interesting, and to some extent more surprising, conclusion to be drawn, in particular from the Giavazzi and Giovannini (1990) study, however, is that there has been a significant reduction in the covariance between the **sterling**-DM bilateral exchange rate and the dollar effective index between 1973–87.(1) (2) Though Giavazzi and Giovannini offer little explanation of this finding, implicitly it is attributed to an 'EMS-effect' of some form—despite the United Kingdom's non-participation in the ERM over their sample period.

While we would not question the basic conclusion drawn from this study, we would argue that there are a number of methodological questions raised by the techniques used in the existing literature on this issue. This note explores these issues, and suggests an alternative way of analysing the data based on a time varying parameter model, which can be estimated using the Kalman filter. We illustrate our new approach by considering the relationship between the dollar-sterling, the DM-sterling and the DM-dollar bilateral exchange rates using high frequency daily data between January 1976 and August 1989.

Employing bilateral exchange rates between the dollar, sterling and the DM enables us to condense the world foreign exchange market into a stylised three-country system, with one currency always acting as the numeraire within this system. The use of a stochastic parameter model enables us to negate many of the statistical problems which otherwise emerge if OLS is used to estimate such a three-country system.

Section 2 outlines some of the methodological issues which arise when considering the exchange rate relationships defined above, while Section 3 gives the technical details of our estimation procedure. Section 4 presents the empirical results and attempts to provide some economic justification for the observed movements. Finally, Section 5 summarises and draws some brief conclusions.

2. The methodology

We define the question under consideration to be the following: to what extent are movements in sterling bilateral exchange rates associated with movements in the dollar, and with movements in the DM. We formalise this question by considering the following two relationships:

$$\$/£_t = \alpha_{1t} + \beta_{1t}\, DM/\$_t + e_{1t} \qquad (1)$$

$$DM/£_t = \alpha_{2t} + \beta_{2t}\, DM/\$_t + e_{2t} \qquad (2)$$

where $\$/£_t$ is the natural logarithm of the dollar-sterling exchange rate, $DM/\$_t$ the log of the DM-dollar exchange rate, and $DM/£_t$ the log of the DM-sterling exchange rate.

The α_{it} (i=1,2) parameters are stochastic constants, and partial out all systematic influences upon the dollar-sterling and DM-sterling bilateral rates, other than those resulting from movements in the DM-dollar exchange rate. The problem of omitted variables is thereby effectively offset, be it at the *apparent* expense of detaching ourselves from any rigorous 'economic' explanation of the determinants

(1) This conclusion is in some ways at odds with the findings of previous empirical studies [see, for example, Ungerer et al (1983), and Artis and Taylor (1988)], which typically have found evidence of an increase in the variance of ERM bilateral rates with extra-ERM countries since the inception of the EMS.

(2) Though Giavazzi and Giovannini (1990) conclude that the Dollar-DM polarisation is still strongest for sterling, the extra-ERM currency.

of the exchange rates under investigation. In particular, this means that we are unable to specify the existence, much less the direction, of any causal links between the pairs of bilateral rates listed.

The (potentially) time varying parameters β_{it} (i= 1, 2) measure sterling's temporal relationship with the DM and the dollar respectively in this three-country setting. For example, if sterling were fixed against the dollar, then $/£ would be independent of DM/$, and DM/£ and DM/$ would be perfectly positively correlated. We would therefore expect the joint restriction $\beta_1 = 0$, $\beta_2 = 1$ to be broadly satisfied. Conversely, if sterling were perfectly pegged to the DM, then we anticipate the restriction $\beta_1 = -1$, $\beta_2 = 0$ would be satisfied.

An important point to note is that our postulated relationships (1),(2) are expressed in *levels* of the variables. This can be justified in part by reference to equilibrium models of the exchange rate ('Law of One Price'), and in part by statistical considerations: nominal exchange rates are generally believed to be integrated processes, which must cointegrate with another subset of bilateral rates by construction, provided this subset is sufficiently large.

