

COMMON VOLATILITY IN THE FOREIGN EXCHANGE MARKET

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1. Introduction

The adverse effect of currency volatility on international trade has prompted the inception of the European Monetary System (EMS) and other measures of international policy coordination aimed at reducing intracurrency variability. Until "Black Wednesday" in September 1992 the EMS had some success in this objective, but following pressure on the Italian Lira, other ERM currencies (viz. Sterling, the Spanish Peseta, Portuguese Escudos, Danish Kroner, Belgian Franc and the French Franc) have all experienced extremely volatile periods which culminated in the virtual break up of the EMS in August 1993, when all but the German Mark and Dutch Guilder moved to much wider bands.

However speculative investment in over-the-counter derivatives (such as at-the-money straddles) does not help to reduce currency volatility. Regulation of OTC derivatives trading is now a major international concern, and the Basle committee meetings during 1993 have led to a new Capital Adequacy Directive of the European commission, which is now being enforced by national banks. In order to assess the extent of currency risks which are being taken in OTC derivatives trading, it is necessary to understand any common volatility factors in exchange rates. This is the purpose of the present paper.

We ask whether intracurrency variability is dominated by regional factors (including association with the EMS), global factors, or speculative investment. An autoregressive conditionally heteroscedastic (ARCH) framework is employed for this analysis, and over limited periods a number of common conditionally heteroscedastic

factors may exist: some of these could be responses to global factors such as the Gulf war or events in Eastern Europe, others may be region specific such as the turmoil of some ERM currencies around Black Wednesday, but neither global nor regional factors alone can explain sustained common factors with conditional heteroscedasticity.

Following the abolition of UK exchange controls in 1979, London has become the centre of the world's currency trading: in 1992 the Bank of England estimated that \$300 billion passed through London dealing rooms every day - far more than in either Tokyo or New York. The domination of currency movements by speculative investment is therefore best examined on data from the London market: REUTERS FX data from January 1982 to December 1992 has been used.

The plan of the paper is as follows: the next section reviews the common ARCH econometric methodology; section three applies ARCH and common ARCH tests to daily and weekly exchange rates; generalized autoregressive conditional heteroscedastic (GARCH) models of exchange rates are estimated and their conditional variances used to provide some intuition for the results; and section four concludes.

2. Econometric Methodology

Common ARCH factors in exchange rates are tested using the common feature methodology introduced in Engle and Kozicki (1993). This is based on the result that stationary, autoregressive conditionally heteroscedastic time series x_{1t}, \dots, x_{nt} have a common ARCH factor if and only if there exists a 'no-ARCH' portfolio, viz., a linear combination $\sum_{i=1}^n I_i x_{it}$ which displays no conditional heteroscedasticity. This result is simple to illustrate for two time series, which for our purposes will be currency returns x_t and y_t : suppose

$$x_t = w_t + u_{xt} \quad \text{where} \quad w_t | \Omega_t \sim D(0, h_t^2)$$

and

$$y_t = v_t + u_{yt} \quad \text{where} \quad v_t | \Omega_t \sim D(0, k_t^2)$$

where Ω_t denotes information available at time t and u_x and u_y are mutually independent homoscedestic error components. Consider the portfolio $x_t + \mathbf{I}y_t$:

$$V_t(x_t + \mathbf{I}y_t) = h_t^2 + \mathbf{I}^2 k_t^2 + 2\mathbf{I}Cov_t(w_t, v_t) + \text{constant}$$

and so $V_t(x_t + \mathbf{I}y_t)$ is independent of time if and only if

$$w_t = -\mathbf{I}v_t + \text{constant}.$$

For in this case $h_t^2 = \mathbf{I}^2 k_t^2$ and $Cov_t(w_t, v_t) = -\mathbf{I}k_t^2$ (and w and v are perfectly negatively correlated). Thus a 'no-ARCH' portfolio $x_t + \mathbf{I}y_t$ exists if and only if

