EXCHANGE RATE COINTEGRATION ACROSS CENTRAL BANK REGIME SHIFTS

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ABSTRACT: Foreign exchange rates are examined using cointegration tests over various time periods linked to regime shifts in central bank behavior. The number of cointegrating vectors seems to vary across these regime changes within the foreign exchange market. For example, cointegration is not generally found prior to the Plaza Agreement of September 22, 1985, but it is present after that date. The significance of these changes is evaluated using a likelihood ratio procedure proposed by Quintos (1993). The changing nature of the cointegrating relationships indicate that certain aspects of central bank activity do have long-term effects on exchange rates.

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I. Introduction

> "Nevertheless, the empirical evidence, although allowing for the possibility of short-lived effects, does not ascribe to [central bank] intervention a long-lasting effect on the foreign exchange market." - Edison (1993)

The above quote is the concluding sentence of Edison's recent survey on the efficacy of central bank intervention in the foreign exchange market. The short-term impact of central bank intervention has been extensively studied, even down to the level of continuous time data (Goodhart and Hosse, 1993). However, the long-term impact of central bank behavior in the foreign exchange market has not been carefully examined. The long-term behavior of exchange rates is an important area of economic research and has been addressed by Engel and Hamilton (1990), Mark (1995) and others. An important component of this research is regime shifts in central bank behavior, such as the Plaza Agreement of 1985. In this paper, the long-term impact of such regime shifts is examined using cointegration procedures.

Cointegration, as introduced by Engle and Granger (1987), is used to test for the existence of long-term relationships among nonstationary economic variables. Exchange rates are considered to be nonstationary time series, as first established by Meese and Singleton (1982), and systems of exchange rates may exhibit cointegrating relationships. However, as pointed out by Granger (1986), financial asset prices determined in efficient markets should not be cointegrated. That is, if they were cointegrated, one could forecast a given series on the basis of other series in the cointegrated system, and the efficient markets hypothesis would not hold. Several studies have tested for cointegration in systems of foreign exchange rates, such as Hakkio and Rush (1989), Copeland (1991), Baillie and Bollerslev (1989), and Diebold *et al.* (1994). Using various cointegration testing procedures, these studies achieve different results. Specifically, Baillie and Bollerslev (1989) find cointegration in a system of seven daily exchange rates, but Diebold *et al.* (1994) find no cointegration in this system once a trend is explicitly modelled.

This paper attempts to extend these studies by incorporating structural breakpoints into the cointegration analysis. Structural breaks in data series, particularly in asset price series, usually indicate fundamental changes in the underlying data generating processes. Such breaks may significantly alter the equilibrium relationships between data series, and tests of the long-term behavior of these series should take account of them.[1] The breakpoints examined are linked to specific regime shifts in central bank behavior in the foreign exchange market. Generally, studies of such central bank activities have been limited to intervention, official sales or purchases of foreign assets against domestic assets. Much research has found these activities to have little, if any, impact on the behavior of exchange rates. This paper focusses instead on transactions or official announcements by central banks that, in essence, indicate a regime shift in their behavior. Examples of such intervention activities are the formation of the European Monetary System in March 1979 and the Plaza Agreement of September 1985. Five such episodes are examined in this paper.

With respect to the cointegration analysis, such regime shifts may be considered structural breaks that fundamentally alter any long-term equilibrium relationships which may exist. Thus, the number of cointegrating vectors present in the periods before and after the

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[1] Granger and Escribano (1986) find evidence that exceptional events in the gold and silver markets cause these two price series, which should not be cointegrated under the efficient markets hypothesis, to be cointegrated during certain time periods.

specified structural break may differ. Quintos (1993) presents a procedure for testing whether such differences in the number of cointegrating vectors induced by structural breaks are statistically significant. She specifically states that the procedure addresses structural breaks that potentially change the definition of a system's equilibrium relationship. She suggests that such a change could be brought about by fundamental changes in the behavior of institutions, such as central banks.

The main finding of this paper is that the specified incidents of central bank regime shifts do impact the long-term behavior of exchange rates. Varying numbers of cointegrating relationships are found before and after the structural breaks, and the changes are mostly found to be significant. For example, no cointegrating relationships are found in the period before the Plaza Agreement of September 22, 1985, but after that date, evidence of cointegration is found. Since the Plaza Agreement signalled concerted intervention by central banks to cause a dollar depreciation, it is not surprising that new long-term relationships (or market equilibria) between exchange rates arose in the post-Plaza period. Similar results are found for other breakpoints and for a subsystem of exchange rates consisting solely of EMS currencies.

Section II describes the exchange rate data used as well as the proposed structural breakpoints examined. Section III outlines the cointegration techniques used in the analysis. Section IV summarizes the literature on cointegration tests of exchange rates and presents the cointegration results for the various specified time periods and currencies. Section V concludes.

