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International comparison of asset market volatility : a further application of the ARCH model

by

R R Dickens

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INTERNATIONAL COMPARISON OF

ASSET MARKET VOLATILITY

A FURTHER APPLICATION

OF THE ARCH MODEL

1. INTRODUCTION

Dickens(1986b)(1) applied Engle's(1982) autoregressive conditional heteroskedastic (ARCH) variance estimator to weekly data to describe volatility in some major UK asset markets since the mid-1960s. The present paper extends the description of asset market volatility to include the US, Germany, Japan, France and Italy. More specifically, ARCH variance series are estimated and presented for both a short-term and a long-term interest rate series for each country, as well as for a broad share price index for all countries except France.

In markets where the price mechanism is the key rationing device there is nothing inherently bad about price movements per se. However, one reason for interest in the variability of asset prices, as with interest in the variance of inflation, is because of the cost imposed on risk averse agents by increased variability. While even risk neutral agents will face higher costs in a more volatile market if the higher volatility reduces their ability to forecast the mean of the process.

The estimated ARCH variance series are first analysed to see whether they are time dependent, and second to see whether there are either significant within-country cross-market or cross-country within-market similarities in their behaviour.

A further question of interest addressed in this paper is the extent to which US developments over the 1979-82 period impinged abroad. The estimated ARCH variance series indicate that there were very marked and similar increases in the volatility of both US short-term and US long-term interest rates over this period. The increased interest rate volatility did not appear to have a significant impact on the level of volatility in the US share market, although there are some definite similarities in the cyclical behaviour of all three US series over this period.

Within the 1979-82 period, significant increases in volatility were experienced at the long end of the term structure in all countries under consideration, although when compared to the US experience the duration of the upturns in volatility in the other countries were transitory. The cross-country similarities in volatility are weaker for short-term interest rates over this period, although the results indicate that the US developments possibly played a part in triggering the short lived but dramatic increases in short-term interest rate volatility which occurred in the triad of Germany, Japan and France. Not surprisingly, given the limited coincidence of the behaviour of the level of volatility in US interest rates on the one hand and US share prices on the other, there are no indications of the US experience having any impact on share market volatility in the other countries.

To the extent that generalisations can be made across countries, only two similarities are discernible in the estimated variance series: (1) most markets under consideration were more volatile

(1) Dickens op. cit. also compared the estimated ARCH variance series with variance estimates from a 'traditional' time series variance estimator -- the moving variance about moving mean (MVAMM) estimator. Dickens(1986a), which is a companion article to Dickens(1986b) and the present paper, compares the ARCH and MVAMM estimators, as well as explaining how the ARCH model has been adopted to the investigation of international asset market volatility.

post-1973-75 than in the late-1960s and early-1970s, although the tendency was more noticeable in the money and bond markets than in the share markets; (2) 'cycles' in volatility ranging from six to eighteen months in duration were experienced during the 1973-75 period for all markets considered. In some markets, and in particular all UK markets, the levels of volatility reached in the peaks of the 1973-75 cycles were the highest levels experienced over the sample period.

The remainder of this paper is ordered as follows: in Section 2 the ARCH model is presented; Section 3 describes the data and identifies and comments on outlying data observations; Section 4 presents the conditional mean models which are used to explain the behaviour of the asset market series; in Section 5 the ARCH test results are presented, as are the adopted ARCH variance equations; potential relationships between the levels and variances of the series are considered briefly in Section 6; Section 7 contains cross-market comparisons of volatility in the asset markets of each country in turn, while both within market cross-country comparisons of asset market volatility and some limited multi-market cross-country results are presented in Section 8; a brief conclusion is contained in Section 9.

2. THE ARCH MODEL

The application of the ARCH model involves firstly fitting an econometric equation to explain the series of interest. This equation is the conditional mean estimator and is represented by (1) below. In (1) y is the variable of interest, x is a row vector of relevant exogenous and lagged endogenous explanatory variables, β is a column vector of the parameters to be estimated, and is a zero mean serially uncorrelated error term whose variance over time is described by the ARCH variance specification (2).

$$(1) \qquad y_t = x_t \beta + \epsilon_t \qquad E(\epsilon_t) \sim N(0, h_t)$$

$$(2) \qquad h_t = \alpha_0 + \alpha_1 \epsilon^2_{t-1} + \alpha_2 \epsilon^2_{t-2} + \ldots + \alpha_p \epsilon^2_{t-p}$$

The ARCH test is applied by estimating the two equations in sequence using OLS. Under the null hypothesis of no ARCH process (i.e. $\alpha = 0$ all i) the R^2 from (2) multiplied by the sample size is asymptotically distributed as chi-squared with p degrees of freedom -- where p is the order of (2). Calculated values in excess of the critical chi-squared value imply rejection of the null hypothesis.

Once the order of the variance equation has been identified, Engle(1980,1982) re-estimates the model jointly using an iterative maximum likelihood estimator. He ensures negative variance estimates are not produced by restricting the coefficients in (2) to be nonnegative. This is achieved by replacing (2) with the two parameter equation (2b), in which a linearly declining lag structure is imposed.

$$(2b) \qquad h_t = \alpha_0 + \alpha_1 \left(\sum_{i=0}^{p-1} (p-i)\epsilon^2_{t-i-1} \right) / \sum_{j=0}^{p-1} (p-j))$$

The estimates of h produced by the resulting variance equation are the one-step-ahead ARCH variance forecasts for each period t. In the present context, this is the series of interest.

In practice, a more flexible lag structure is introduced in the present paper by adopting Professor Engle's suggestion of including linearly declining summation variables of different orders in the same equation. For example, if the ARCH test indicates that the appropriate order of the variance equation is 30, then summation variables of orders 4, 13, and 30 are included. With weekly data these represent lag lengths of one month, one quarter, and approximately one half-year, respectively. When two or more variables with different lag lengths are included, the overall lag structure will still have linear segments, although it is free to take various forms and can even approximate Almon type characteristics. This does, however, reintroduce the possibility of negative coefficients -- more on this later.

The major advance of the ARCH approach over conventional variance estimators is that it measures the dispersion around the conditional mean rather than that about the sample mean. The problem with the latter approach, as pointed out by Engle (1980, p. 3) in relation to the measurement of the variability of inflation, is that *"even when the inflation rate is on a steady climb, which can easily be predicted, the variance will appear to be high. The* (MVAMM-type) *estimates, therefore, attribute some of the changes in observed inflation to unanticipated surprises where they should properly be considered part of the mean or anticipated inflation."* In contrast, the conditional mean of the series is the anticipated level of the series as derived from the "appropriate" econometric equation.

3. THE DATA

3.1. Data Series and Sources

What follows is a brief description of the data series employed in this paper and their sources, a full data appendix is available on request from the author. The data for the US, Germany, Japan, France and Italy were kindly provided by the respective central bank of each country. A short-term and a long-term interest rate series were obtained for each country, while a broad composite share price index was obtained for all countries except France. The descriptions, short titles, and data periods of all series are listed in Table 1.

The aim was to obtain the series most compatible with the UK series employed in Dickens(1986b), which were the three month interbank rate, calculated gross redemption yields on twenty year Gilts, and the Financial Times 500 share price index. The US$/£ spot exchange rate (ER$£) was also investigated, and while it is similarly included here, exchange rate data were not obtained for the other countries. The results for the UK series presented here are very similar to those reported by Dickens op. cit. The main difference is the inclusion of a further seven months-worth of data in the present paper.

The short-term interest rates series for Germany, Japan and France (RSG, RSJ and RSF) all display stickiness which is not consistent with them being freely determined market rates. The extent of the 'administration' of these rates varies both across the series and over time. The extreme case is RSJ, where prior to 1978 the weekly observations frequently remained unchanged for periods of up to nine weeks in duration, while subsequent to 1978 it is not uncommon for them to remain unchanged for periods of three to four weeks.

All of the series obtained are understood to be the most representative series available in the preferred maturities over the full sample period, and therefore there does not seem to be any scope for overcoming the problem of stickiness by collecting alternative series. As seemingly sensible results were produced by the three series they are reported below, however, this tendency must be considered when interpreting the results for these series.

The short title naming convention used to identify the series in the remainder of the paper is quite simple. The first two letters of the short title identify the series (RS = short-term interest rates, RL = long-term interest rates, SP = the natural logarithm of the share price indices), while the third letter in the title identifies the country (B = UK, A = US, G = Germany, J = Japan, F = France, I = Italy). Later in the paper the estimated ARCH variance series are identified by a V before the usual short titles.

3.2. Outlying Observations

Dickens(1986b) identified 'outlying' observations in the increments of the UK asset markets series. The distributions of the differenced series were investigated because of the nonstationarity of the levels of the series. In the cases of the share market indices, a power transformation similar to the natural logarithm was also applied to the series before differencing them. The normalised sample distributions of the differenced series were not only found to be long tailed and more peaked than the N(0,1) distribution (i.e. leptokurtic relative to the normal), they were also found to be significantly skewed.

The implications and potential explanations for the outlying observations are canvassed at some length in Dickens(1986a,1986b). The most favourable explanation for their existence would appear to be that they were generated by a different, or secondary, process from the rest of the sampled data. It was further hypothesised that, "If the secondary process is the result of discrete policy interventions or regime changes, for example, which occur relatively infrequently and, once having occurred, the market does not perceive an increased probability of their occurrence in subsequent periods; then, once the regime change has been observed, the market's variance estimate should not increase from the level suggested by the underlying process determining the series, plus that due to the very small probability of a large discrete policy-induced jump in any one period. This is aside from the possibility of widened forecast confidence intervals because of uncertainty about how any new system will operate. In this instance, the variance estimates excluding the outliers would be closest to the market's estimates. At the other extreme, if the market expected such discrete policy interventions to be clustered, then, once one had been observed, the market would attach a far higher probability than the long run probability of observing another one in the near future. If so, their variance estimates would increase significantly, and this would favour inclusion of the outliers in any variance estimate." (Dickens(1986b, p. 15))

Casual empiricism identified a number of outliers, particularly in the UK short-term interest rate series (RSB), which were associated with policy interventions. While attempts have been made to incorporate discussion of the impact of discrete policy changes on the calculated variance series in the subsequent sections of this paper, it was decided as a general rule not to devote resources to handling the outliers differently from the rest of the data as was suggested could be done in Dickens op. cit. The one exception is RSB where, unless the outliers are specifically modelled, the ARCH specification is rejected. If the two or more process explanation is realistic for all series investigated then, where outliers occur, the variance estimates reported later will, if anything, tend to be an overstatement of the market's perception of volatility.

Outlying observations were observed in all of the international asset market series, and so to assist in the identification of the impact of the outlying observations on the estimated variance series, all observations three or more standard deviations either side of the sample means for each differenced series have been tabulated and dated, and are reported in Tables 2 to 7.