In view of the stochastic trend which typically is present in *nominal* exchange rates, and the 'spurious regression' problem this potentially may throw up when estimating (fixed parameter) versions of (1) and (2) by OLS, most existing studies have used the first difference form of these equations. For example, Giavazzi and Giovannini (1990) regress the change in the log of DM bilateral rates with ERM currencies and sterling on the first difference of the dollar effective index. Estimating this relationship over a number of discrete sub-samples, Giavazzi and Giovannini conclude that the sensitivity of ERM bilateral rates to dollar perturbations has declined markedly since the inception of the EMS.

We would argue that there are a number of problems with this methodology, however, notably:

(i) The maintained hypothesis when performing standard OLS fixed parameter regressions is that the correlation between regressor and regressand is constant, at least over each sub-period. The hypothesis under investigation here, however, concerns the extent to which this correlation may have changed over time. It would appear that equations (1),(2) are much better equipped to answer such questions, since they allow for a gradual, and hence more plausible, adjustment path for the temporal correlation coefficient between the pairs of bilateral rates.

(ii) If the 'true' model is specified in levels, as would appear plausible from a theoretical and statistical perspective, then a first difference specification, of the form outlined above, will generate artificially problems with the underlying error process.[1] This can be seen, for example, if we first difference (1), which gives:

$$\Delta\$/£_t = \Delta\alpha_{1t} + \Delta\beta_{1t}\, DM/\$_t + e_{1t} - e_{1t-1} \quad (3)$$

that is, a moving average error process is created. Of course, the reason for using differences is that if we estimate a fixed parameter version of (1) using OLS then the error process will only be stationary if the two nominal exchange rates cointegrate in isolation; a condition which is unlikely to be satisfied in our specifications given the *apparent* lack of any fundamental exchange rate determinants. While (over-)differencing the data is superior to using standard OLS on the levels, therefore, it still presents the problem of a serially correlated error term: moving average estimation is not easy at the best of times, and is particularly difficult when the coefficient lies on the unit circle.

(iii) The underlying error process of equations such as (3) is likely to be made more complex by the problem of omitted variables highlighted above. OLS estimates are therefore likely to be inconsistent, with the result that conventional tests of structural shifts in the estimated coefficients over time are made near impossible.

Given the above problems of OLS estimation of a first difference specification such as (3), we might think of attempting to estimate directly time varying models of the form (1), (2). Such models come much closer conceptually to answering the questions relevant to our exercise than do fixed parameter specifications. In particular, such time varying parameter relationships allow for completely endogenous estimation of the timing of any potential exchange rate regime shifts, as reflected in the temporal path of the estimated coefficients.

Additionally, these models overcome many of the more serious statistical objections raised to OLS estimation. Direct estimation of (1) and (2) effectively does away with the technical problems associated with the error process, since these models are specified in levels of the variables, and include a stochastic constant which allows us to partial out potentially omitted variables. The error processes of

(1) The exception being when the levels formulation of the model has an error with root on the unit circle, giving a first difference specification with white noise error. Such a finding would be inconsistent with our observation that the levels formulation is the preferred form of the model from a theoretical perspective.

the estimated relationships (1) and (2) are therefore stationary by construction.

3. Time varying parameter estimation

In this section a standard state space formulation of the time varying parameter model is presented, with the appropriate Kalman filter equations for the univariate case, following Harvey (1987).

Let

$$y_t = \delta' z_t + \varepsilon_t \qquad (4)$$

be the measurement equation, where y_t is a measured variable, z_t is the state vector of unobserved variables, δ is a vector of parameters and $\varepsilon_t \sim \mathrm{NID}\,(0, \Gamma_t)$. The state equation is then given as:

$$z_t = \Psi z_{t-1} + \omega_t \qquad (5)$$

where Ψ are parameters and $\omega \sim \mathrm{NID}(0, Q_t)$.