II. The Data and Structural Breakpoints

A. The Data

The spot foreign exchange rates used in this paper are the Federal Reserve Bank of New York (FRBNY) rates as recorded at noon in the New York foreign exchange market. The eight exchange rates examined are the British pound (BP), the German mark (DM), the Japanese yen (JY), the French franc (FR), the Dutch guilder (NG), the Italian lira (LI), the Swiss franc (SF) and the Canadian dollar (CD); see Figures 1 to 8. The exchange rates are expressed as the natural log of foreign currency units per U.S. dollar, and the first differences of these series are the daily rates of return for dollar-based investors; i.e.,

$$\Delta y_t = 100\log\left(s_t\right) - 100\log\left(s_{t-1}\right)$$

B. The Time Periods

Cointegration tests examine the long-term behavior of economic data. Thus, as discussed by Hakkio and Rush (1991), the length of the "long term" is an immediately relevant question. They argue that the proper length of the "long term" must be determined in light of the economic question being addressed. Two factors can be used to determine the proper time interval over which to examine exchange rates: one is market based, the other is forecast based. Given the massive daily trading volume in the foreign exchange markets,[2] new information is quickly incorporated into exchange rates; this suggests a rather short "long-term" horizon for exchange rate determination. Secondly, forecasts based on daily data are

[2] Approximately $192 billion per day in the United States alone, according to the FRBNY Foreign Exchange Market Survey of 1992.

usually made only several months ahead, as in Diebold *et al.* (1994). Given these two reasons, time periods longer than one year (approximately 250 observations) seem to be appropriate horizons over which to examine the long-term behavior of daily exchange rates. As shown in Table 1, the principal time periods examined in this paper meet this criterion.

In addition to a period's length, the choice of its endpoints is also important. With respect to cointegration tests, Sephton and Larsen (1991) conclude that the evidence for cointegration is "fragile" and exhibits "temporal sensitivity" since different subsample periods provide differing results. Given this result, testing for cointegration over an arbitrarily chosen time period, as in Baillie and Bollerslev (1989) and other studies, does not seem appropriate.

An alternative method for selecting a period's endpoints is to impose structural breaks exogenously in the spirit of Perron (1989). In this paper, the endpoints of the 18-year period examined are determined by an approximation to the start of the current floating-rate regime and by data availability, and the five proposed structural breakpoints examined are linked to regime shifts in central bank behavior in the foreign exchange market.

The first breakpoint suggested is November 1, 1978.[3] On that date, a so-called "dollar-rescue package" was enacted by the U.S. to at least halt the depreciation of the dollar. The package consisted of tightened monetary policy and the creation of an intervention fund. The ensuing sustained and coordinated intervention temporarily raised the value of the dollar, but it returned to its previous level by year end. The outcome of this intervention was interpreted to mean that substantial effects could be achieved, but that these effects would be temporary

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[3] This breakpoint is explicitly examined in Loopesko (1984). In-depth summaries of the events surrounding all five breakpoints are provided in Dominguez and Frankel (1993).

unless supported by genuine policy changes. This change in central bank behavior is included in the subsequent analysis to determine whether it did have a long-term impact.

The second proposed breakpoint, March 13, 1979, marks the formation of the European Monetary System (EMS). The original members agreed to fix their mutual exchange rates within certain bands and float jointly against the dollar. Although other exchange rate agreements had existed amongst European currencies, the EMS marked the formation of a new and more strongly codified system.

The third suggested breakpoint, February 25, 1985, primarily arises from the data. Five of the six European exchange rates achieve their post-1973 maximum on that day, and the sixth (SF) achieves its post-EMS maximum eight days later on March 5, 1985. According to financial news reports at the time, market participants could not cite any particular event that led to the dollar's rapid depreciation. However, the German Bundesbank and other European central banks, as well as the Federal Reserve to a lesser extent, intervened heavily throughout the first quarter of 1985 to halt the appreciation of the dollar. This intervention activity by the U.S. was directly linked to the change in the Secretary of the Treasury; Brady was willing to intervene while Regan was not. Most of these intervention operations were widely reported and signalled the central banks' intentions to market participants.

The fourth breakpoint examined is September 23, 1985, the first trading day after the announcement of the Plaza Agreement. In this agreement, the G-5 central banks stated that "some further orderly appreciation of the main non-dollar currencies against the dollar is desirable" and that they would "stand ready to cooperate more closely to encourage this when to do so would be helpful."[4] After this announcement, the dollar continued its prolonged depreciation as central banks intervened actively in the foreign exchange markets.

The fifth breakpoint is February 22, 1987, the day after the Louvre Accord. The G-7 central banks, excluding Italy, "agreed to cooperate closely to foster the stability of exchange rates around current levels."[5] In essence, the central banks agreed to stop the depreciation of the dollar and maintain a reference range for the major non-dollar currencies by intervening in the market, as necessary.

Given the dataset's endpoints and these five breakpoints, the data can be subdivided into the entire post-1973 period, the pre- and post-"dollar rescue" periods, the pre- and post-EMS periods, the pre- and post-peak periods, the pre- and post-Plaza periods and the pre- and post-Louvre periods. Overall, the long-term behavior of exchange rates is examined in these 11 periods; Table 1 lists the endpoints and the number of observations for each period, and Figure 9 provides a graphical representation of the periods.

III. Overview of Cointegration Procedures

A. Unit Root Test Results

Cointegration examines the relationships between nonstationary, or I(1), variables. The nonstationarity of post-1973 exchange rates was initially documented by Meese and Singleton (1982) and has been verified by many authors. In this paper, three types of unit root tests are

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[4] G-5 Announcement of September 22, 1985. The G-5 countries are Britain, France, Japan, the U.S. and Germany.

[5] G-7 Announcement of February 22, 1987. The G-7 countries are the G-5 countries plus Canada and Italy.

used to examine the nonstationarity of exchange rates: Dickey-Fuller tests (1979), augmented Dickey-Fuller tests (Fuller, 1976) and Phillips-Perron tests (1988). Diebold and Nerlove (1990) state that the augmented Dickey-Fuller test is the most attractive unit root test.

The unit root tests are applied to the eight exchange rates in all 11 periods, and the null hypothesis of unit root behavior cannot be rejected in almost all time periods at the one-sided 1% and 5% levels.[6] That is, the null hypothesis of $\rho = 1$ cannot be rejected in favor of the alternative hypothesis $\rho < 1$, where ρ is the autoregressive parameter. The only period in which the unit root hypothesis may be rejected is the post-peak period. Given these results, the various exchange rate series will be considered to be I(1) variables.