The outlying observations in RSB are modelled here by introducing dummy variables into the ARCH variance equations as discussed by Dickens(1986a, p. 13). The dummy variables are included in such a way as to allow the data to decide what weight the outlying observations are to be given between the two extremes of no weight and full weight.

4. CONDITIONAL MEAN EQUATIONS

In all cases autoregressive models have been used to explain the conditional means of the asset market series. The lack of appropriate data to fit more sophisticated models is the main reason for using simple time series models. However, the empirical finding of approximate martingale behaviour of such asset series is quite common, which suggests that fitting autoregressive models to the series is not necessarily such a bad option. (See Dickens(1986a, p. 7) for a definition of a martingale process.) On the theoretical side, a selective review of the literature that derives the expected time series behaviour of asset market series under the assumption of efficient behaviour of market participants is contained in the appendix to Dickens op. cit.

The orders of the mean equations were decided on after observation of the autocorrelation and partial autocorrelation plots (henceforth correlograms) for both the levels and first differences of all the series -- it was the first differences of the natural logarithms of the share price indices that were investigated. The correlograms were calculated up to order 52 (ie a years-worth of weekly data) for most series, although for RLG and SPG, which were both obtained on the four German bank week dates of each month, there are only 48 annual observations. Unlike Dickens(1986b), where parsimonious conditional mean model were fitted, in this paper all significant orders up to and including the 52nd are included in the estimated mean equations. This was done firstly because it involved less work than weeding out the 'spuriously' significant orders, and secondly, because in a couple of trial cases it was found that if all of the higher ordered significant serial correlation in a series was not explained by the mean equation, then it could produce spuriously significant ARCH test statistics at the same higher orders.

Some diagnostic testing of the fitted models was carried out, which largely consisted of checking the autocorrelation properties of the equations' residuals. The equations finally chosen are reported in Table 8. Constants are included in all equations to ensure that the means of the series of residuals are zero as required for them to be ARCH processes. In most cases the first lag on the differenced series accounted for most of the explanatory power of the equations, although there were noticeable deviations from this norm. The significant lags are listed in column two of Table 8, with the lags that returned negative coefficients underlined. The significant lags are listed in descending order of absolute magnitude of their respective coefficients.

The sums of the coefficients for each equation are quite high in some instances, with the highest being 0.709 for RLI, while the largest single coefficient is 0.534 on the first lag in the equation for RSI. While there are at least four significant lags on the dependent variable in each equation, the overall explanatory power, as measured by the R^2 for each equation, is low in most cases. The highest reported R^2 is 0.319 for RSI, which is by far the largest for the eighteen equations reported in Table 8, and there are only five other equations for which the R^2 exceeds 0.1.

Only the equations for ER$£, SPA, and RLI do not have skewed residuals at the 5 per cent level, while the residuals for all equations are leptokurtic relative to the normal distribution. It was found for the UK data that the 'outliers' responsible for making both the sample distributions of the differenced series, and the sample distributions of the residuals of the mean models skewed, were often associated with discrete policy interventions. While it has not been investigated extensively, it would appear that there is a similar tendency in the data for the other countries.

The last two columns of Table 8 indicate the extent to which the mean equations remove the autocorrelation found in the differenced series. The reported figures represent the calculated values of the usual chi-squared statistic used to measure the extent of autocorrelation in a series over orders 1 to k inclusive, where in this instance k has been set so the test includes one years-worth of weekly data for each series. The first of the two columns reports the calculated chi-squared statistics for the dependent variables, while the second column contains the statistics calculated for the residuals of the mean equations.

Only in the cases of ER$£, SPA, and RSF are the dependent variables free of significant autocorrelation over the calculated orders -- remembering that while the null hypotheses of the tests are that all included lags from 1 to k are not correlated with the current level of the series, this does not necessarily mean that individual lags can not be correlated with their respective current levels. None of the series of residuals from the fitted mean equations rejected the null hypothesis of no significant autocorrelation, which attests to the overall whiteness of the residuals in terms of their serial correlation properties. When fitting the mean equations the individual lags were also checked for correlation, rather than just relying on these summary statistics.

5. ARCH VARIANCE EQUATIONS

5.1. ARCH Test Results

The ARCH test described in Section 2 was applied to the residuals from the conditional mean equations reported in Table 8, and the results for UK, US, Germany, Japan, France, and Italy are reported in Tables 9 to 14, respectively.

The order of the ARCH test refers to the number of sequential lags on the dependent variable included as regressors in the test equation, where the dependent variable in each case is the current periods squared residual from the relevant conditional mean equation. For all series the ARCH test was run for each order up to and including order 52 (48 in the case of RLG and SPG).

The ARCH test results from only a selected number of orders are included in Tables 9 to 14. Only those orders which could potentially be chosen as the appropriate orders of the ARCH processes are included, where that potentiality is based on the dual criteria of including only those orders which: (1) return significant ARCH test results; (2) where the highest ordered lag of the dependent variable in the test equation returns a significant t value.

Dickens(1986a, pp. 7-10) discusses the rational for this selection criteria at some length, for the present purposes it is sufficient to point out that for identifying the order of an ARCH process the ARCH test parallels the investigation of an autocorrelation plot when attempting to determine the order of an autoregressive process. A secondary technique, like the investigation of the partial autocorrelation plot which is used in the identification of autoregressive processes, is therefore required to determine the order of an ARCH process.

The test chosen was the usual F test for the relevance of additional regressors. (See Kmenta(1971, pp. 370-371) for a description of the test.) When this test is applied not only must the highest lag in the test equation be significant in terms of its associated t value, it must also be sufficiently significant that it can effectively carry all lower ordered lags between itself and the previously highest ordered lag which also returned a significant t value. Only when consecutively ordered lags are tested does this test collapse, approximately, to being the same as only taking account of the t values.

Therefore, for each of the series under consideration, three columns of results are reported in Tables 9 to 14. In the first column the orders which pass the joint criteria discussed above are listed. In the second column the ARCH test statistics calculated for the related orders in the first column are listed. Finally, in the third column the calculated F statistics arising from testing orders against lower ordered equations which returned significant F statistics are reported.

In practise the tests were applied by starting with the lowest orders which returned significant ARCH statistics at the 1 per cent level. Subsequently higher orders which satisfied the joint criteria were then tested against this equation until one was found that produced a significant F statistic, in which case it became the new base equation against which subsequent orders were tested. This procedure was continued until the highest orders which return significant F statistics are found, and these were the orders chosen for the ARCH processes associated with the different series. As with the ARCH tests, the F tests were carried out up to order 52 (48 in the cases of RLG and SPG) for each series.

The only exceptions to these rules for selecting the orders of the ARCH processes are ER$£ and RSJ. In the case of RSJ the chosen order -- order 23 -- returned an F statistic of 1.86 when tested against order 3, compared to the 1 per cent critical value is 1.90. Because of the closeness of this result it was decided to accept order 23. In the case of ER$£ none of the calculated F statistics were significant at the 1 per cent level, and so a 5 per cent rule was adopted.

The orders chosen for the eighteen series range from 1 in the case of RSI to 49 in the case of RLA; the majority are in the range 7 to 23 although six returned orders of 3 or less. Only the two US interest rate series returned orders in excess of 23, and in the cases of RLA it was the result of only a couple of strongly significant lags beyond order 19.

As indicated in Section 3.2, none of the orders up to and including the 52nd returned significant ARCH test results for RLB. However, it was found that six 'outlying' observations, all of which were of the same sign in the first differenced series, were responsible for the result. Following Professor Engle's suggestion, as outlined in Dickens(1986a, p. 13), dummy variables were introduced into the test equations to enable the data to reweight these outlying observations. This was considered to be a more rigorous method of handling the outliers than that adopted in Dickens(1986b), where results are reported for variance series both including and excluding the outliers.

One dummy variable was included in the ARCH test equation for each lag on the dependent variable included as an explanatory variable. The dummy series were set to zero where non-outlying observations occurred in the corresponding lagged dependent variable, and the data observation itself when an outlier occurred. Initially no constraints were placed on the values that the estimated coefficients could take, although for the results to be sensible the extreme cases are: (1) if the estimated equation returned zero coefficients on each dummy variable then the outliers would be given full weight in the equation; (2) if the coefficients were of equal magnitude but opposite sign as the coefficients on the corresponding lagged dependent variables, then the outliers would have no affect on the variance estimates produced by the equation.

It was hoped that the estimated coefficients on the outlier dummy variables for RLB would fall within the 'sensible' range. However, while the estimated coefficients on the dummy variables were on average of the opposite sign of those on the corresponding lagged dependent variables, they were also on average of greater absolute magnitude. This suggested that the affect of the outliers should be more than completely removed. In light of this the coefficients on the dummy variables were constrained to be of equal magnitude but opposite value as the coefficients on the corresponding lagged dependent variables (ie the outliers were not allowed to have any affect on the variance estimates). The results reported in Table 9 for RLB are those with the outliers modelled using this method. As the test results indicate, the outliers appear to have masked quite a strong ARCH process.

5.2. Restricted ARCH Variance Equations

As discussed in Section 2, the coefficients returned by the unrestricted ARCH test equations need to satisfy both a nonnegativity and a stationarity constraint for the equations to have sensible specifications. All estimated test equations satisfied the stationarity condition (ie the sums of the coefficients on the lagged dependent variables in the equations did not exceed unity). However, all equations returned some negative coefficients. While always a minority in terms of both number and absolute magnitude, they produced negative variance estimates in some periods for all series. As also discussed in Section 2, Engle's two parameter model, with the addition of more summation variables to reintroduce more flexibility into the lag structure, has been adopted to overcome this problem.

The resulting restricted ARCH variance equations are reported in Tables 15 to 18. The only series which is not treated in the manner described in Section 2 is RSJ. An ARCH order of 23 was chosen for RSJ, and normally this would have meant fitting a restricted variance function with lagged summation variables of orders 4 and 13, as well as 23. However, in the case of RSJ all intermediate summation variables returned coefficients that were so close to zero they were excluded from the equation reported in Table 17.

The results reported in Table 15 for RLB are again those where dummy variables are included which on average fully remove the influence on the variance estimates of the six outlying observations identified in the first difference of that series.

The use of more than one summation variable also reintroduces the possibility of negative coefficients. This potentiality was only realised in the cases of RSA and RLA. In the restricted variance equation for RSA, 2 of the 42 individual coefficients (orders 14 and 15) implied by the coefficients estimated for the summation variables used for this series were negative. Eight of the 49 implied coefficients (orders 13 to 20) were negative in the restricted variance equation for RLA. In all cases the coefficients were very close to zero, and in the case of RSA no negative variance estimates resulted, while only one negative weekly variance estimate was produced for RLA.

As the negative variance estimate produced for RLA was very close to zero, and because in the subsequent sections it is the quarterly averages of the weekly variance estimates that are investigated, this one 'nonsensical' result is overlooked. This decision is not thought to be at all pertinent to the results and conclusions that follow.