$$x_t = -\mathbf{I}v_t + u_{xt} \quad \text{and} \quad y_t = v_t + u_{yt}$$

(up to a constant) in which case x_t and y_t have the common ARCH factor v_t . The parameter \mathbf{I} is a scale factor whose sign also determines the relationship between the means: the common ARCH factor has the same sign in the means $\Leftrightarrow \mathbf{I} < 0$. Another interpretation of λ is the relative weight in a risk minimizing portfolio: thus assets x and y should be combined in the proportion $(1, \lambda)$ for effective hedging of volatility. The result generalizes to n (stationary) time series x_{1t}, \dots, x_{nt} : $\sum_{i=1}^n \mathbf{I}_i x_{it}$ is a 'no-ARCH' portfolio if and only if the ARCH factors w_i of each x_i satisfy

$$\sum_{i=1}^n \mathbf{I}_i w_{it} = \text{constant}.$$

The Engle-Kozicki methodology involves testing first for univariate and multivariate ARCH effects in the individual currency return series. These Lagrange multiplier tests, which were first derived in Engle (1982) take the TR^2 (i.e. the product of the sample size with the uncentred R^2) from regressions of squared currency returns on a constant and p lags, for univariate ARCH(p), adding p lags of other squared currency returns for the multivariate MARCH(p) tests. The test statistics are chi-

squared distributed with degrees of freedom equal to the number of lagged squared returns.

The bivariate common feature test is then applied to those series x_t , y_t with significant univariate ARCH effects, by finding the λ which minimizes the TR^2 from ARCH tests on the portfolio $z_t(\lambda) = x_t + \lambda y_t$. These Lagrange multiplier tests employ lagged squares and cross products of x_t and y_t , and if the minimum TR^2 is below the appropriate critical value, the portfolio is subjected to other univariate and multivariate ARCH tests. Then if no further evidence of ARCH is apparent we deduce that a 'no-ARCH' portfolio exists - and therefore that the returns share a common conditionally heteroscedastic component with scale factor λ^1 .

Before applying these tests to currency return data, it is necessary to sound a preliminary note of caution in their interpretation: ARCH tests can yield a low value for series where big events are not repeated, and so some portfolios may pass all 'common volatility' tests even though volatilities are different - provided that large differences are only very temporary. Another point to note when employing ARCH tests on currency returns, where GARCH models can fit better than ARCH models with few lags, is that sufficient lags should be taken in the ARCH tests to capture the GARCH behaviour.

3. Data Analysis

(a) Daily Dollar Returns

Initially the analysis was conducted using daily London closing bid dollar rates on the Australian Dollar (AUD), German Mark (DEM), Spanish Peseta (ESP), British Pound (GBP), Italian Lira (ITL), Japanese Yen (JPY) and Dutch Guilder (NLG), from 2nd January 1982 to 10th December 1992, a total of 2768 observations, and these are

¹ See also Engle and Susmel (1993).

illustrated in figure 1. First differences of the logarithms are taken, as these are both stationary and approximately equal to the daily currency returns².

The results of univariate and bivariate ARCH tests, shown in table 1, reveal several features, some of which will be used in subsequent analysis: firstly, the univariate ARCH(1) effects are very weak in the Australian dollar³ and so including AUD in common ARCH tests will inevitably lead to a value $\hat{\lambda} = 0$ on the other currency return for the minimum TR²; secondly, increasing the lag used in univariate ARCH tests increases the significance of the effect, and this is to be expected given the well-documented GARCH effects in daily currency returns (see Baillie and Bollerslev (1989), Hsieh (1989), Alexander and Riyait (1992) and many others). Table 2 reports maximum likelihood estimates of univariate generalized autoregressive conditionally heteroscedastic (GARCH) models of the form $x_t = c + u_t$. Here u_t is a GARCH(1,1) disturbance of the form

$$u_t \mid \Omega_t \sim N(0, h_t^2)$$

where

$$h_t^2 = \mathbf{a}_0 + \mathbf{a}_1 u_{t-1}^2 + \mathbf{b} h_{t-1}^2 \quad \mathbf{a}_0 > 0, \quad \mathbf{a}_1, \mathbf{b} \geq 0.$$

Figure 2 shows the annualized volatilities of each dollar exchange rate obtained from a GARCH(1,1) model⁴. Notice that all the rates except the Yen are particularly volatile during the spring of 1985, when dollar depreciation began after the long dollar surge. Other events which influence some of the rates are world events such as the collapse of communism in 1987/88, which induced high volatility in the German Mark, Guilder, Sterling and the Yen, and the global stock market crash of October 1987. A

² See, for example, Alexander and Johnson (1992).