B. The Johansen Procedure

Various tests for the presence of cointegration amongst I(1) variables have been proposed beginning with Engle and Granger (1987). The test procedure used in this paper is a multivariate procedure based on maximum likelihood methods introduced in Johansen (1988,1991) and expanded upon in Johansen and Juselius (1990).

The Johansen procedure examines a vector autoregressive (VAR) model of X_t, an (nx1) vector of I(1) time series. The error-correction form is written in first differences as

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi X_{t-k} + \mu + + \varepsilon_t$$

6 The unit root test results are available upon request.

$$\varepsilon_t \sim N(0,\Lambda) \quad t = 1,\dots T,$$

where Γ_i for $i=1\dots k-1$ and Π are (nxn) matrices, μ is a (nx1) vector of constants, ε_t is a (nx1) error vector and Λ is its (nxn) covariance matrix. Since some or all of the elements of X_t are I(1), ΔX_t is an I(0) process. Thus, the stationarity of the right side of the equation is achieved only if ΠX_{t-k} is stationary.

The Johansen procedure tests the rank of Π, which determines the number of cointegrating vectors present in the system. If rank(Π) = n, X_{t-k} must be a stationary process, and no cointegrating vectors are present. If rank(Π) = 0, then $\Pi = 0$, and the model reduces to a standard VAR in differences. However, if rank(Π) = r < n, then $\Pi = \alpha\beta'$, where both α and β are (nxr) matrices. β is the matrix of cointegrating vectors, and the number of such vectors is r. The cointegrating vectors have the property that $\beta_j' X_t$, $j=1,\dots,r$ is stationary even though X_t is nonstationary; these vectors represent the long-term relationships present in the system. Thus, the number of long-term equilibrium relationships present in a system is equal to the number of cointegrating vectors. Note, however, that α and β cannot be separately identified since for any non-singular matrix P, the product of αP and $\beta(P')^{-1}$ is also Π.

The Johansen cointegration tests used in this paper examine the null hypothesis against the alternative that no cointegrating vectors are present in the system X_t. The two null hypotheses tested are that r cointegrating vectors are present in the system under the assumption that either $\mu = 0$ or $\mu \neq 0$. The statistic chosen for testing these null hypotheses is the trace statistic. It tests for the presence of r cointegrating vectors in a system against the alternative hypothesis that X_t is stationary; i.e, the system has r = n cointegrating vectors. The trace statistic is a likelihood ratio (LR) statistic of the form

$$tr(r) = -T \sum_{i=r+1}^{n} \ln\left(1 - \hat{\lambda}_i\right),$$

where the $\hat{\lambda}_i's$ are the ordered solutions to the eigenvalue problem $\left|\lambda S_{kk} - S_{k0}S_{00}^{-1}S_{0k}\right| = 0$. The S_{ij} matrices are the residual moment matrices derived from the postulated error-correction model. The distributions of the various forms of the trace statistic depend only on (n-r) and are tabulated in Osterwald-Lenum (1992).

C. The Quintos Procedure for Testing Rank Constancy

Quintos (1993) presents a procedure for testing the rank constancy of the cointegrating matrix Π over sample subperiods; that is, the procedure tests whether the number of cointegrating vectors varies across sample subperiods. If the rank does vary, then the number of driving forces in the economic system changes across the breakpoint. Both long-run and short-run coefficients in the error-correction model may change as well. The relevant test statistics are simply weighted averages of Johansen's LR statistics, and the weights are the subperiod sample sizes. The test procedure is briefly summarized below.

The Quintos procedure permits one to test a wide variety of null hypotheses, but only a small subset of the available options will be tested in this paper. For example, the procedure allows for J structural breaks in the system, but throughout this paper, J = 1. Furthermore, the procedure allows the breakpoints to be endogenous to the process, but in this paper, the breakpoints used will be exogenously imposed as in Perron (1989).

The main hypothesis tested in this paper is that the number of cointegrating vectors (or equilibrium relationships) remains constant across time; that is, $H_0^q : q_1 = q = q_2$, where q is the number of cointegrating vectors in the entire period, q_1 and q_2 are the number of cointegrating vectors in the pre- and post-breakpoint periods, and $0 \leq q < n$. Note that the coefficients of Π are allowed to vary across subperiods.

Different LR statistics are used for the different permutations of the ranks of the full and subperiod Π matrices. For $q < q_1$ and $q < q_2$, the LR test statistic used is

$$LR = -p_1 \sum_{i=q+1}^{q_1} \ln\left(1 - \hat{\lambda}_{1i}\right) - p_2 \sum_{i=q+1}^{q_2} \ln\left(1 - \hat{\lambda}_{2i}\right),$$

where p_1 and p_2 are the number of observations in each subperiod and the $\hat{\lambda}_{ji}$, $j=1,2$ are the eigenvalues of the respective, estimated Π matrices. The distribution of this statistic is a function of scaled, n-dimensional Brownian motions and depends upon the variables n, q, q_1 and q_2. For $q > q_1$ and $q > q_2$, the relevant LR statistic is

$$LR^{\#} = p_1 \sum_{i=q_1+1}^{q} \ln\left(1 + \lambda_{1i}\right) + p_2 \sum_{i=q_2+1}^{q} \ln\left(1 + \hat{\lambda}_{2i}\right),$$

which is distributed $\chi^2_{(2q - q_1 - q_2)n}$. These statistics can also be used in case of an equality between q and either one of the subperiod ranks. For the case $q_1 < q < q_2$, the relevant LR statistic is

$$LR_1^* = -p_1 \sum_{i=q_1+1}^{q} \ln\left(\hat{\lambda}_{1i}\right) - p_2 \sum_{i=q+1}^{q_2} \ln\left(1 - \hat{\lambda}_{2i}\right),$$

and for the case $q_2 < q < q_1$, the LR statistic is

$$LR_2^* = -p_1 \sum_{i=q+1}^{q_1} \ln\left(1 - \hat{\lambda}_{1i}\right) + p_2 \sum_{i=q_2+1}^{q} \ln\left(1 - \hat{\lambda}_{2i}\right)$$