There does not appear to be any obvious within-market or within-country similarities in the characteristics of the lag structures. In some cases the structures approximate Koyck type geometrically declining characteristics, while for other series they are closer to Almon type polynomial shapes.

There is some loss of explanatory power because of the restrictions imposed on the coefficients, the extent of which is indicated in Tables 15 to 18 by the difference between the ARCH statistics calculated for the unrestricted and the restricted equations. Only in the cases of ER$£, SPG and RSJ are the ARCH statistics calculated for the restricted equations not significant at the 1 per cent level -- all statistics calculated for the unrestricted equations being significant at the 1 per cent level.

In all three cases only a handful of the lags on the dependent variable were significant in the unrestricted equations, and in none were the first two lags significant, while in the case of RSJ the 12th lag was the lowest significant lag.

Obviously even the more flexible nature of the lag structure imposed on the equations in this paper was not well equipped to replicate the major characteristics of the lag structures of the unrestricted equations for these three series. As much as anything this result is an indication that the significant ARCH statistics reported for the unrestricted equations could be the product of spuriously significant lags on the dependent variable, and that the residuals of the conditional mean equations are not strongly heteroskedastic. Alternatively, if they are, the heteroskedasticity is not of an ARCH nature. The relative smoothness of the variance series estimated for all three series -- see Charts 3, 4 and 7 -- would appear to support the contention that the assumption of homoskedasticity is probably reasonable for the mean model residuals of these series.

6. LEVEL-VARIANCE RELATIONSHIPS

In Dickens(1986b) relationships between the levels and variances of each UK series were investigated using standard deviation mean plots. (See McLeod(1983, pp. 11-18 to 11-24) for a discussion of standard deviation mean plots.) This involved firstly splitting the total sample period into year-long subsamples and calculating the mean and the standard deviation of the series within each subsample, and secondly, for each series plotting the resulting series of annual means and standard deviations against each other. Strong positive correlations were found between the series of calculated means and variances for the UK share price series and the long-term interest rate series, while similar tendencies were not observed in either the short-term interest rate series or the exchange rate series.

A power transformation similar to the natural logarithm was used to remove the proportionality -- the tendency for the mean and variance of a series to be correlated -- from the UK share price index. This is often done to such nominal price indices to remove the exponential trend in the series caused by inflation, and is the reason why the natural logarithm is used for all share price series included in this paper. Then, once the series is differenced, as was required by all series to make them stationary before the conditional mean models were fitted, the resulting series measures the weekly capital gains/losses in holding the composite bundle of shares covered by the index.

Two explanations why the variance of RLB increases with its mean were considered in Dickens(1986b). The first was the likelihood that the behaviour of the nominal interest rate had been largely influenced by the behaviour of inflation over the sample period and, as has been claimed by a number of researchers, the higher level of inflation caused the rate of inflation to be more variable. As pointed out by Engle(1980), this view has been expressed by Milton Friedman among others. The second view, investigated by Engle, Lilien and Robins(1984) in their study of time varying risk premia in the term structure, was that risk adverse lenders required a higher rate of interest to compensate for the higher risk associated with a higher variance of the rate of return.

The obvious method for investigating such a relationship between the level and the variance of a series, would seem to be to include the conditional variance measure in the conditional mean model as was done by Engle et. al., as well as including the conditional mean as an explanatory variable in the conditional variance equation. This could be handled if the iterative maximum likelihood estimation technique suggested by Engle(1982) were used to estimate the ARCH model.

To carry out such an investigation is outside the scope decided for this paper. However, some very preliminary investigation of the relationship between the levels and variances of the series has been undertaken. The level of the interest rate series and of the exchange rate series were added to the respective restricted ARCH variance equations reported in Tables 15 to 18, to see whether the levels of the series provided an explanation of their variances over-and-above that provided by the ARCH specification. The equations including the levels of the series are also reported in Tables 15 to 18.

The levels of the series were significant in ten of the thirteen restricted ARCH variance equations under consideration, with the exceptions being ER$£ ,RSF and RSI. The coefficients estimated for the levels of all series were positive. There was some reduction in the significance of the ARCH summation variables when the levels of the series were included, with the higher ordered equations suffering the most, while the major impact was on the constant terms.

In the restricted equations all estimated constants were positive and all but were significant, while most became negative once the levels of the series were included and none remained significantly positive. Only in the cases of RLG and RSJ were all of the ARCH variables rendered insignificant. In the case of RSJ this is not particularly surprising, as can be seen in Chart 4 the traditional assumption of homoskedasticity is, for the most part, realistic for this series.

The usual F test for the relevance of additional regressor -- as already discussed in Section 5.1 -- was used to test whether the levels of the series added significant explanatory power to the equations. In all cases except ER$£ , RSF and RSI, this was found to be the case. The relevant F statistics are reported in Tables 15 to 18, as are equivalent F statistics testing whether the ARCH specifications of the time varying nature of the variance for each series adds significant explanatory power over-and-above that provided by the equations including only a constant and the level of the respective series. Only in the case of RSJ was the ARCH specifications rejected.

These results for the interest rate series are consistent with both of the explanations for relationships between the levels and the variances of the series given above, and only by also estimating the conditional mean equations including variance series as explanatory variables and using more sophisticated estimation techniques could it be hoped to determine the direction(s) of causality. Alternatively, there may not be any direct causation, rather the positive relationships between the levels and the variances of the interest rate series could be a product of them being jointly caused by other variables.

7. WITHIN COUNTRY CROSS-MARKET COMPARISONS

7.1. Introduction

In this section within country cross-market comparisons of the ARCH variance series are made. Firstly, each country is taken in turn and comparisons made on the basis of the graphical representation of the series presented in Charts 1 to 6, and secondly, comparisons are made on the basis of bilateral correlation analysis. The results of this section, as well as that presented in Section 8, are based on quarterly averages of the weekly ARCH variance series. While such averaging will by its nature obscure some short term behaviour, it is not considered too serious a problem because the interest in this study is in the 'trend' behaviour of the estimated variance series, not in week-to-week developments. Such ex post rationalisation aside, the large number of weekly observations for each series meant that the the presentation of the weekly series, in graphical form at least, was not a feasible proposition.

To make the graphical presentation of the quarterly averaged variance series tractable, the means of all the series have been unitised by dividing the observations of each series by its respective mean. The actual means of the series are presented in Table 19, and are discussed in Section 8.2. The sample periods of the quarterly series are also given in Table 19, and it must be remembered that the different sample periods will have some influence on both the cross-market and the cross-country comparisons of the following sections. Similarly, the nonidentical nature of the series across countries, both in terms of what they measure (eg the cross-country differences in the maturities of the instruments from which the respective short-term and long-term interest rate series are taken, and the composition of the respective share market indices), and in terms of how market determined the series are (as discussed in Section 3.1, some series are clearly not determined from week-to-week by market forces), will have some impact on the results.

7.2. UK ARCH Variance Series

The behaviour of ARCH variance series estimated for RSB, RLB and SPB were discussed at some length in Dickens(1986b). The only major difference between the results reported there and those implied by the restricted ARCH variance equations reported in Table 15, is the inclusion of an extra two quarters worth of weekly data in the latter. The equations reported in this paper are also estimated with more flexible lag structures, although this has not had a major impact on the results when the quarterly averages of the weekly variance series are considered.

The major overall features of variability in the UK series over the sample period starting in the mid-1960s pointed out by Dickens op. cit. were: (1) variability was relatively low, stable, and co-ordinated up until the early 1970s, when the most variable period of the whole sample was experienced; (2) there was a 'cyclical' upturn in variability for all series during the 1973-75 period, with peak levels around four times the average levels experienced prior to 1973; (3) distinct cycles in variability were evident after this period, with trough levels generally around the average levels experienced in the 1967-72 period, and peak levels well in excess of the trough levels, although, except for the exchange rate series, below the peak levels in the 1973-75 period; (4) the variability in the first half of the 1980s appeared to have been quite similar to that experienced in the second half of the 1970s in terms of frequency, duration, and the magnitude of the cycles in the variance series; (5) in all series, except RSB, the variance estimates were at or near the trough levels at the end of the sample period -- March 1985 -- and it turned out that the divergent result for RSB was due to the influence of a single 'outlying' observation; (6) except in the pre-1973 period, the overall impression of similarity in the evolution of variability of the UK series breaks down considerably when the timing of specific cycles are compared.

The major development over the period from March to October 1985 for the series included in Dickens op. cit., was the dramatic increase in the variability of the US$/£ exchange rate. In the June quarter of 1985 (1985.2) VER$£ was well above all previous levels since the floating of sterling in 1972. By historical standards variability was still high in the September quarter, although it had turned down significantly from the June peak. The quarterly average ARCH variance series for RSB, RLB and SPB are plotted in Chart 1, while the exchange rate series is plotted in Charts 7 and 10 along with VRSB and VRSA, and VRLB and VRLA, respectively.

7.3. US ARCH Variance Series

The three US quarterly averaged ARCH variance series are plotted in Chart 2. The most noticeable feature is the behaviour of the two interest rate series over the 1979-82 period. Both increase sharply during late-1979 to remain at levels over the 1979-82 period from five to eight times the levels prior to 1979. In the case of RSA the variance estimates had fallen to pre-1979 levels by mid-1983, and remained at those levels during the remainder of the sample period. VRLA also declined significantly during the second half of 1982, and to a lesser extent during 1983, but it wasn't until the beginning of 1984 that it reached pre-1979 levels, and then only temporarily as it increased during 1984 to around the peak level of the 1972-73 cycle before falling again during the first half of 1985.

The most obvious explanation of the post-1979 experience is the change of Fed operating procedures. Prior to 1979 the Fed funds rate was directly targeted, while during the 1979-82 period the Fed both changed the target to non-borrowed reserves and dramatically tightened monetary policy. The target was switched to borrowed reserves in 1982 and, as a result of the success that had been experienced in reducing inflation, it is generally believed that at the same time the Fed both reduced the tightness of monetary policy and began to again place more emphasis on interest rate developments.

There were also several other important developments over the 1979-82 period which will have contributed to the behaviour of the variability of interest rates. In 1979 there was the second oil price shock. There were two cycles during the period, with cyclical peaks in January 1980 and July 1981, and respective troughs in July 1980 and November 1982. A deterioration in the fiscal position was expected during much of 1981 but which did not occur until 1982, while during the 1980-83 period there was the rapid disinflation.

One possible explanation of the differential behaviour of the two interest rate series post-1982 could be the market's uncertainty about the permanence of the reduction in inflation. If this is the case, then one would expect the variability in the long rate to lessen once confidence in the continuation of low rates of inflation is instilled.