³ The Australian dollar was tied to the US dollar during the beginning of the data period, and before it began to float several big changes in the exchange rate were not repeated - hence the low ARCH value.

⁴ Plots are based on weekly data. The conditional variances exhibit the same global and regional features as the corresponding daily series, and these features are now easier to distinguish because the data are less noisy.

common peak in all return volatilities, except the AUD, occurs during the spring of 1992, when the dollar rose on news of economic revival in the US. Regional factors also exist, such as the floating of the Australian dollar in 1985, and the European currencies have been particularly volatile during the last two years of turbulence in the ERM: volatility during 1991 increased as the problems of German unification became apparent, and in 1992 the Maastricht referendums precipitated an ERM crisis in September.

The last and most interesting point to note about table 1 is that the Cable rate is extraordinarily efficient at detecting ARCH effects in each other currency. Reasons for this are not immediately obvious, but one possibility is that speculative dollar investors have static expectations about currency returns. In this case Sterling appreciation could induce a switch of investment from foreign to UK asset markets and consequently a downwards movement in other dollar exchange rates⁵. If this is the case, one could expect to find conditionally heteroscedastic co-movements in currencies which are dominated by movements in dollar funds, and this possibility will be explored by investigating common volatility in both dollar and German Mark (DM) returns.

The explanatory power of Sterling in predicting the volatility of other currencies implies that squared Sterling/dollar returns will be a useful instrument for detecting ARCH in any portfolios which pass the first stage of common feature testing⁶. Notice also the outstanding effect that lagged Lira squared returns has on current Sterling squared returns - a result which is probably dominated by the early and dramatic response of the Lira to pressures in the ERM in September 1992, before Sterling fell through its floor and consequently both currencies left the EMS.

Common ARCH tests on daily data are not reported because they reveal not *one* single 'no-ARCH' portfolio for *any* exchange rate pair! This absence of common features holds even when the data are restricted to the last two years of the sample, by

⁵ Following the results of table 5 we do indeed find that movements in foreign currencies corresponding to a common conditionally heteroscedastic factor with sterling are in the opposite direction: the parameters in the 'no ARCH' portfolios with GBP are all negative but, since the Cable rate is \$/£ whereas all other rates are in dollar terms, the corresponding movements in the currencies are in opposite directions.

⁶ It also implies a market inefficiency which has not, as yet been arbitrated away. However as the trading of currency derivatives advances, so we would expect an anomaly such as this to disappear.

which time Sterling had joined the EMS and so independent currency variability should have been minimized⁷. The obvious conclusion is that daily data contain too much noise for a single common feature to emerge.

(b) Weekly Dollar Returns

The analysis of weekly currency returns, using the Wednesday rates (to avoid any weekend effects) leads to much better results. The univariate and bivariate ARCH tests in table 3 again reveal Sterling return variability to be an important determinant of the variability of returns on other currencies, but the effect is very much weaker than in daily returns, indeed Sterling is no better at detecting ARCH effects in possible 'no ARCH' portfolios than any of the other major currencies (see table 5). So the 'Cable effect' is only detectable in daily rates, and this does not contradict the idea that it is generated by speculative investment.

All currency returns except the Spanish Peseta have univariate ARCH, provided sufficient lags are included to capture GARCH effects (4 lags are illustrated in the table). Its absence of 'ARCH' implies that inclusion of the Peseta in common ARCH(4) tests would be misleading, since it will always yield a minimum TR^2 less than the 5% critical value.