Both of these statistics have distributions that are mixtures of a χ^2 distribution and a function of scaled Brownian motions.[7]

IV. Empirical Test Results

A. Previous Cointegration Tests of Exchange Rates

Four studies have tested for the presence of cointegration in systems of foreign exchange rates: Hakkio and Rush (1989), Copeland (1991), Baillie and Bollerslev (1989) and Diebold *et al.* (1994). The first two explicitly test for the efficiency of the foreign exchange markets; as mentioned before, the presence of cointegration among exchange rates would contradict the efficient markets hypothesis by implying that current rates can be predicted by past deviations from the long-run cointegrating relationships. The second two papers focus on modeling and forecasting exchange rates.

Hakkio and Rush (1989) use the Engle-Granger cointegration procedure to examine monthly spot rates for BP and DM from July 1975 to October 1986. They conclude that the two rates are not cointegrated at the 5% significance level; this result is consistent with the market efficiency hypothesis. However, further tests involving the error-correction representation of the system leads the authors to reject the market efficiency hypothesis for

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[7] Carmela Quintos was kind enough to provide the critical values necessary for some of the hypothesis tests conducted in this paper.

these two currencies. Copeland (1991) examines bivariate systems of exchange rates for cointegration using the Johansen (1988) procedure. The data used is daily spot rates for BP, DM, JY, FR and SF over the period 1976 to 1990. Copeland finds no cointegration among the ten currency pairs at the 5% significance level, which supports the efficient market hypothesis.

Baillie and Bollerslev (1989) examine daily opening spot rates from the New York market for the period March 1, 1980 to January 28, 1985. The seven currencies used are BP, DM, JY, FR, LI, SF and CD. One cointegrating vector is found in this system using the Johansen (1988) procedure. They conclude that the deviations from the long-term relationship between these spot rates is an important component of the next period's observed rates; thus, the efficient markets hypothesis is violated. The authors further conclude that an error-correction model is appropriate for modelling foreign exchange rates. However, using the Johansen procedure, Diebold *et al.* (1994) find no cointegration in this dataset. Furthermore, in a forecasting exercise, the authors find no improvements in forecast performance by the fitted error-correction model relative to the simple martingale model. A similar result is found for the entire post-1973 period.

The cointegration tests in this paper extend the latter two results by using a longer time period and a larger currency system. Furthermore, a subsystem of exchange rates consisting of the four EMS currencies is tested for the presence of cointegrating vectors. This cointegration analysis incorporates the structural breaks discussed in Section II. The cointegration results are derived using the Johansen procedure and the 5% critical values from Osterwald-Lenum (1992). The Quintos procedure described in Section III is applied to these cointegration results to determine whether the number of cointegrating vectors (or equilibrium relationships) changed significantly between the pre- and post-breakpoint periods.

B. Cointegration Test Results: Post-1973 Period

To test for cointegration, error-correction models are fit to all the exchange rate systems under study. The orders of the VAR's are determined by minimizing the multivariate Schwarz information criterion (SIC). In all cases examined, the order chosen is two;[8] that is,

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \Pi X_{t-2} + \mu + \varepsilon_t.$$

A summary of these cointegration results is presented in Table 2. The results of the cointegration analysis for the full system of exchange rates are presented in Tables 3 to 13, and the results for the EMS subsystem are in Tables 14 to 24. As noted above, the appropriate critical values depend upon whether μ is present in the data. Since this cannot be determined a priori, the calculated test statistics are compared to the critical values based on both assumptions.

The 11 time periods, as determined by the five structural breakpoints discussed in Section II, as well as the entire post-1973 period are tested for the presence of cointegration. Two significant results arise from this analysis. First, for the entire post-1973 period, one cointegrating vector is found; thus, indicating that this system of exchange rates has at least one long-term cointegrating relationship. This result differs from that of Diebold *et al.* (1994)

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[8] In the interest of space, the VAR estimation results are not presented. The various SIC statistics and the estimated VAR parameters are available upon request.

which excludes the Dutch guilder (NG) from the analysis.

Second, the cointegration results for the pre-breakpoint periods generally indicate the absence of any long-term relationships, except for the pre-EMS period. However, the post-breakpoint periods generally indicate the presence of one or more cointegrating relationships, with the exception of the post-Louvre period. These results seem to indicate that the "dollar rescue", peak and Plaza breakpoints change the nature of the underlying long-term relationships in the foreign exchange market; these regime shifts in central bank behavior had a long-term impact on the exchange rates. The Louvre breakpoint also seems to have had an impact, but its nature is unclear. It seems that the EMS breakpoint did not have an impact on the entire system of exchange rates.

These results indicate that the equilibrium relationship found in the entire post-1973 period has not necessarily remained constant. The varying number of cointegrating vectors in the pre- and post-breakpoint periods indicates that the underlying market equilibria for this system of exchange rates are affected by these structural breaks. To further explore the impact of these structural breaks, a subsystem of EMS currencies (i.e., DM, FF, NG and LI) is tested for the presence of cointegration. The results of the cointegration analysis for the EMS subsystem are different from those of the full system. At least two cointegrating relationships are indicated over the entire post-1973 period for this subsystem. In addition, cointegration is present in all subperiods, except for the pre-Plaza period and the pre- and post-Louvre periods. Overall, these results indicate that the cointegration present in the entire system is driven by the cointegration present in the EMS subsystem.