It is interesting that there is no obvious indication that the interest rate developments over the 1979-82 period had any marked impact on the level of share market volatility. However, there does appear to be a general coincidence of the cyclical behaviour of volatility in the three series over the period. For example, all series have peaks in 1980.2 and 1980.4, while peaks for VSPA and VRLA also coincide in 1981.4 and 1982.4. While the similar cyclical behaviour is interesting, little can be said about the direction of any causality which may underlie this behaviour on the basis of the charts.

As with the UK series, all US variance series displayed quite noticeable cyclical upturns over the 1973-75 period. However, unlike the UK series, it was the long-term rate and not the short-term rate which reacted first, while it was the short-term rate and not the long-term rate which displayed the closest cyclical pattern to that of the share price series. Also like the UK series, the variance estimates for two of the US series were at or near the trough levels at the end of the sample period. The exception is VRLA, which was significantly above the pre-1979 trough level, but appeared to be moving down to a more 'normal' level.

7.4. German ARCH Variance Series

The German quarterly averaged ARCH variance series are plotted in Chart 3. As with the UK and US series all three German series show cyclical upturns in the 1973-75 period, following comparatively stable behaviour before this. The cycles in both the long-term and the short-term interest rate series precede the cycle in the share market.

Other than the cycle in 1974, VSPG is almost constant over the whole sample period, suggesting that the traditional constant variance assumption for the mean equation' residuals is probably realistic for this series.

The dramatic increase in VRSG in 1981 coincided with the tightening of monetary policy in February 1981 and the associated introduction of a special Lombard rate at 12 per cent compared to the previous rate of 9 per cent. These policy actions followed concern over pressure on the DM, and related concern about strong monetary growth and the consequential dangers of a pick up in inflation.

The impact of the tighter monetary policy is reflected in large movements in the level of RSG, which were responsible for the magnitude of the increase in VRSG. Reference to Table 4, where all increments of the three German series which are outside the three standard deviation interval about the sample mean are listed, indicates the extent of the reaction in RSG. It increased from 10.50 to 12.88 per cent between the third and fourth bank week days in February, and to 14.83 per cent by the first week in March. There is also some indication of 'overshooting' in the rate, with a reduction to 13.25 per cent in the following week, about which level the rate was centred around with only relatively minor variation over the subsequent quarter.

VRLG also increased through 1981, although the large increments in RLG were not of such spectacular magnitude as those in RSG. However, unlike VRSG, VRLG did not return completely to the pre-February 1981 levels for more than a brief period until late-1983. One assumes that the explanation for this is similar to the reason why VRLA remained above VRSA over the 1983 to mid-1985 period. If there were fluctuating fears about whether inflation had not been defeated permanently, then the risk premia associated with holding long-term bonds would be expected to be higher than usual.

The fact that the slope of the yield curve -- based on these two rates -- was significantly negative during 1981, but had turned to being positive in late-1982 and remained significantly positive through 1983 and most of 1984, indicates that there were concerns about the permanence of the reduction in inflation. The higher variance in the long rate over this period itself suggests that these expectations were not stable.

7.5. Japanese ARCH Variance Series

The three Japanese quarterly averaged ARCH variance series are plotted in Chart 4. The most noticeable feature of this chart is the behaviour of the interest rate series in the 1973-74 and 1980 periods. The dramatic increases in VRLJ, and to a lesser extent in VRSJ, were the product of factors both specific to Japan and of international origin.

In both periods Japan experienced inflationary peaks following the respective oil price hikes. From an annual rate of inflation in the CPI of 4.5 per cent in 1972, the rate jumped to 11.7 in 1973 and again to 24.5 in 1974. Similarly, the rate of inflation peaked at 8 per cent in 1980 after 3.6 per cent in 1979. The sharp adjustment paths adopted by the authorities in both instances saw tight monetary policies in place over the respective periods of 1973.1 to 1975.3, and 1979.1 to 1980.4.

These two factors undoubtedly played major roles in determining the behaviour of interest rates during both 1973-74 and 1980, although, at least in the latter period, other major factors also contributed. Factors of particular relevance include the liberalisation of short-term money markets in the late-1970s, and particularly in 1980; and the liberalisation of international capital flows also in the late-1970s, combined both with the developments in international interest rates from late-1979 -- particularly US rates -- and with the Japanese authorities' desire to stabilise the exchange rate via the manipulation of interest rates.

Like most other series, RSJ and RLJ were generally less volatile prior to the 1973-74 upturn than afterwards, with the exception being RSJ over the period from mid-1981 to the end of the sample period in March 1985. Over this later period VRSJ was at least as low and as stable as in the pre-1973 period. In contrast VSPJ was on average higher and far less stable prior to 1974 than subsequently. The last major increase in VSPJ occurred in late-1974, and one assumes it corresponds with the usual pattern of behaviour over the 1973-75 period. The lack of response in VSPJ to the increased interest rate volatility during 1980 is noticeable, and possibly reflects expectations that the increased interest rate volatility -- largely a reflection of two 'discontinuous' jumps a piece in the levels of RSJ and RLJ in February-March 1980 -- would be transitory in nature.

At the end of the sample period in the March 1985 quarter, VRSJ and VSPJ were both very near their trough levels, while VRLJ had experienced a moderate upward trend over the last two quarters, although its level remained low when compared to the peak levels in the 1974 and 1980 cycles.

7.6. French ARCH Variance Series

The quarterly averaged ARCH variance series for the French interest rate series RSF and RLF are plotted in Chart 5. VRLF and VRSF both experienced the usual cyclical upturns in the 1973-75 period, although the peaks are not as high as for most countries, and they are not the major features of Chart 5. The most prominent features are the dramatic, but short lived, increases in VRSF in 1968.3 and 1981.2, and the increases in VRLF in 1980.1 and 1981.2.

Domestic developments related to these periods include: (1) in 1968 there was political unrest and industrial stoppages which led to a lack of confidence in the franc, and the Banque de France was forced to raise their intervention rate on several occasions to protect the currency, the industrial stoppages and related loss of production resulted in revenue shortfalls and a higher than expected fiscal deficit; (2) in 1979 the inflationary effects of the second oil shock played a part in the authorities decision to implement a restrictive short-term interest rate policy to combat inflation; (3) the Socialist Government came to power in 1981 and introduced an expansionary policy. Short-term interest rate increased sharply from 12.25 per cent in April to 20 per cent by the end of May, while long-term rates increased by around 3 percentage points over the same period -- one must remember that the rate used for RSF is an overnight rate and therefore is more volatile than the respective short rates used for the other countries. The increases in the rates were not enough to halt the large capital flows leaving France over this period, and as a result the franc was devalued in October 1981 and again in June 1982, and on both occasions some pressure was taken off interest rates and they eased back a percentage point or so.

At the end of the sample period short rate volatility appears on its way down after a moderately unstable period through late-1983 and 1984 associated with movement of the rates around a reasonable constant level. The sharp increase in VRLF at the end of 1984 is associated with similar week-to-week saw-tooth type behaviour of RLF, again with no obvious 'trend' in the series.

7.7. Italian ARCH Variance Series

The three Italian quarterly averaged ARCH variance series are plotted in Chart 6. After low and stable behaviour prior to 1973, both VRSI and VSPI show the usual cyclical pattern through the 1973-75 period, ending in 1976 for VRSI. The next major, although short lived, shocks in these two series occur in 1979. The increase in VSPI in 1979.2 reflected a sharp upturn in the share price index during April, which was largely reversed during May. The factors understood to be behind the buoyancy in the share market prior to May were the export lead upturn in economic activity which began in late-1978 and, reinforced by rapid growth in private consumption and non-residential construction, continued through 1979. However, two of the major 1979 oil price increases occurred in May, and the implications of these are thought to be behind the downturn in the share market in that month.

In the case of RSI, the movement in the variance estimates in late-1979 reflect step-wise upward movements in the level of the series associated with a 1.5 percentage point increase in the discount rate early in October and a further 3 percentage point increase in the rate in early December. The pressures built up as a result of the second oil price shock are thought to be one of the major factors contributing to these discrete policy lead movements in rates.

The variance estimates for RLI do not start until 1977, and are quite stable until 1981. While in a very muted way, they do mirror the behaviour in RSI in late-1979. At the end of 1979 the slope of the yield curve, based on these two rates, turns from being positive to negative because long rates do not move up so dramatically as short rates. It is this limited movement in RLI which explains the small increase in the variance of RLI compared to RSI, and indicates, one assumes, that the market expected the increase in short rates to be short lived.

The sharp increases in the variance estimates for both RSI and RLI in the March 1981 quarter reflect several developments. These include the 6 per cent devaluation of the lira against its central EMS rate on March 22, and the related 2.5 percentage point increase in the discount rate and the raising of compulsory bank reserves from 15.75 to 20 per cent of new deposits. These developments are indicative of both the relatively high rate of inflation in Italy compared to other EMS countries, and the tightening of monetary policy in an attempt to reduce inflation.

Most of the adjustment in RSI occurred within a month of these developments, while RLI continued to adjust upwards over the following five months and the yield curve had again turn positive by May, indicating a change in market sentiments about the expected duration of high short-term rates. The ongoing adjustment in the level of RLI is largely responsible for the variance of this series remaining high throughout most of 1981. However, both rates declined from mid-1982 to the end of their respective sample periods in 1984. The decline in RSI was both less and steadier than that in RLI, resulting both in the yield curve again becoming negatively sloped and in VRLI being far more volatile over this period.

As with RLI, the first half of the 1980s was the most volatile subperiod for SPI. Over this period the index both increased strongly at times (during 1981, late-February to March 1979, and from August to the end of October 1983) and fell markedly on several occasions (the first several weeks of 1982, a steady decline from mid-1982 to February 1983 and in the last two months of 1983). This whole period was generally a turbulent one for the Italian economy. As well as ongoing realignments of the lira against the central EMS rate during the 1980s, it was a period which saw numerous policy adjustments and regime changes aimed at attempting to both stabilise the currency and to constrain money and credit growth.

All three Italian variance series end the sample period at around their trough levels. While there is some variation in the periods in which the samples of all countries' variance series end, with the range being from the 1984 June quarter to the 1985 September quarter, it is generally the case that the end-period variance estimates are closer to the levels prevailing in the troughs than the peaks of the variance cycles (ie the mid-1980s was sizing up to being a relatively tranquil period in the asset markets under study).

7.8. Comparisons Based On Correlation Analysis

The two most noticeable features of these within country relationships are the high correlation between the major movements of volatility experienced in the US money and bond markets, and the duration of the upturn in the variance of these series which last from late-1979 to early-1983. More generally, cross-market comparisons of these within country relationships are made with reference to Table 20, where correlation coefficients are reported between the respective simultaneous movements of the quarterly averaged variance series within each country.