The appropriate Kalman filter prediction equations are then given by defining $\hat{z}_t$ as the best estimate of z_t based on information up to t, and P_t as the covariance matrix of the estimate $\hat{z}_t$, and stating:

$$\hat{z}_{t|t-1} = \Psi \hat{z}_{t-1} \qquad (6)$$

and

$$P_{t|t-1} = \Psi P_{t-1} \Psi' + Q_t \qquad (7)$$

Once the current observation on y_t becomes available, we can update these estimates using the following equations:

$$\hat{z}_t = \hat{z}_{t|t-1} + P_{t|t-1}\delta(y_t - \delta'\hat{z}_{t|t-1})/(\delta' P_{t|t-1}\delta + \Gamma_t) \qquad (8)$$

and

$$P_t = P_{t|t-1} - P_{t|t-1}\,\delta\,\delta' P_{t|t-1}/(\delta' P_{t|t-1}\,\delta + \Gamma_t) \qquad (9)$$

Equations (6)–(9) then represent jointly the Kalman filter equations.

If we then define the one-step-ahead prediction errors as,

$$v_t = y_t - \delta'\hat{z}_{t|t-1} + \beta' w_t$$

then the concentrated log likelihood function can be shown to be proportional to

$$\log(I) = \Sigma \log(f_t) + N \log(\Sigma v_t^2 / N f_t)$$

where $f_t = \alpha' P_{t|t-1}\,\alpha + \Gamma_t$ and $N = T - k$, where k is the number of periods needed to derive estimates of the state vector; that is, the likelihood function can be expressed as a function of the one-step-ahead prediction errors, suitably weighted.

Equipped with these formulae, we can estimate time varying parameter models such as (1) and (2) directly. We do this by first specifying δ as a vector of known variables (in this case the bilateral exchange rates) and z_t as a vector of time varying parameters (α_{it}, β_{it}, $i = 1, 2$). If Ψ is assumed to be a constant identity matrix, then additionally we have specified the form of the time variation within our model: each of the stochastic parameters follow a random walk. Finally, Q_t is specified as a diagonal matrix, the elements of which are to be estimated using maximum likelihood given the form of the likelihood function outlined.

Given this specification, the assumptions outlined, and the likelihood function defined above, we can estimate exactly time varying models of the form (1) and (2).

4. Empirical evidence on sterling's linkage with the dollar and the deutschemark

The three bilateral exchange rates in question, \$/£, DM/\$ and DM/£, are linked by identity. As a result, OLS fixed parameter estimation of the equations (1),(2) will impose the restriction $\beta_2 - \beta_1 = 1$ automatically.[1] This restriction has a simple enough intuitive explanation: in a stylised system comprising only three currencies, movements in each bilateral exchange rate must be associated with movements in one or other of the remaining bilateral rates in the system.

The Kalman filter time varying parameter model generally will not have this property unless (1) and (2) are estimated as a system imposing the cross equation restriction. Given the large number of observations and the relative complexity of the calculation, however, we have chosen not to impose this restriction, but to use it as an approximate check on the properties of the estimator.

Our methodology, then, is to estimate (1) and (2) independently, using each in turn as a measurement equation, where the state equations (5) have the specific form:

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(1) Let x = DM/\$, y = DM/£, z = \$/£. OLS fixed parameter estimates of β_1 and β_2 in equations (1) and (2) would therefore take the form:
(i) $\beta_1 = (x'x)^{-1}x'z$
(ii) $\beta_2 = (x'x)^{-1}x'y$
Observing that $z = -(x-y)$, and substituting into (i) gives us our restriction: $\beta_2 - \beta_1 = 1$.

$$\alpha_{it} = \alpha_{it-1} + e_{it}$$

$$\beta_{it} = \beta_{it-1} + e_{it} \qquad (10)$$

$$i = 1, 2$$

Note that this implies that even if the level of the DM-sterling (or dollar-sterling) exchange rate is independent of the level of the DM-dollar bilateral rate, ie $\beta_{it} = 0$ ($i = 1$ or 2), then we are not imposing the restriction that the DM-sterling (dollar-sterling) rate be fixed, as would be the case in a fixed parameter regression with a deterministic constant, but only that it is an ARMA(1,1) process, or generalized random walk. The model with stochastic parameters would appear therefore to offer a much more plausible adjustment path for each of the bilateral rates than the corresponding OLS specification, should the restriction $\beta_{it} = 0$ ($i = 1$ or 2) be satisfied for either (1) or (2).