C. Quintos Rank Constancy Tests

To determine whether these differences in the number of cointegrating vectors are significant, the Quintos tests described in Section III is applied to the cointegration results.

(i). Full System of Exchange Rates

Table 25 contains the results of the Quintos tests applied to the cointegration results for the full system of exchange rates over the entire post-1973 period. Given the various combinations of the estimated full and subperiod ranks examined, various LR statistics described in Section III are used.

For all cases, other than the EMS breakpoint, the null hypothesis of rank constancy with unstable coefficients is rejected. Several implications immediately follow from these results. The most prominent is that these episodes of central bank intervention did have an impact on the long-term relationships (or equilibria) in this system of exchange rates. Thus, certain central bank activities can have a long-term impact on the foreign exchange market.

The meaning of these results for the individual breakpoints requires further study. The "dollar rescue" package, as described in Section II, did not have a strong impact on the market since shortly after its enactment, the market countered all of the gains the package provided. Yet, according to the Quintos test results, the cointegrating relationships across this breakpoint did change. On the other hand, the EMS breakpoint, which one would expect to have an impact on the system since it explicitly imposes a long-term relationship on the exchange rates, does not change the rank of the cointegrating matrix. The results for the peak, Plaza and Louvre breakpoints are as expected; these breakpoints seem cause a significant change in the cointegrating relationships in the system. Furthermore, the similarity between the peak and Plaza breakpoints is as expected.

To supplement these full-period results while recognizing the drop in power due to reduced sample size, subperiods around these breakpoints are examined in order to isolate the effects of a single breakpoint. The relevant test results are contained in Table 27.[9] This subperiod analysis seems to cast some light on the impact of the "dollar rescue" breakpoint. The null of rank constancy with unstable coefficients is rejected for the start-EMS breakpoint period and cannot be tested for the longer start-peak and start-Plaza breakpoint periods. These results seem to indicate that the "dollar rescue" breakpoint had little overall impact and that its impact with respect to the entire post-1973 period is mainly due to the events surrounding the peak and Plaza breakpoints. However, the results for subperiods surrounding the EMS, peak and Plaza breakpoints indicate that they did impact the system's cointegrating relationships.

(ii). EMS Subsystem of Exchange Rates

Table 26 contains the results of the Quintos test applied to the cointegration results for the EMS subsystem of exchange rates over the entire post-1973 period. For all cases, the null hypothesis of rank constancy with unstable coefficients is clearly rejected. Several implications follow from this set of results. The proposed central bank regime shifts seem to have an impact on the long-term relationships present in this subsystem of exchange rates. The "dollar rescue" breakpoint results are mixed in that the null hypothesis is rejected at the

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[9] Complete test results are available upon request.

5% significance level but not at the 1% level. The result that the "dollar rescue" period may not impact the EMS subsystem as strongly as the whole system is understandable since the event did not focus specifically on the EMS currencies.

To supplement these results, subperiods around these breakpoints are examined as before, while still acknowledging the decline in power due to reduced sample size. The results of this analysis are contained in Table 28. The interesting result here regards the Plaza breakpoint. The subperiods examined for this breakpoint begin at the four previous breakpoints and end at the Louvre breakpoint; i.e., the post-Louvre period is excluded from the analysis. For the first three startpoints, $q = q_1 = q_2$; thus, the null of rank constancy cannot be rejected. For the subperiod starting at the peak breakpoint, the null can be rejected. These results seem to indicate that, for the EMS subsystem, the effects of Plaza breakpoint were not as strong as for the whole system.

V. Conclusions

The long-term impact of central bank activities, broadly defined, on the foreign exchange market is an issue that has not been directly examined. This paper attempts to address this question using cointegration analysis that incorporates structural breaks linked to regime changes in central bank behavior. The five breakpoints examined are instances of changes in central bank behavior that may have substantially altered the long-term relationships among the eight currencies examined.

Using the Johansen procedure, cointegrating relationships are found for the full system of exchange rates and a subset consisting of four EMS currencies. The number of cointegrating vectors in the periods before and after the suggested breakpoints are found to be different in several cases. Furthermore, these differences are found to be statistically significant using the testing procedure proposed by Quintos (1993). Structural changes of the type that alter the definition of the system's equilibria seem to have occurred at these breakpoints. Thus, regime shifts in central bank behavior do have a long-term impact on foreign exchange rates.

Further research into this finding is warranted, both along methodological and theoretical lines. With respect to methodological issues, the rich structure of the Quintos test procedure should be used to endogenize the breakpoints as well as test for more than one breakpoint at a time. In addition, extensions of the cointegration results, such as fractional cointegration analysis proposed by Baillie and Bollerslev (1993) and further explored in Lopez (1995), should be examined. With respect to theoretical issues, another outstanding question is what the existence of cointegrating vectors implies with respect to models of exchange rate determination. If cointegration is a feature of the data, models incorporating it must be constructed and possibly be made robust to structural breaks.