The highest correlations are, indeed, between the volatility of short and long rates in the US, Japan and France. This correlation is much lower in Italy, Germany and the UK, and indeed insignificant, at the 5 per cent level, in the latter two. The correlation between short-term interest rates and share prices is insignificant in all countries examined. There is a significant relationship between the volatility of long-term rates and share prices in the UK, which is not repeated in other countries. Possibly this is a reflection of the relatively larger portion of high-grade marketable long-term bonds in UK asset portfolios than is found abroad.

Marginally positive correlations were indicated between the exchange rate variance series and both of VRSA and VRLA. Reference to Charts 7 and 10, where VER$£ is plotted with VRSA and VRSB, and VRLA and VRLB, respectively, suggests that the positive relationships are largely a product of the behaviour of the respective series over a subset of the 1979-82 period.

From late-1980 VER$£ experienced its strongest cyclical upturn which continued through 1981, and only turned down in the 1982 March quarter. The behaviour of VER$£ over this period was largely a product of the high level of US interest rates -- and the associated US capital inflow -- and the consequent depreciation of sterling against the dollar, and probably to a lesser extent the high variability in US rates.

The marginally significant negative correlation between VER$£ and VRLB is quite possibly the product of coincidence, or causal behaviour that does not involve a direct link between these two variables or, at least, not a uni-directional link. In general terms it would not seem that a positive relationship between interest rate and exchange rate volatility was the only possibility, even if there is a direct causal link from one to the other.

Consider the example where interest rates increased and became more variable in country A (eg because of the adoption of a tight quantity based monetary policy), while at the same time country B targeted interest rates -- both their level and variance. Then, assuming that the bilateral exchange rate responded to the divergent behaviour in the levels of the two countries' interest rates, if not also the divergence in their volatility, there would most likely be a positive relationship between the variance of interest rates in country A and the exchange rate, and a negative relationship between the variance of interest rates in country B and the exchange rate. Although, to the extent that the authorities can influence short rates more than long rates, one would expect any such relationships to be between short rates and the exchange rate.

As a general point it should be noted that the significance tests reported in Table 20 (and those subsequently reported in Table 21) assume a normal distribution. As is common with variance series, the sample distributions of the estimated ARCH variance series are significantly positively skewed. Consequently the tests of the significance of the calculated correlation coefficients are of questionable reliability, and may be biased by spurious relationships among a few outliers.

8. WITHIN MARKET CROSS-COUNTRY COMPARISONS

8.1. Introduction

In Section 7 a description was given of the recent history of volatility in three main asset markets (money market, bond market, share market), in the six developed industrial countries under consideration. It was shown there that volatility in these markets has not generally remained constant over time, but neither has it exhibited a secular increase. The tendency for contemporaries to believe that current volatility is increasing in asset markets is usually myopic. The exception to this is the marked increase in volatility in the US money and bond markets in the 1979-82 period, which subsequently fell away again to normal levels in the money market, although some residual higher (than pre-1979) volatility still remained in the US bond market at the end of the sample period.

At the time of this increased volatility in US money and bond markets, observers believed that they could see some tendency for US volatility, largely attributed to the changed monetary control techniques by the Fed in October 1979 and subsequently abandoned in the course of 1982, to be transmitted into increased volatility in both exchange rates and asset markets elsewhere. This perception was usually casual empiricism, and the attempt in this section is to offer some preliminary quantification to the study of the inter-relationships between the time paths of volatility among similar markets in different countries.

At this stage the exercise primarily remains one of providing descriptive statistics. Although there is some tendency to regard events in US markets as weakly exogenous with respect to events in other countries' markets, we did not have the time to test for that. For the rest, the channels of causation are presumably multi-directional and largely simultaneous. We have not, therefore, in general sought to 'explain' the pattern of inter-relationships that is identified and discussed below.

8.2. Comparison of Mean Levels of Variability

Under consideration in this section are the comparative means of the quarterly averaged ARCH variance series reported in Table 19. The results for France, showing a particularly high money market volatility, are not properly comparable with the others, because the French series is for overnight rates, while the other money market series are for 2 or 3 month funds. The description of the basic data series in Section 3.1 indicates that the series are not otherwise identical as between countries, but the differences are not so great in other cases.

Three factors, although in part overlapping, considered to be fundamental determinants of the volatility rankings of different countries are: (1) the underlying stability of the economy, with its diverse influences; (2) the impact of external shocks; (3) the nature of the economic policies adopted by the authorities in each country, in terms of both the policies adopted and the firmness of the application of policy.

Based on the first 'fundamental', one might reasonably posit a ranking with Germany and Japan being the most stable, followed closely by the US, while Italy would be the least stable, and the UK and France would both slot in somewhere between these two extremes.

Many indicators could be used to determine a volatility ranking more precisely. One such indicator is the level of consumer price inflation, where the assumption is that countries with higher rates of inflation can generally be considered to be less stable, although this is also of course an indicator of the policy stance of the authorities. Over the 1970-84 period this indicator supports the subjective ranking in all cases except the relative ranking of Japan and the US, although the exclusion of 1974 from both countries' inflation data sets reverses the ranking.

Looking at the share market rankings, aside from there not being a series for France, the subjective ranking holds exactly. This would seem to indicate that the impact on the respective share markets of both external shocks and internal policy-induced shocks were not too different as between the countries as to upset the underlying relative volatility rankings. The six countries are comparatively homogeneous, and so there should not have been many major differences in the impact on them of the external shocks experienced over the period. There are of course some moderate differences, but certainly nothing when compared to the differential impact of the sample period shocks on major oil exporting vis-a-vis oil importing countries, or as between developing and industrial countries. One qualification to this, however, is the emergence of the UK as a 'petro-currency nation' between the first and second oil price shocks.

As regards the impact of domestic policy, while there have clearly been major differences in terms of the policy regimes adopted by the countries, both in the speed of adjustments adopted to shocks and in the firmness of policy where similar regimes have been followed, of the three markets considered the share market would appear to have been the least affected by such policy interventions.

A further factor potentially relevant to share market volatility is the breadth of the market, where this clearly differs across the countries. However, given the magnitudes of the other influences experienced over the sample period, it seems unlikely that anything can be gleaned from the results of Table 19 about the influence of this factor.

Apart from the French figure, which is not comparable, volatility was highest in the US money market, very largely influenced by the 1979-82 episode, followed by the UK, Italy, Germany and Japan in that order. Our impression, from examination of the data, is that the volatility of money market rates has been more influenced by the policy stance of the authorities of the respective countries (eg a version of monetary base control, or firm control over short-term interest rates, or some combination between the two) than was the case with the share markets, although the US and probably Italy aside, the rankings are not inconsistent with the broader economic context within each country.

Turning to the bond market, the subjective ranking is broadly supported by the four major countries (US, UK, Germany and Japan), while the comparative volatility of France and Italy are lower than would have been expected. One assumes that the nonconformity of France and Italy to our expectations is a product of the differential operation of policy. In particular, both differences in the policy tools and targets adopted, and differences in any impediments to interest rates fully reflecting market conditions such as exchange controls and direct interest rate controls.

8.3. Comparisons Based On Correlation Analysis

Again, the simple contemporaneous correlation coefficients calculated for each pair of countries within each market were investigated, and are presented in Table 21 with those of apparent significance being starred. The previous caveat that the basic series are not normal and the significance tests therefore of questionable reliability needs to be remembered.

Perhaps the most interesting feature is a negative result, that there has been generally very little correlation between the volatility in short-term market rates during the data period in these countries. There is, perhaps, some slight relationships between the volatility in US money market rates and in money market rates in Japan, Germany and France, and between France and Italy, but that is all.

There appear to be much stronger relationships between the volatilities in bond markets in different countries. The exception is the UK, whose bond market volatility appears serenely unaffected by fluctuations in the volatility of similar markets abroad. Apart from the UK, fluctuations in volatility in one country's bond market appear to find reflection in other countries also, with the exception that there are no links between volatility in bond markets in France and Italy on the one hand and Japan on the other.

If we can reasonably assume that events in US asset markets are weakly exogenous to events in other countries, then the resultant chain of causation would appear to be: (1) changes in policy regimes have affected US money market volatility; (2) changes in US short rate volatility has affected volatility in the US bond market; (3) shifts in US bond market volatility have affected the volatility of bond markets in other countries, other than the UK.

The behaviour of UK asset markets in this respect was not in all cases unresponsive to events abroad. There did appear to be a positive relationship between the volatility of share prices in the UK on the one hand and in Wall St and Germany on the other. Once again, however, as with long-term interest rates, the closest relationship among the share price volatilities is between Germany and the US. The strength of the US/German nexus is noticeable and considerably closer than any other set of cross-country bilateral relationships.

The other interesting finding is the negative result of no relationship between volatility in UK fixed interest markets and in similar markets abroad. It is not easy to provide even an ex post rationalisation for this latter, somewhat surprising, negative finding, but it indicates that the British, at least, cannot necessarily blame periods of greater fluctuation in domestic fixed interest rates on the Fed, or other foreign scapegoats. On the other hand, again assuming weak US exogeneity, periods of greater disturbance in Wall St do appear to be mirrored in Throgmorton St, and even more strongly in Frankfurt.

8.4. Comparisons Based On Graphical Analysis

The short-term interest rate variance series which showed signs of significant contemporaneous correlation are graphed together in Charts 8 and 9. Minor outliers aside, the general behaviour of the series are more similar than the correlation coefficients suggest. All the series exhibit relatively smooth behaviour prior to 1973, followed by turbulence in the 1973-76 period which was in turn followed by relatively stable conditions during the second half of the 1970s. Major upturns in volatility of short duration -- except in the case of RSA -- were experienced in the early 1980s which were, this time except for RSI, followed by relatively stable conditions through to the end of the respective sample periods.

The long-term interest rate variance series which showed significant correlations are grouped together in Charts 11 and 12. Again, minor outliers aside, the general behaviour of these series are quite similar over the sample period, and also very similar to that of the short-term rates. However, particularly for the short rates, but also for the long rates, the specific timing of the variance cycles across the countries differs at least as often as it coincides, indicating the importance of domestic developments in determining the timing of the volatility, if not the general volatility experience.

Turning to the share markets, setting aside Italy for the moment, there is again a general cross-country similarity in the behaviour of the variance series throughout the sample period. while there are two main differences between the general behaviour of the share markets and that of both the bond and money markets. The correlated share market variance series being plotted in Charts 13 and 14.

The most variable period in the share markets is 1974-75. This is the first difference with the other two markets where the highest variance levels, except those for the UK, are recorded in the early 1980s. However, the US is the only country for which the durations of the periods of high interest rate variability are longer in the early 1980s than in the 1974-75 period.

The second general feature of the share markets -- which is also the second difference between them and the money and bond markets -- is that the pre-1974 period is generally no less variable than the post-1975 period. Finally, compared to the post-1975 period, not only is the general experience of volatility in the share markets across the different countries quite similar prior to 1974, so also is the timing of the cyclical movements in the variance series, particularly in the 1969, 1970 and 1974 volatility cycles.