The data is daily close of business prices for the DM-sterling, DM-dollar and dollar-sterling exchange rates (as quoted on the London foreign exchange market) between January 1976 and August 1989. With weekends removed, this gives a data set comprising 3,559 observations.

Figures 1 and 2 show the log of the dollar-sterling and DM-sterling bilateral exchange rates respectively between 1976 and 1989. One might conclude, purely by inspection, that sterling's relationship with the DM was more stable than that with the dollar over the period. Stationarity tests suggest that there is little likelihood of either *nominal* exchange rate being stationary, however: Dickey-Fuller (Augmented Dickey-Fuller) test statistics of the unit root hypothesis for the dollar-sterling and DM-sterling exchange rates take the values -1.26 (-0.94) and -1.89 (-1.78) respectively. This indicates that the null hypothesis of

Figure 2: Natural logarithm of DM-Sterling bilateral exchange rate, 1976-89

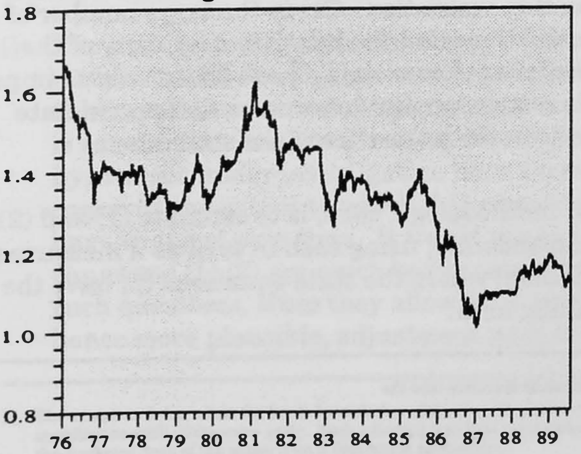
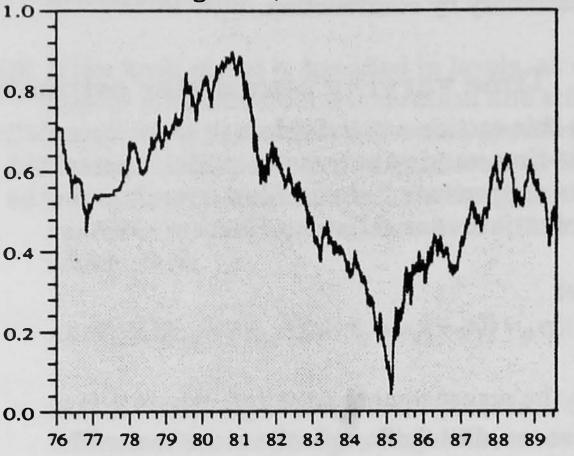


Figure 1: Natural logarithm of Dollar-Sterling bilateral exchange rate, 1976-89



non-stationarity cannot be rejected for either rate at 5%. We are, however, nearer rejection of non-stationarity for the DM-sterling bilateral rate, suggesting, *ceteris paribus*, that sterling may have been more closely tied to the DM than to the dollar over the period as a whole.

We now proceed to estimate equations (1) and (2) using the technique outlined in Section 3 above. The maximum likelihood estimates of the relative variance of the state equations (Q_t) to the measurement equation (Γ_t) were very large for both (1) and (2). This suggests, as we might expect, that there is a high degree of time variation in the parameters of our postulated relationships. The resulting parameter estimates, β_{1t} and β_{2t}, are shown in Figures 3 and 4 respectively over the full sample. A number of noteworthy points emerge from these estimates.

First, it is interesting to observe that the adding-up restriction $\beta_2 - \beta_1 = 1$ is broadly satisfied by the data, despite not having been imposed directly: the final period value of β_1 is around -0.9, while β_2 approximates 0.1 in the last period. This implies that the omitted variable problem may be less acute than we might have expected *ex-ante*, with the stochastic constant appearing to exert little leverage: movements in each bilateral rate can be almost entirely attributed to movements in the other two bilateral rates in the system.