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Table 1: Summary the 11 Time Periods Examined

	Start Date	End Date	Observations
Post-1973 Period	01/04/74	12/31/91	4513
Pre-"Dollar Rescue" Period	01/04/74	11/01/78	1213
Post-"Dollar Rescue" Period	11/02/78	12/31/91	3300
Pre-EMS Period	01/04/74	03/13/79	1301
Post-EMS Period	03/14/79	12/31/91	3212
Pre-Peak Period	01/04/74	02/25/85	2791
Post-Peak Period	02/26/85	12/31/91	1722
Pre-Plaza Period	01/04/74	09/20/85	2938
Post-Plaza Period	09/23/85	12/31/91	1575
Pre-Louvre Period	01/04/74	02/20/87	3291
Post-Louvre Period	02/23/87	12/31/91	1222

Table 2:

Summary of the Johansen Cointegration Results for the Systems of FX Rates

Time Period	Number of Cointegrating Vectors under $H_2(r)$	
	Full System	EMS Subsystem
Post-1973 Period	1	2
Pre-"Dollar Rescue" Period	0	1
Post-"Dollar Rescue" Period	1	2
Pre-EMS Period	1	1
Post-EMS Period	1	1
Pre-Peak Period	0	1
Post-Peak Period	3	1
Pre-Plaza Period	0	0
Post-Plaza Period	3	1
Pre-Louvre Period	0	0
Post-Louvre Period	0	0

Tables 3-24: Johansen Cointegration Test Results

The 5% critical values for the two forms of the H(r) hypothesis tests using the trace statistic are listed below. The source for these critical values is Osterwald-Lenum (1992). If a trace statistic for the H(r) hypotheses is significant under $\mu = 0$, it is marked with *; if it is significant under $\mu \neq 0$, it is marked with **; and if it is significant for both, it is marked with #.

Dimension of Π (n-r)	H(r) $\mu = 0$	$\mu \neq 0$
1	8.176	3.762
2	17.953	15.410
3	31.525	29.680
4	48.280	47.410
5	70.598	68.524
6	95.177	94.155
7	124.253	124.243
8	157.109	155.999

Table 3.
Johansen Cointegration Test Results for the Full System in the Post-1973 Period

	Trace Statistics
r	H(r)
7	1.4816
6	5.7237
5	16.9077
4	32.3175
3	47.9406
2	68.6433
1	110.0213
0	160.2744#

Table 4.
Johansen Cointegration Test Results for the Full System in the Pre-Dollar Rescue Period

	Trace Statistics
r	H(r)
7	0.1340
6	6.7796
5	17.0687
4	31.0271
3	49.4256
2	69.2059
1	105.3181
0	155.8310

Table 5.
Johansen Cointegration Test Results for the Full System in the Post-Dollar Rescue Period

	Trace Statistics
r	H(r)
7	2.6645
6	6.3700
5	15.8702
4	31.4557
3	58.5751
2	88.2633
1	120.9527
0	164.0304#

Table 6.
Johansen Cointegration Test Results for the Full System in the Pre-EMS Period

	Trace Statistics
r	H(r)
7	1.6814
6	4.9382
5	14.6901
4	25.4597
3	42.0717
2	65.8132
1	104.4806
0	156.4098**

Table 7.
Johansen Cointegration Test Results for the Full System in the Post-EMS Period

	Trace Statistics
r	H(r)
7	2.4110
6	6.2067
5	17.3797
4	31.3092
3	54.8606
2	79.4686
1	112.3466
0	162.6838 #

Table 8.
Johansen Cointegration Test Results for the Full System in the Pre-Peak Period

r	Trace Statistics H(r)
7	0.1244
6	4.9693
5	10.4071
4	23.2316
3	40.5152
2	58.5681
1	90.7833
0	137.8266

Table 9.
Johansen Cointegration Test Results for the Full System in the Post-Peak Period

r	Trace Statistics H(r)
7	3.3206
6	9.5549
5	22.5927
4	44.2406
3	68.5852 **
2	98.0516 #
1	142.3415 #
0	267.1033 #

Table 10.
Johansen Cointegration Test Results for the Full System in the Pre-Plaza Period

r	Trace Statistics H(r)
7	0.0348
6	5.0068
5	11.7034
4	24.1218
3	40.5794
2	60.4225
1	91.0500
0	127.0183

Table 11.
Johansen Cointegration Test Results for the Full System in the Post-Plaza Period

r	Trace Statistics H(r)
7	4.2605
6	13.2175
5	23.0940
4	42.2340
3	64.5921 *
2	95.3069 #
1	133.2467 #
0	179.5316 #

Table 12.
Johansen Cointegration Test Results for the Full System in the Pre-Louvre Period

r	Trace Statistics H(r)
7	1.5130
6	6.1328
5	11.7505
4	25.0944
3	39.9255
2	59.9189
1	90.8637
0	128.4835

Table 13.
Johansen Cointegration Test Results for the Full System in the Post-Louvre Period

r	Trace Statistics H(r)
7	1.5472
6	6.9431
5	16.7302
4	31.8432
3	49.6656
2	77.4124
1	110.6171
0	150.850

Table 14.
Johansen Cointegration Test Results for the EMS Subsystem in the Post-1973 Period

r	Trace Statistics H(r)
3	1.6127
2	14.8994
1	32.5348 #
0	63.8383 #

Table 15.
Johansen Cointegration Test Results for the EMS Subsystem in the Pre-Dollar Rescue Period

r	Trace Statistics H(r)
3	1.1814
2	4.8994
1	16.3359
0	48.6840 #

Table 16.
Johansen Cointegration Test Results for the EMS Subsystem in the Post-Dollar Rescue Period

r	Trace Statistics H(r)
3	1.7818
2	12.8313
1	29.7344 #
0	58.5574 #

Table 17.
Johansen Cointegration Test Results for the EMS Subsystem in the Pre-EMS Period

r	Trace Statistics H(r)
3	2.2075
2	6.3416
1	18.1843
0	54.9489 #

Table 18.
Johansen Cointegration Test Results for the EMS Subsystem in the Post-EMS Period