As for the divergence of the experience of the Italian share market from those of the other countries, the major general difference is the behaviour of the Italian series for most of the post-1978 period. This difference would seem to be attributable to the relative turbulence of the Italian economy over this period, as already discussed in Section 7.7, and in particular to the relative slowness of the Italian authorities to gain control of monetary conditions and therefore inflation.

8.5. Some Multilateral Regression Results

In some part the relationship between volatility in fixed interest markets in different countries is likely to be transmitted via the exchange rate. Thus volatility in the initiating country, say the US, will affect the exchange rate between it and the recipient country. In this respect it is a pity that we did not simultaneously collect weekly data of bilateral spot exchange rates, eg the US$/DM rate. That is left for other research workers.

The only exchange rate series that we had collected on a comparable basis was the US$/£ exchange rate. However, this did enable us to run a number of regressions relating asset market volatilities between the US and the UK. A problem in this case is that there is no good reason to posit a recursive causal structure, except in so far as US events may be weakly exogenous to events in the UK.

An alternative route might have been to estimate a full variance-covariance matrix type system of equations, instead of the individual ARCH variance equations where only lags on the dependent variable were included as explanatory variables. This possibility was suggested by Engle, Lilien and Robins(1984, p. 19). There are various other exercises which might in principle be attempted. In the event time prevented further experimentations. Instead, we ran multiple regressions using the quarterly averaged ARCH variance series to examine the relationship between UK asset market volatility, US$/£ exchange rate volatility, and US asset market volatility, taking either the respective UK series or the exchange rate series as the dependent variable and regressing each on the other and on the respective US asset market volatility series.

The results, which are available on request, only show strong relationships between the respective share market variance series. Volatility in US fixed interest markets appear to have had more effect on volatility in the exchange rate than have UK fixed interest markets, while volatility in the US bond market appears to have been more influential in this respect than volatility in the US money market. As noted earlier in the bilateral comparisons, there appear to be no significant relationships between volatility in US fixed interest markets and in their UK counterparts, while the effect of the exchange rate volatility on UK fixed interest markets is also weak.

As in the case of the bilateral relationships, the strongest relationships are between the volatility of share prices in London and Wall St. The series of exchange rate volatility, current and lagged, adds nothing to the relationship. It is, however, interesting that the strongest relationship appears to be between volatility in London and that in Wall St lagged one, or two quarters -- see equations 3 and 4 below, where t values are in parenthesis.

$$(3) \quad VSPB_t = \underset{(0.2)}{-0.082} + \underset{(2.3)}{0.532}\,VSPA_t + \underset{(0.0)}{0.095}\,VER\$\pounds_t + \underset{(4.7)}{0.555}\,VSPB_{t-1}$$

$$R^2 = 0.437; \quad \text{Durbin } h = -0.297; \quad 1974.1\text{-}1985.3 \ (n = 47).$$

$$(4) \quad VSPB_t = \underset{(0.7)}{-0.317} + \underset{(0.5)}{0.115}\,VSPA_t + \underset{(3.0)}{0.808}\,VSPA_{t-1} + \underset{(0.3)}{0.082}\,VER\$\pounds_t \underset{(0.4)}{-0.139}\,VER\$\pounds_{t-1} + \underset{(3.8)}{0.442}\,VSPB_{t-1}$$

$$R^2 = 0.545; \quad \text{Durbin } h = -0.775; \quad 1974.2\text{-}1985.3 \ (n = 46).$$

All told, these preliminary regression exercises added little, but did provide consistent results to the earlier bilateral comparisons of the inter-relationships between volatilities in US and UK asset markets, viz a significant relationship in this respect between share markets but little relationship discernible between fixed interest markets.

9. CONCLUSION

This study of the inter-relationships between asset price volatility in different countries has just involved some preliminary, and mainly descriptive, statistical exercises. In particular we were not successful in extending the study beyond simple bilateral into multilateral relationships.

Nevertheless we believe that we have unearthed some interesting facts, notably that the cross-country relationship between money market volatilities is much less close in most cases (an exception being the UK with no significant cross-country relationship in either case) than between bond market volatilities. There is also quite a close relationship between volatilities in equity markets among US, UK and Germany, but less with other countries. The relationship between volatilities in money and bond markets in individual countries varies, with some countries showing strong correlation (US, Japan, France), but others weak relationships (Italy, Germany, UK).

Overall, assuming that asset market events in the US exhibit weak exogeneity relative to asset markets elsewhere -- though this hypothesis was not tested -- the main chain of causation appears to have run as follows: (1) US policy regime changes; (2) changing US short rate volatility; (3) changing US long rate volatility; (4) changing long rate (and exchange rate?) volatility in other countries. The UK, however, appeared least affected, and Germany the most affected by this.

The empirical results do, however, suggest that this line of causality is considerably weaker than might have been expected, particularly over the 1979-82 period which saw very strong cyclical increases in the volatility of both US money and bond market interest rates.

A competing scenario which gains moderate support from the results, is that similarity in volatility across countries has been more a product of the coincidence of similar economic 'mentalities' and policy regimes than any uni-directional causality. This scenario is consistent with the evidence found that only major international developments such as the 1973/74 oil price shock and related world recession have produced similar contemporaneous volatility responses across all markets and all countries.

TABLE 1 INTERNATIONAL ASSET MARKET DATA SERIES[1]

Country	Short Term Interest Rate		Long Term Interest Rate		Share Price Index	
	Series (Short Title)	Sample Period	Series (Short Title)	Sample Period	Series (Short Title)	Sample Period
UK[2]	3 Month[3] Interbank (RSB)	5/10/66 to 16/10/85	20 year Gilts (RLB)	5/10/66 to 16/10/85	Financial Times 500 (SPB)	5/10/66 to 16/10/85
Germany	3 Month Money Market (RSG)	6/1/65 to 24/4/85	Federal Bonds (RLG)	5/1/68 to 28/12/84	Federal Statistics Office All Sector Index (SPG)	7/1/65 to 28/12/84
Japan	2 Month[3] Discount Bills (RSJ)	5/1/66 to 27/3/85	Government[3] Bonds (RLJ)	23/2/66 27/3/85	Tokyo Stock Exchange Composite Index (SPJ)	5/1/66 to 27/2/85
France	Over Night Money Market (RSF)	6/1/67 to 28/12/84	Public and Semi-Public Sector Bonds (RLF)	3/1/69 to 28/12/84	-	-
Italy	3 Month Interbank (RSI)	4/12/70 to 29/6/84	Special Credit Institution Bonds (RLI)	2/1/76 to 28/12/84	Composite Index (SPI)	6/1/67 to 28/12/84
US	3 Month[4] Commercial Deposits (RSA)	22/12/69 to 31/7/85	20 Year Treasury Bonds (RLA)	29/12/69 to 31/7/85	New York Stock Exchange (SPA)	5/1/66 to 24/10/85

1 All series have weekly frequency. More series than not have Wednesday observations, the exceptions are all French and Italian series which have Friday observations, the US short term interest rate series which has Monday observations, while the share price index and long term interest rate series for Germany were obtained on the four German "bank week return dates" of each month.

2 The US$/£ spot exchange rate has also been collected. It was obtained on a Wednesday observation basis for the period 28 July 1972 to 16 October 1985.

3 These are composite series. See the separate data appendix available from the author of request.

4 Wednesday observation weekly data were obtained back to 18 July 1973.

TABLE 2 EXTREME VALUES OF DIFFERENCED UK ASSET MARKET SERIES[1]

RSB		RLB		SPB		ER$£	
Date	Observation	Date	Observation	Date	Observation	Date	Observation
1972.25	6.05	1974.25	3.19	1973.49	-3.40	1973.7	3.66
		44	3.09				
1973.30	4.42	46	3.66	1974.25	-3.39	1976.10	-4.15
31	3.43			31	-3.19		
32	3.43	1975.2	-4.02	33	-3.45	1978.1	3.11
34	3.58	4	-3.78	39	-3.65		
46	6.47	7	-3.87			1979.38	-3.06
				1975.4	3.93		
1974.10	3.27	1976.41	3.52	5	8.13	1981.26	-3.30
15	-4.13			7	5.91		
		1977.39	-4.35	10	3.02	1985.14	5.25
1976.17	4.00			17	4.19	28	3.04
21	3.43	1979.9	-5.62			39	3.57
37	3.11	27	-3.55	1976.43	-3.15		
41	4.16	45	3.28				
1977.4	-4.08	1980.3	-4.06				
48	5.87						
		1982.33	-5.29				
1979.24	5.32	41	-4.25				
1981.39	4.08	1983.2	4.08				
1983.2	3.11	1984.32	-3.59				
1984.28	6.05						
1985.3	5.37						
Sample Period	1966.41 - 1985.42		1966.41 - 1985.42		1966.41 - 1985.42		1972.27 - 1985.42
Mean	0.0041		0.0030		0.0020		-0.0016
Standard Deviation	0.3811		0.2124		0.0263		0.0242

1 The extreme values are observations 3 or more sample standard deviations either side of the sample mean. The normalised observations are given in the table (ie the actual observation minus the sample mean and divided by the sample standard deviation). The interest rate and exchange rate series are first differenced, while it is the first difference of the natural logarithm of the share price series which are used.

TABLE 3 EXTREME VALUES IN DIFFERENCED US ASSET MARKET SERIES[1]

RSA		RLA		SPA	
Date	Observation	Date	Observation	Date	Observation
1980.11	4.26	1973.2	4.14	1970.22	3.94
17	-4.02				
18	-5.08	1980.6	3.58	1974.31	-3.41
19	-7.00	8	4.19	33	-3.52
22	-4.88	13	3.63	40	-3.11
40	4.26	15	-3.11	41	3.14
48	3.17	16	-4.65	47	-3.68
50	3.64	19	-3.93		
52	-4.90	43	3.32	1975.5	3.49
		52	-4.09		
1981.3	3.32			1980.50	-3.26
8	-4.66	1981.12	3.22		
11	-3.28	34	3.73	1982.34	3.78
18	5.27	39	4.35	41	3.93
22	-3.16	40	-3.88		
45	-3.92	44	-5.58		
50	3.99	45	-3.78		
		51	3.11		
1982.8	-4.44				
28	-3.85	1982.8	-3.57		
30	-3.53	33	-5.48		
33	-3.85	41	-5.28		
41	-4.04				
Sample Period	1969.52 - 1985.31		1970.1 - 1985.31		1966.2 - 1985.43
Mean	0.0012		0.0049		0.00075
Standard Deviation	0.4060		0.1944		0.02047

1 See footnote 1, Table 2.

TABLE 4 EXTREME VALUES IN DIFFERENCED GERMAN ASSET MARKET SERIES[1]

RSG		RLG		SPG	
Date	Observation	Date	Observation	Date	Observation
1965.40	3.80	1973.21	3.62	1966.19	-3.91
		23	-3.17		
1966.1	-5.26			1967.29	4.89
40	4.30	1974.7	3.72		
		45	-3.26	1970.18	-3.30
1967.1	-5.95				
		1977.1	-3.07	1974.25	-8.40
1968.1	-3.36			37	6.13
40	5.21	1980.11	3.90		
		14	-3.35		
1971.45	-3.09	15	-3.91		
		18	-3.73		
1972.1	-3.59				
40	3.31	1981.7	3.25		
		10	-3.35		
1973.16	3.80	17	3.53		
23	5.21	22	-4.56		
31	3.80	35	-3.17		
		37	-4.66		
1974.3	-5.26	42	-3.45		
15	-4.54				
		1982.31	-3.63		
1975.6	-3.63				
1981.8	9.06				
9	7.42				
10	-6.02				
1982.49	-3.05				
Sample[2] Period	1965.2 - 1985.17		1968.2 - 1984.48		1965.2 - 1984.48
Mean	0.0021		0.00043		0.00057
Standard Deviation	0.2626		0.10749		0.01771

1 See footnote 1, Table 2

2 For RLG and SPG the weekly dates refer to the German banking week dates of which there are four per month and so only 48 per year.