The broad pattern of the estimated relationships is very much in line with the conclusions reached by Giavazzi and Giovannini (1990) in suggesting that the strength of sterling's relationship with the dollar has declined markedly between 1976–89. Correspondingly in our three-country system, sterling's relationship with the DM has significantly strenghthened through the sample. The scale of this reduction in the strength of the dollar/sterling relationship is much greater than implied by

Figure 3: Time varying parameter, β_{1t}

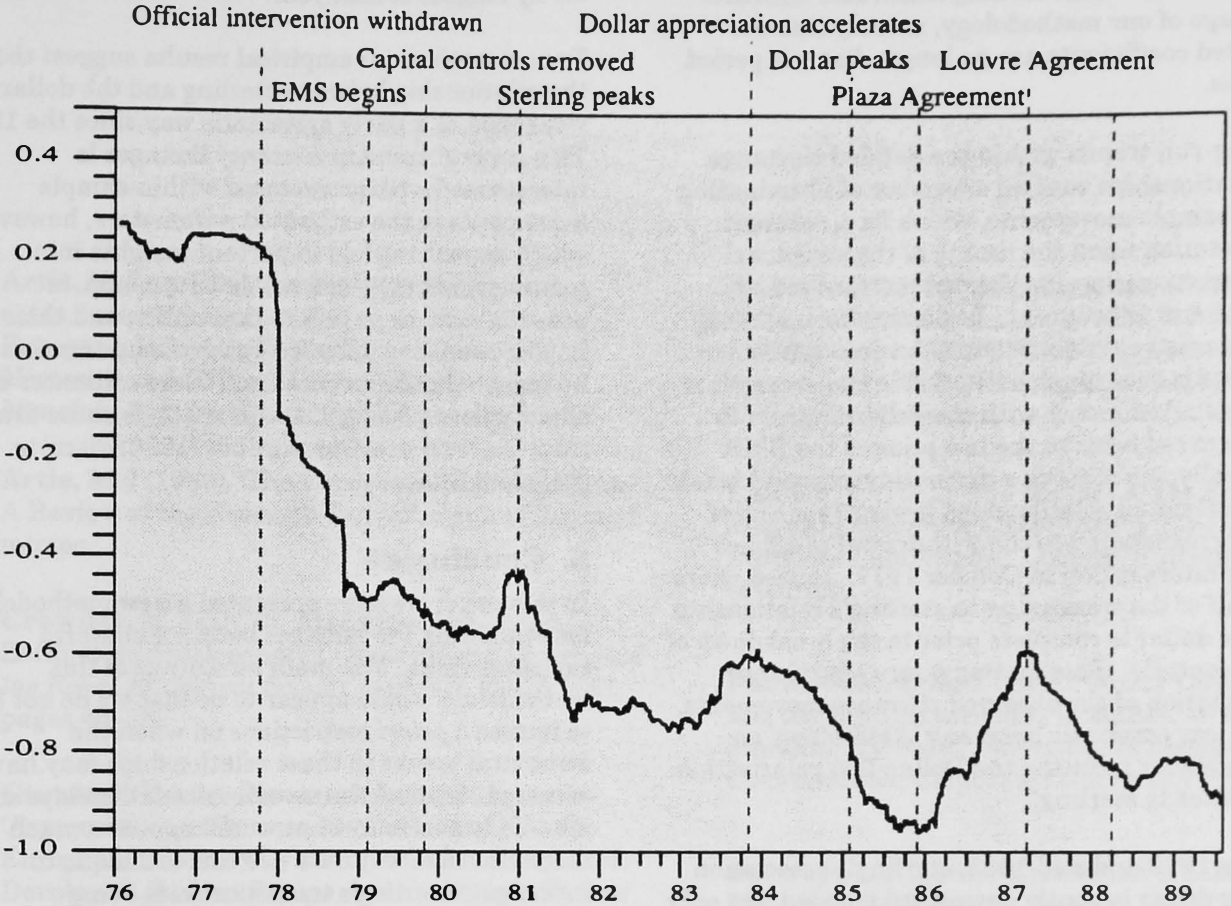
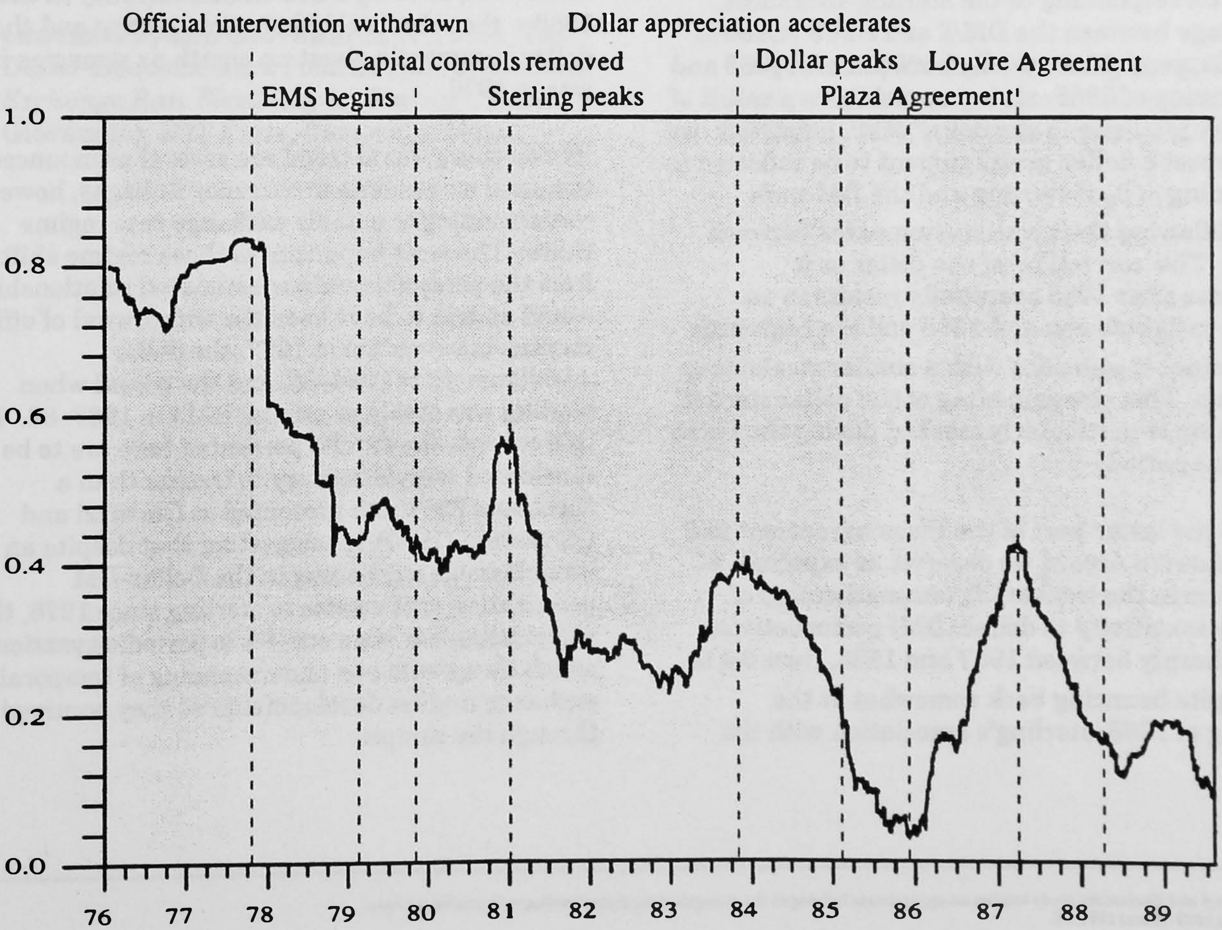