r	Trace Statistics H(r)
3	2.2459
2	15.7156 **
1	36.5782 #
0	71.0912 #

Table 19.
Johansen Cointegration Test Results for the EMS Subsystem in the Pre-Peak Period

r	Trace Statistics H(r)
3	0.4921
2	8.5004
1	26.7178
0	50.7560 #

Table 20.
Johansen Cointegration Test Results for the EMS Subsystem in the Post-Peak Period

r	Trace Statistics H(r)
3	5.5125
2	14.3179
1	30.6567**
0	69.0913 #

Table 21.
Johansen Cointegration Test Results for the EMS Subsystem in the Pre-Plaza Period

r	Trace Statistics H(r)
3	0.0001
2	8.0007
1	19.7551
0	45.2917

Table 22.
Johansen Cointegration Test Results for the EMS Subsystem in the Post-Plaza Period

r	Trace Statistics H(r)
3	2.9823
2	10.8225
1	25.8553
0	51.5630 #

Table 23.
Johansen Cointegration Test Results for the EMS Subsystem in the Pre-Louvre Period

r	Trace Statistics H(r)
3	1.1206
2	10.4934
1	22.0338
0	46.7566

Table 24.
Johansen Cointegration Test Results for the EMS Subsystem in the Post-Louvre Period

r	Trace Statistics H(r)
3	1.3289
2	7.7759
1	20.1681
0	39.7472

Table 25.
Quintos Cointegration Test Results for the Full System in the Post-1973 Period

Breakpoint	q	q_1	q_2	LR Statistic
"Dollar Rescue"	1	0	1	$LR^{\#} = 48.51$ *
EMS	1	1	1	---
Peak	1	0	3	$LR_1^{*} = 11515$ *
Plaza	1	0	3	$LR_1^{*} = 13014$ *
Louvre	1	0	0	$LR^{\#} = 76.27$ *

Note: The LR statistics that are significant at the 5% level are labelled with *.

Table 26.
Quintos Cointegration Test Results for the EMS Subsystem in the Post-1973 Period

Breakpoint	q	q_1	q_2	LR Statistic
"Dollar Rescue"	2	1	2	$LR^{\#} = 11.71$ *
EMS	2	1	1	$LR^{\#} = 27.80$ *
Peak	2	1	1	$LR^{\#} = 34.47$ *
Plaza	2	0	1	$LR^{\#} = 52.07$ *
Louvre	2	0	0	$LR^{\#} = 67.65$ *

Note: The LR statistics that are significant at the 5% level are labelled with *.

Table 27.
Quintos Cointegration Test Results for the Full System in the Defined Subperiods

Subperiod	q	q_1	q_2	LR Statistic
"Dollar				
Rescue"				
Start-EMS	1	0	1	$LR^{\#}$ = 48.51 *
Start-Peak	0	0	0	---
Start-Plaza	0	0	0	---
EMS				
Start-Peak	0	1	0	LR = 54.06 *
Start-Plaza	0	1	0	LR = 54.06 *
"DR"-Peak	0	1	0	LR = 55.94 *
"DR"-Plaza	0	1	0	LR = 55.94 *
Peak				
Start-Plaza	0	0	3	LR = 167.05 *
"DR"-Plaza	0	0	3	LR = 167.05 *
EMS-Plaza	0	0	3	LR = 167.05 *
Plaza				
Start-Louvre	0	0	2	LR = 124.25 *
"DR"-	0	0	2	LR = 124.25 *
Louvre	0	0	2	LR = 124.25 *
EMS-Louvre	1	3	2	LR = 154.64 *
Peak-Louvre				
Louvre	1	0	0	$LR^{\#}$ = 75.65 *
"DR"-End	1	0	0	$LR^{\#}$ = 77.02 *
EMS-End	3	1	0	$LR^{\#}$ = 200.32 *
Peak-End	3	2	0	$LR^{\#}$ = 154.65 *
Plaza-End				

Note: The LR statistics that are significant at the 5% level are labelled with *. The critical values were provided by Carmela Quintos and are based on 1000 Monte Carlo repititions.

Table 28.
Quintos Cointegration Test Results for the EMS Subsystem in the Defined Subperiods

Subperiod	q	q_1	q_2	LR Statistic
"Dollar Rescue"				
Start-EMS	1	1	2	LR = 27.57 *
Start-Peak	1	1	0	LR = 31.24 *
Start-Plaza	0	1	0	LR = 31.33 *
EMS				
Start-Peak	1	1	0	$LR^{\#}$ = 19.10 *
Start-Plaza	0	1	0	LR = 14.92 *
"DR"-Peak	0	2	0	LR = 60.83 *
"DR"-Plaza	0	2	0	LR = 60.83 *
Peak				
Start-Plaza	0	1	1	LR = 65.86 *
"DR"-Plaza	0	0	1	LR = 19.14 *
EMS-Plaza	0	0	1	LR = 19.14 *
Plaza				
Start-Louvre	0	0	0	---
"DR"-	0	0	0	---
Louvre	0	0	0	---
EMS-Louvre	1	1	0	$LR^{\#}$ = 22.93 *
Peak-Louvre				
Louvre	2	0	0	$LR^{\#}$ = 63.03 *
"DR"-End	1	0	0	$LR^{\#}$ = 41.05 *
EMS-End	1	1	0	$LR^{\#}$ = 19.28 *
Peak-End	1	0	0	$LR^{\#}$ = 42.20 *
Plaza-End				

Note: The LR statistics that are significant at the 5% level are labelled with *. The critical values were provided by Carmela Quintos and are based on 1000 Monte Carlo repititions.