In contrast to daily returns, in the weekly data a surprising number of portfolios passed the first stage of common ARCH(4) testing⁸: 10 out of the 15 possible portfolios yield a minimum TR^2 less than the 5% critical value for some value of the portfolio scale parameter (see table 4). Notice that there is no evidence of common volatility between the Dutch Guilder and the German Mark, even though these currencies were so closely linked (before German unification) as to be cointegrated! During the 1986 Dutch credit control period, however, the Guilder/Mark rate was excessively volatile (see figure 1) and this has obviously precluded the existence of a common ARCH feature over the whole data period. However, there is even no evidence of common ARCH in the Guilder/\$ and Mark/\$ rates over any of the

⁷Results of common ARCH tests for daily returns are available on request from the author.

⁸ That is, finding 1 to minimize the TR^2 from regression of squared portfolio returns on 4 lagged squared returns of each currency and 4 lagged cross products.

consequent sub-periods. How can this fact be reconciled with the similarity between their GARCH(1,1) volatilities in figure 2? A possible explanation is that common volatility is induced by other common factors, such as those determined by a common interest rate policy⁹.

In table 5 we list the 10 candidates for 'no ARCH' portfolios in the first column and the minimum TR² from table 4 in the second column. The third column gives a univariate ARCH test with 4 lags of the squared portfolio returns, and the last five columns are bivariate ARCH(4) tests where each currency return is added to the information set in turn. An asterisk denotes a Lagrange multiplier statistic which exceeds the 5% critical value, and which therefore contradicts the initial evidence in column 2 of a common ARCH factor.

All portfolios which include the Australian dollar fail at least one of the tests, which is not surprising given the behaviour in its conditional variance just before it ceased to be fixed to the dollar (see figure 2). Only the portfolio of Sterling and Yen returns passes all the common feature tests¹⁰, and the results indicate that these exchange rates share a single ARCH factor with scale factor 1.156. That is, conditionally heteroscedastic movements in Yen returns are approximately 15.6% larger than the corresponding movements in Sterling returns and, since the parameter is negative, these movements are in *opposite* directions (see footnote 5).

In the absence of an adequate explanation of why no common ARCH is detected between the Guilder and DM dollar returns, whereas strong evidence of common ARCH is apparent in the rather dissimilar Sterling and Yen, we should, perhaps, call into question the Engle-Kozicki methodology for finding common ARCH factors. Certainly Neil Ericsson's critique following the Engle-Kozicki article should be taken very seriously. In particular it may be that we need to allow for a *dynamic*

⁹Alexander (1994) investigates common ARCH factors in international bond and equity markets. Germany and The Netherlands are the only countries which display any evidence of common ARCH factors in their bond markets.

¹⁰ Even the portfolios which include the Peseta fail MARCH tests of 'no-ARCH' when squared Yen/\$ returns are included in the information set. GARCH(1,1) models are again estimated to aid the intuition of our results, and the estimated conditional variances are given in table 6. These are plotted, after converting into annualized volatilities, in figure 2.

structure in the Engle-Kozicki methodology in order to detect a common ARCH feature between the Deutschmark and the Guilder¹¹. And what, exactly, has been identified by the supposed common ARCH factor in Cable and the Yen/\$ rates? Whatever it is, it can only constitute a small part of the total ARCH volatility, given the difference in their GARCH volatilities shown in figure 2! It is possible that high variability in the Cable and Yen/\$ rates has decreased the power of the Engle-Kozicki tests to such an extent that we do not reject a false null hypothesis (of a common ARCH factor). On the other hand it may be that a single common ARCH factor does exist, but then other *individual* ARCH factors must also exist which dominate the volatility plots in figure 2.

(c) German Mark Returns

The univariate and bivariate ARCH tests of weekly DM returns in table 7 reveal huge conditional heteroscedastic effects in the Dutch Guilder, as expected from the 1986 credit control period. Spain joined the EMS in 1989, but the Italian Lira, which has been a member throughout the data period, has more conditional volatility than the Peseta. The possibility of common ARCH factors in Sterling/DM, Guilder/DM, Lira/DM and Yen/DM returns is explored in table 8, with no positive results.

(d) A behavioural explanation?