TABLE 5 EXTREME VALUES IN DIFFERENCED JAPANESE ASSET MARKET SERIES[1]

RSJ		RLJ		SPJ	
Date	Observation	Date	Observation	Date	Observation
1973.35	5.38	1973.48	3.96	1969.25	-3.54
52	8.07				
		1974.52	5.38	1970.18	-4.70
1975.16	-5.39			23	3.62
36	-5.39	1975.1	3.06		
44	-5.39	3	5.16	1971.34	-7.17
		5	-3.97	35	-3.35
1976.1	-4.04	6	-5.67		
		7	-3.59	1972.52	3.40
1977.16	-5.39	10	-3.40		
36	-5.39	11	3.36	1973.6	-4.99
		14	5.96	17	-3.32
1978.12	-4.04	50	-3.72	50	-4.57
1979.30	4.03	1979.14	3.06	1974.41	-5.40
45	3.02			42	3.51
		1980.11	7.12		
1980.8	6.89	12	-3.04	1981.36	-3.65
10	3.03	15	8.57		
11	12.44	17	-5.14	1982.42	3.09
12	3.36	20	-4.45		
34	-6.90			1984.21	-3.17
		1981.36	3.54		
1981.12	-3.37				
		1982.49	-3.73		
		1985.7	3.05		
Sample Period	1966.2 - 1985.13		1966.9 - 1985.13		1966.2 - 1985.6
Mean	0.0005		-0.0009		0.0022
Standard Deviation	0.1858		0.1466		0.0178

1 See footnote 1, Table 2

TABLE 6 EXTREME VALUES IN DIFFERENCED FRENCH ASSET MARKET SERIES[1]

RSF		RLF	
Date	Observation	Date	Observation
1968.41	-3.16	1969.2	3.60
46	6.00		
47	-4.31	1974.24	4.21
1973.38	4.00	1979.22	3.70
		28	4.01
1974.5	-3.46		
		1980.8	9.81
1975.39	-3.04	9	4.72
		16	-3.93
1976.42	5.29	39	4.31
		41	3.09
1978.6	3.13		
12	-3.16	1981.19	4.41
		20	13.06
1981.20	8.60	21	7.98
21	9.17		
		1984.41	-3.11
1982.12	6.30	43	-4.03
		45	4.11
1984.19	-3.18		
34	-3.32		
Sample Period	1967.2 - 1984.52		1969.2 - 1984.52
Mean	0.0058		0.0061
Standard Deviation	0.4356		0.0983

1 See footnote 1, Table 2

TABLE 7 EXTREME VALUES IN DIFFERENCED ITALIAN ASSET MARKET SERIES[1]

RSI		RLI		SPI	
Date	Observation	Date	Observation	Date	Observation
1974.26	4.49	1976.41	3.12	1973.49	-4.07
27	3.19	42	3.12		
				1975.10	-3.03
1975.4	-3.67	1981.13	6.47		
11	-6.84	22	3.52	1979.15	3.64
		23	3.25		
1976.12	9.60	24	4.06	1981.24	-4.43
13	8.57	26	-4.33		
14	4.00	42	-3.12	1982.3	-3.35
25	3.26			5	-3.87
29	-6.03	1982.36	-3.39	9	4.83
30	-4.77				
		1983.9	-3.99	1983.44	-4.23
1979.42	3.13				
51	7.05	1984.7	-3.45		
1981.14	6.98				
Sample Period	1970.50 - 1984.26		1976.2 - 1984.52		1967.2 - 1984.52
Mean	0.0136		0.0049		0.00024
Standard Deviation	0.3089		0.1491		0.02974

1 See footnote 1, Table 2

TABLE 8: AUTOREGRESSIVE CONDITIONAL MEAN MODELS FITTED TO WEEKLY INTERNATIONAL ASSET MARKET SERIES[1]

Series	Constant	Orders of[2] Lags on Dependent Variable	Sum of Lagged Coefficients	Max/Min[3] Coefficients	R^2	Skewness[4]	Kurtosis[4]	Sample Period	Autocorrelation Test[5] Dependent Variance	Mean Model Resdiuals
UK										
RSB	0.0061	1,35,17,2, 30,41,5,27	-0.003	0.130/0.046	0.051	1.39*	10.96*	1967.30-1985.42	97.7**	36.6
RLB	0.0035	1,13,2,40, 35,31,29,50, 28,48	0.054	0.117/0.059	0.060	-0.38*	6.39*	1967.39-1985.42	93.0**	30.4
SPB	0.0012	2,37,40,1	0.383	0.157/0.064	0.043	0.56*	7.42*	1967.29-1985.42	98.9**	45.6
ER$£	-0.0013	16,37,4,19,48	0.259	0.092/0.086	0.037	0.13	5.35*	1973.23-1985.42	51.4	25.7
US										
RSA	0.0011	2,1,26,10,45, 43,39,11,6,7, 8,28,3,39,40	0.080	0.157/0.043	0.165	-0.44*	11.12*	1970.45-1985.31	252.3**	44.6
RLA	-0.0051	1,2,26,18,28, 45,42,39,14, 21,36,50,33	0.172	0.172/0.046	0.073	-0.43*	8.03*	1971.1-1985.31	94.4**	36.5
SPA	0.0007	30,46,35,1,7, 16,23,49,36	0.282	0.069/0.049	0.034	0.04	3.88*	1966.51-1985.43	63.4	30.7
Germany										
RSG	0.0007	52,1,9,4,39, 21,12,51,32,41	0.456	0.151/0.044	0.088	0.40*	16.57*	1966.2-1985.17	120.4**	35.3
RLG	0.0005	1,7,2,5,4, 25,20,8,36,48	0.477	0.340/0.060	0.184	-0.50*	6.07*	1968.50-1984.52	217.3**	17.1
SPG	0.0007	1,33,12,2, 40,17	0.013	0.095/0.066	0.044	-0.38*	9.23*	1965.42-1985.52	76.9*	34.8

Table 8 continued

Japan										
RSJ	0.0002	3,1,20,30, 23,17,31,8,2	0.563	0.148/0.051	0.105	1.32*	29.17*	1966.33-1985.13	214.4**	25.3
RLJ	-0.0005	1,6,3,40,5,28 31,2,4,20,24	0.435	0.192/0.061	0.099	0.97*	16.79*	1966.49-1985.13	172.3**	35.1
SPJ	0.0013	3,1,45,50, 51,15,4	0.398	0.118/0.044	0.051	-0.72*	8.69*	1967.1-1985.6	87.1**	39.2
France										
RSF	0.0066	43,44,21,15,1	0.113	0.099/0.064	0.030	2.20*	21.81*	1967.46-1984.52	60.3	34.2
RLF	0.0020	1,31,35,8,26 3,18	0.603	0.434/0.044	0.229	3.60*	46.15*	1969.37-1984.52	305.5**	33.5
Italy										
RSI	0.0077	1,16,25,26, 14,43,9,12, 51,47	0.556	0.534/0.041	0.319	1.90*	32.69*	1971.49-1984.26	366.7**	29.6
RLI	-0.0027	1,26,4,9,52, 11,19,23,8,15	0.709	0.189/0.072	0.157	0.11	9.05*	1977.2-1984.52	195.7**	28.4
SPI	0.0002	48,52,14,7,2, 3,6,18,38,16, 46,23,10	0.211	0.129/0.053	0.093	0.16*	4.86*	1968.2-1984.52	132.8**	28.8

TABLE 8 FOOTNOTES

1 The mean models are fitted to the differenced series for all interest rate series and the US$/ exchange rate, and to the first difference of the natural logarithm of the share price indices.

2 The lags on the dependent variables are listed from left to right in order of highest to lowest absolute value of their coefficients, with a dash under a lag indicating a negative coefficient.

3 The maximum and minimum coefficients are based on the absolute values of the coefficients, and correspond with the first and last lags listed in column 3 of this table.

4 An asterisk (*) indicates rejection of normality at the 5 per cent level. The tests were only carried out at the 5 per cent level, although in many cases the null would also be rejected if a 1 per cent level of significance test were used. Positive skewness indicates a longer right hand (positive) than left hand (negative) tail on the sample distribution, and vice-versa for negative skewness. A kurtosis statistic in excess of the critical range, which is the case for all series examined, means the sample distribution is leptokurtic relative to the normal (ie it has both fatter tails, and is more peaked than the normal distribution). The widest 5 per cent level acceptance regions for skewness and kurtosis were (-0.24;0.24) and (2.52;3.48), respectively, for RLI where the sample size (n) was 417;; the narrowest regions were (-0.15;0.15) and (2.69;3.31), respectively, for RSG (n = 1,007).

5 The reported statistics are distributed as chi-squared with p degrees of freedom under the null hypothesis of no autocorrelation in the series over orders 1 to p inclusive. All tests are carried out so that p incorporates a year of weekly data (p = 52 in most cases, but p = 48 for RLG and SPG which are recorded on "bank week returns dates" of which there are only four per month and 48 per year). The null is rejected at the 1 per cent (5 per cent) level if the calculated statistic exceeds 77.7 (69.6) and is indicated by **(*) in the table.