Figure 1.
Daily Spot BP/$ Exchange Rate
1974-1992

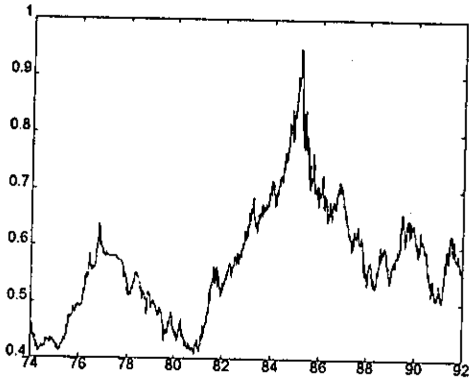

Figure 2.
Daily Spot DM/$ Exchange Rate
1974-1992

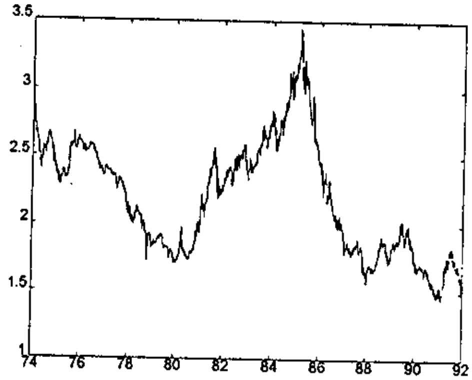

Figure 3.
Daily Spot JY/$ Exchange Rate
1974-1992

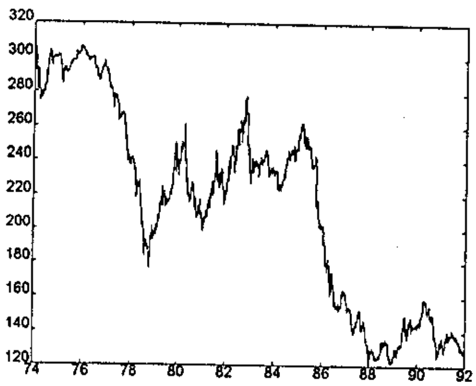

Figure 4.
Daily Spot FR/$ Exchange Rate
1974-1992

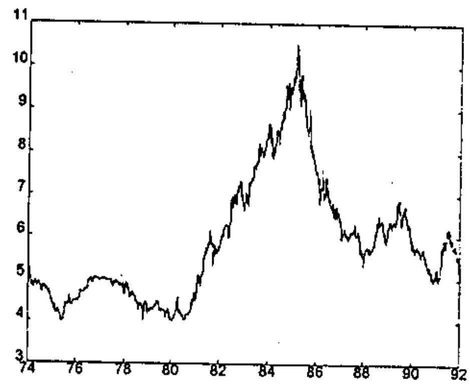

Figure 5.
Daily Spot NG/$ Exchange Rate
1974-1992

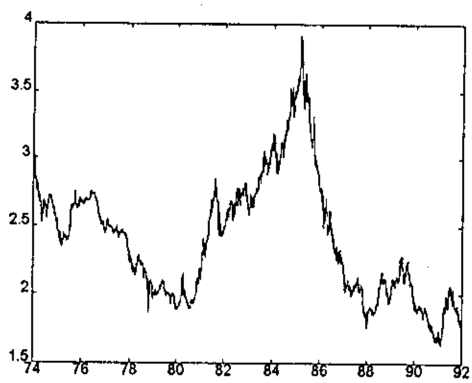

Figure 6.
Daily Spot LI/$ Exchange Rate
1974-1992

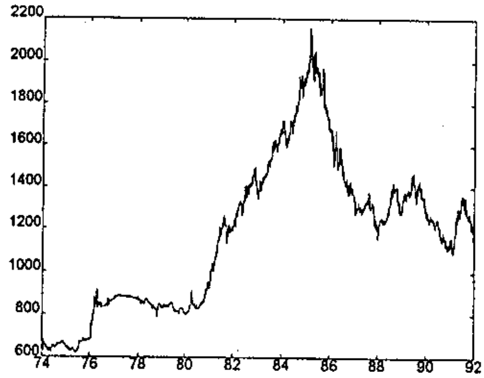

Figure 7.
Daily Spot SF/$ Exchange Rate
1974-1992

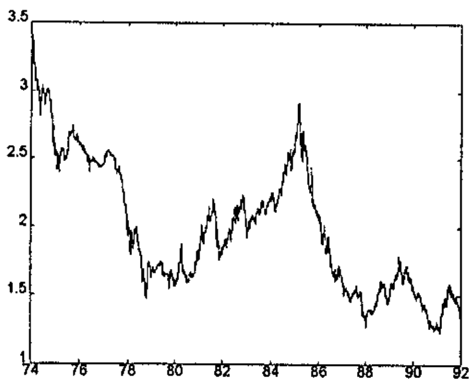

Figure 8.
Daily Spot CD/$ Exchange Rate
1974-1992

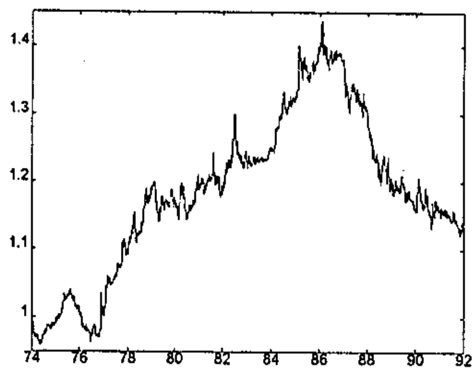

Figure 9. Timeline of Proposed Structural Breakpoints