A mechanism which could give rise to a common ARCH factor in the Sterling/\$ and Yen/\$ exchange rates is now proposed: First, examination of the signs on the portfolio parameters in table 5 indicates that movements in the mean currency returns corresponding to a common conditionally heteroscedastic factor are always in opposite directions (recall that GBP, being \$/£, should have its sign switched). Secondly, we have found huge explanatory power from Sterling squared returns to those of other currencies - and the Yen is also efficient at picking up ARCH in other European DM rates (see table 7). Finding both of these is consistent with the hypothesis that dollar funds, invested largely in British and Japanese asset markets, are

¹¹ This analysis is left to a subsequent paper (Alexander, 1994).

switched to (and from) other markets in response to static expectations of returns: when Sterling (or Yen) show marked depreciation (resp. appreciation) the expectation is that it should continue, and dollar funds are switched into (resp. out of) other currencies.

There is no evidence that such speculative behaviour is employed by DM denominated funds, since no evidence of common conditional heteroscedasticity has been found in DM rates. Of course, this 'dollar dominated speculative investment' refers only to common conditionally heteroscedastic factors, not to any of the other factors which influence currency returns, and the influence of common ARCH factors in the total volatility of currency returns appears to be quite small¹².

4. Concluding Remarks

Both daily and weekly dollar returns of seven currencies have been investigated for common ARCH factors over a period of eleven years. Daily data were found to be too noisy for any such common factors to be detected, even when the data period is restricted. For the weekly returns, results were rather counter-intuitive: no evidence of common ARCH between the Deutschmark and the Guilder, but evidence of a common ARCH factor between Sterling and the Yen! It is possible that the high variability of both Cable and the Yen/\$ rates has in fact reduced the power of the Engle-Kozicki tests, and a type 2 error has been made. A strong prior that the Deutschmark and Guilder returns DO have a common ARCH factor is explored in a later paper which allows for a dynamic structure in the Engle-Kozicki common feature methodology.

However, if a common ARCH factor does exist between Sterling/\$ and Yen/\$ rates, the data also offer a possible explanation for this, in terms of dollar dominated speculative investment flows. Firstly, volatility both Cable and the Yen/\$ rate is found to be an important determinant of future volatility in other currency returns. Secondly,

¹²Because no common ARCH factors are found in NLG and DEM, which have very similar total ARCH volatilities, whereas evidence of common ARCH is found between the more dissimilar GBP and JPY.

the movements in the mean corresponding to potential common ARCH factors are in opposite directions. Thus investors on the London market, with static expectations of currency returns, might be moving dollars between Sterling (or the Yen) and other currencies in response to expected changes in returns. No evidence of common ARCH factors is found in weekly DM rates, and so it appears that *dollar* dominated speculative investment could form the basis of common conditionally heteroscedastic factors in mean currency returns.

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REFERENCES

Alexander, C.O. (1994) "Common ARCH factors in International Currency, Equity and Bond Markets" *Written for Applied Mathematical Finance*.

Alexander, C.O. and A. Johnson (1992) "Are Foreign Exchange Markets Really Efficient?" *Economics Letters* 40 449-453.

Alexander, C.O. and N. Riyait (1992) "The World According to GARCH" *Risk* 5 No.8 120-125.

Baillie, R.T. and T. Bollerslev (1989) "The Message in Daily Exchange Rates: A Conditional Variance Tale" *Jour. Business and Econ. Stats.* 7 297-305.

Engle, R.F. (1982) "Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of U.K. Inflation" *Econometrica* 50 987-1008.

Engle, R.F. and S. Kozicki (1993) "Testing for Common Features" *Journal of Business Economics and Statistics* 11 (4) pp369-395 (including discussions).

Engle, R.F. and R. Susmel (1993) "Common Volatility in International Equity Markets" *Journal of Business Economics and Statistics* 11

Hsieh, D.A. (1989) "Modelling Heteroscedasticity in Daily Foreign-Exchange Rates" *Jour. Business and Econ. Stats.* 7 307-317.

Taylor, S.J. (1992) "Modelling Stochastic Volatility" *Lancaster University working paper*.