Figure 4: Time varying parameter, β_{2t}



Giavazzi and Giovannini, however, from 0.8 in 1976 to 0.1 in 1989.[1] This finding illustrates a further advantage of our methodology, namely that our estimated coefficients are no longer discrete period averages.

The long-run trends within the defined exchange rate relationships conceal a number of illuminating within-sample movements, which fix a different interpretation upon the timing of the structural breaks in our system to the one put forward by Giavazzi and Giovannini. In particular, one of the most interesting conclusions to be drawn from our estimates is that much of the fall in the strength of sterling's relationship with the dollar appears to have occurred *prior* to the inception of the EMS. Specifically, we observe a dramatic structural break in the estimated relationships towards the end of 1977, corresponding to the withdrawal of official sterling intervention in October 1977. Indeed, more than half of the weakening in sterling's relationship with the dollar is complete prior to the breakdown of capital controls. This finding alters slightly our interpretation of the observed currency movements, placing less emphasis upon any 'EMS-effect' as responsible for reducing the Dollar-DM polarisation as it relates to sterling.

Between 1979 and mid-1983, sterling's association with the dollar is gently downward trended, the only anomaly being the blip in the relationship around 1980-81 corresponding to the sterling 'overshoot'. The linkage between the DM/£ and DM/$ bilateral rates falls away dramatically between mid-1983 and the beginning of 1985, almost certainly as a result of the pronounced rise in the dollar over the period; we would expect a dollar misalignment to be reflected in a weakening of β_2 if sterling and the DM were largely following their equilibrium paths between 1983-85. The 'correction' of the dollar as it depreciates after 1985 eventually results in an increase in β_2 between end-1985 and the beginning of 1987, since it coincides with a similar weakening of sterling. This strengthening of the dollar/sterling relationship is particularly marked during the Plaza agreement period.

Towards the latter part of the Plaza agreement and into the Louvre Accord we observe, as expected, a resumption in the weakening (strengthening) of sterling's sensitivity to dollar (DM) perturbations: β_2 falls sharply between 1987 and 1988, from 0.4 to 0.1. Despite bouncing back somewhat at the beginning of 1988, sterling's association with the dollar weakens throughout 1989, to stand at around 0.1 by August of that year.

To summarise, our empirical results suggest that the relationship between sterling and the dollar has weakened in a fairly systematic way since the 1970s. This general trend in currency linkages is interspersed with pronounced within-sample movements in the estimated parameters, however, which appear to yield important insights into temporal exchange market developments, ie potential exchange rate regime shifts, and their impact over time upon foreign exchange market linkages. Our inferences from these estimates differ slightly in emphasis, if not in spirit, to those drawn from Giavazzi and Giovannini's (1990) discrete period analysis.

5. Conclusion

In this paper we have presented a new methodology for evaluating the linkages between bilateral exchange rates. The main advantage of this methodology would appear to be that we do not have to impose *a priori* restrictions on when the structural breaks in these relationships may have occurred. Instead the structural relationships are allowed to evolve in what would appear a much more plausible way. We use this technique to investigate sterling's transition from being essentially a dollar-linked currency in the mid-1970s, to being a DM-linked currency in the late 1980s: the relationship between sterling and the dollar is currently about an eighth as strong as it was in 1976.

Within this general trend are several pronounced temporal movements in currency linkages, however, corresponding to notable exchange rate regime shifts. The most important of these regime shifts, from the perspective of our estimated relationships, would appear to have been the withdrawal of official sterling intervention in 1977, the dollar misalignment of 1984–85, and the period when sterling was stable at around DM3 in 1987–88. In this respect, the results presented here are to be considered complementary to (rather than a substitute for) those presented in Giavazzi and Giovannini (1990), in suggesting that despite an unambiguous weakening in the Dollar-DM polarisation as it relates to sterling since 1976, this polarisation has been subject to periodic gyrations, which tie up with our understanding of temporal exchange market developments as they occurred through the sample.

(1) The Giavazzi and Giovannini study implies an approximate halving in the strength of the dollar/sterling relationship between the periods 1973-79 and 1979-87.

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34	Modelling short-term asset holdings of UK banks	D G Barr K Cuthbertson
35	A Monte Carlo study of alternative approaches to balancing the national accounts	D M Egginton
36	Sterling's relationship with the dollar and the deutschemark: 1976–89	A G Haldane S G Hall

(a) These papers are no longer available from the Bank, but photocopies can be obtained from University Microfilms International, at White Swan House, Godstone, Surrey RH9 8LW.