TABLE 9 ARCH TEST RESULTS FOR UK ASSET MARKET SERIES AND THE US$/£ EXCHANGE RATE[1]

RSB			RLB			SPB			ER$/£		
Order of ARCH Test	ARCH Statistic (T = 900)	F Test Statistic	Order of ARCH Test	ARCH** Statistic (T = 891)	F Test Statistic	Order of ARCH Test	ARCH** Statistic (T = 901)	F Test Statistic	Order of ARCH Test	ARCH** Statistic (T = 594)	F Test Statistic
4	10.71*	-	2	18.05	-	1	48.83	-	2	13.38	-
12	25.37*	-	3	28.05	10.28(2)**	2	114.67	75.20(1)**	3	18.05	4.78(2)*
16	38.58**	-	5	38.36	5.35(3)**	5	122.12	2.85(2)*	11	26.41	1.42(2)
25	48.41**	1.12(16)	8	54.58	5.70(5)**	6	144.30	8.75(2)**	14	33.16	1.70(2)
44	72.10**	1.24(16)	10	60.90	3.35(8)*	10	153.03	2.59(6)*	18	39.13	1.67(2)*
51	79.38**	1.20(16)	13	66.81	2.60(8)*	11	157.88	3.25(6)**	33	56.64	1.45(2)
			18	75.51	2.24(8)*	12	194.04	8.72(11)			
			19	80.23	2.51(8)**	15	198.03	1.37(12)			
			46	100.91	0.82(19)	16	201.84	2.01(12)			
						26	212.08	1.33(12)			
						27	218.02	1.66(12)			

* Significant at 5 per cent.

** Significant at 1 per cent level. All reported ARCH statistics for RLB, SPA and ER$ are significant at the 1 per cent level.

1 The ARCH tests are applied to the squared residuals from the conditional mean models reported in Table 8 for the respective series. The order of the ARCH test refers to the number of sequential lags on the dependent variable included as regressors in the test equation. The orders included here are those for which the coefficients on the highest ordered lags of the lagged squared residuals in the ARCH test equations returned significant t values. T is the sample size over which the ARCH tests were run for each series. The F test is employed to determine the highest relevant order of the ARCH test. The reported F statistic tests the significance of the explanatory power of the additional lags on the squared residuals in the given order equation over and above those of the lower order equation noted in parenthesis. See Kmenta [1971, pp 370-371)] for a description of the test.

TABLE 10 ARCH TEST RESULTS FOR US ASSET MARKET SERIES[1]

RSA			RLA			SPA		
Order of ARCH Test	ARCH** Statistic (T = 717)	F Test Statistic	Order of ARCH Test	ARCH** Statistic (T = 709)	F Test Statistic	Order of ARCH Test	ARCH** Statistic (T = 932)	F Test Statistic
1	25.95	-	1	13.57	-	1	22.42	-
2	41.16	16.07(1)**	2	32.10	19.33(1)**	2	41.50	19.90(1)**
3	52.13	11.76(2)**	3	47.13	16.01(2)**	4	49.38	4.14(2)*
4	72.41	22.41(3)**	4	65.14	19.68(3)**	6	68.26	5.73(2)**
5	88.84	18.59(4)**	5	80.63	17.34(4)**	7	73.74	5.90(6)*
10	110.90	5.14(5)**	7	87.89	4.09(5)*	8	77.77	5.14(6)**
11	115.85	5.80(10)*	8	102.95	8.59(5)**	10	84.72	3.78(8)*
14	121.33	3.07(10)*	11	107.80	1.87(8)	16	93.11	2.09(8)*
19	141.66	4.14(10)**	33	129.24	1.22(8)	24	103.08	1.73(8)*
21	148.88	4.42(19)*	41	139.06	1.28(8)			
27	161.01	3.00(19)**	45	150.17	1.51(8)*			
30	167.61	2.75(27)*	49	195.26	1.71(8)**			
33	173.38	2.59(27)*						
36	182.73	3.07(27)**						
40	192.64	3.19(36)*						
42	206.46	5.22(26)**						
47	212.78	1.68(42)						

* Significant at 5 per cent level.

** Significant at 1 per cent level. All reported ARCH statistics are significant at the 1 per cent level.

1 See footnote 1, Table 9

TABLE 11 ARCH TEST RESULTS FOR GERMAN ASSET MARKET SERIES[1]

RSG			RLG			SPG		
Order of ARCH Test	ARCH** Statistic (T = 955)	F Test Statistic	Order of ARCH Test	ARCH** Statistic (T = 719)	F Test Statistic	Order of ARCH Test	ARCH** Statistic (T = 867)	F Test Statistic
1	150.74	-	1	14.36	-	12	86.73	-
2	176.56	31.58(1)**	2	29.25	15.45(1)**	31	100.63	0.80(12)
3	195.31	23.48(2)**	3	47.06	18.95(2)**	32	104.44	0.97(12)
7	202.45	2.25(3)	4	50.96	4.17(3)*			
			5	60.11	7.06(3)**			
			7	64.05	2.14(5)			
			12	87.55	4.38(5)**			
			20	98.25	1.50(12)			
			42	118.73	1.17(12)			

TABLE 12 ARCH TEST RESULTS FOR JAPANESE ASSET MARKET SERIES[1]

RSJ			RLJ			SPJ		
Order of ARCH Test	ARCH** Statistic (T = 920)	F Test Statistic	Order of ARCH Test	ARCH** Statistic (T = 904)	F Test Statistic	Order of ARCH Test	ARCH Statistic (T = 893)	F Test Statistic
3	46.04	-	1	55.03	-	1	26.96**	-
17	57.98	0.89(3)	2	75.58	22.36(1)**	2	36.74**	10.17(1)**
23[2]	80.95	1.86(3)*	3	129.12	62.18(2)**	44	59.83	0.56(2)
30	88.40	1.68(3)*	4	175.77	57.60(3)**			
			7	187.83	5.03(4)**			

* Significant at 5 per cent level.

** Significant at 1 per cent level. All reported ARCH statistics are significant at the 1 per cent level, except order 44 for SPJ which returned are ARCH statistic of 59.83 compared to the 5 per cent critical value of 60.20.

1 See footnote 1, Table 9.

2 The F statistic for comparing order 23 of RSJ with order 3 was 1.86 compared to a 1 per cent critical value of 1.90.

TABLE 13 ARCH TEST RESULTS FOR FRENCH ASSET MARKET SERIES[1]

RSF			RLF		
Order of ARCH Test	ARCH** Statistic (T = 842)	F Test Statistic	Order of ARCH Test	ARCH** Statistic (T = 747)	F Test Statistic
1	15.14	-	1	145.10	-
2	41.21	27.49(1)**	2	175.12	37.76(1)**
			3	180.80	7.20(2)**
			43	200.00	0.60(3)

TABLE 14 ARCH TEST RESULTS FOR ITALIAN ASSET MARKET SERIES[1]

RSI			RLI			SPI		
Order of ARCH Test	ARCH** Statistic (T = 598)	F Test Statistic	Order of ARCH Test	ARCH** Statistic (T = 365)	F Test Statistic	Order of ARCH Test	ARCH** Statistic (T = 834)	F Test Statistic
1	20.70	-	1	17.42	-	1	43.08	-
17	34.98	0.92(1)	11	30.89	1.42(1)	3	56.18	6.99(1)**
			13	52.49	3.28(1)**	4	61.27	5.46(3)*
			30	68.59	1.07(13)	11	78.65	3.06(3)**
						37	103.39	1.04(11)

* Significant at 5 per cent level.
** Significant at 1 per cent level. All reported ARCH statistics are significant at the 1 per cent level.
1 See footnote 1, Table 9.

TABLE 15 RESTRICTED ARCH VARIANCE EQUATIONS FOR UK ASSET MARKET SERIES[1]

Series	Constant	Orders of Summation Variables (t values in parenthesis)[2]					Level	Sample	ARCH Statistic[3]	
		Four	Twelve	Sixteen	Eighteen	Nineteen	Variable	Period	Restricted	Unrestricted
RSB[4]	0.0678 (5.33)	0.2593 (3.40)	-	0.1705 (1.45)	-	-	-	1967.46-1985.42	45.23** (936)	38.58** (900)
RSB-Level	-0.0350 (1.18)	0.2678 (3.53)	-	0.0090 (0.07)	-	-	0.0112 (3.72)	"	13.85**	12.94**
RLB	0.0174 (3.53)	-0.0612 (0.76)	-	-	-	0.6779 (5.59)	-	1968.6-1985.42	55.76** (924)	80.23** (891)
RLB-Level	-0.0575 (3.32)	-0.0464 (0.58)	-	-	-	0.4329 (3.29)	0.0073 (4.51)	"	20.35**	8.38**
SPB	0.00028 (4.14)	0.2672 (3.19)	0.3215 (2.18)	-	-	-	-	1967.51-1985.42	105.34** (931)	165.11** (901)
ER$	0.00033 (4.14)	0.1162 (1.22)	-	-	0.3302 (2.08)	-	-	1973.41-1985.42	19.94 (628)	39.13** (594)
ER$ -Level	0.00050 (1.88)	0.1146 (1.20)	-	-	0.3289 (2.07)	-	-0.000089 (0.67)	"	0.45	10.06**

* Significant at 5 per cent level
** Significant at 1 per cent level

TABLE 15 FOOTNOTES

1 Where the series title for an equation includes the word "level" it identifies the re-estimated restricted equations including the level of the asset market series as an explanatory variable.

2 A pth order summation variable takes the form

$$\sum_{i=o}^{p-1} (p-i)e^2_{t-i-1} \quad \sum_{j=o}^{p-1} (p-j)$$, where e^2_{t-i} is the ith lag on the dependent

variable. The dependent variable being the series of squared residuals from the relevant conditional mean equations.

3 The restricted ARCH statistics apply to the equations reported in this table, while the unrestricted statistics are from the unrestricted ARCH test equations of the same order. The sample sizes - in parenthesis - differ between the two because the unrestricted equations were estimated over the data period which allowed a year's worth of lags on the squared mean equation residuals to be included in the ARCH tests for each series, while the restricted equations are estimated over the maximum data period available.

The statistic reported in the "restricted" column for the "level" equations is the F statistic measuring whether the inclusion of the level of the series in the restricted ARCH variance equation significantly increases the explanatory power of the equation. The statistic reported in the "unrestricted" column for the equations is the F statistic testing whether the ARCH summation variables add significant explanatory power to the equation including only the constant and the level of the series.

4 The "outlier" dummies are included in the summation variables for RSB so their coefficients are restricted to being of equal size but opposite sign of the coefficients on the summation variables (i.e. the effects of the "outliers" on the variance estimates are completely removed on average).

TABLE 16 RESTRICTED ARCH VARIANCE EQUATIONS FOR US ASSET MARKET SERIES[1]

Series	Constant	Orders of Summation Variables (t values in parenthesis)[2]						Level Variable	Sample Period	ARCH Statistic[3]	
		Four	Eight	Thirteen	Twenty-six	Forty-two	Forty-nine			Restricted	Unrestricted
RSA	0.0225 (1.12)	-0.0917 (0.79)	-	0.8397 (2.42)	-1.3805 (2.16)	1.4867 (3.24)	-	-	1971.35- 1985.31	107.01** (727)	206.46** (717)
RSA-Level	-0.1860 (3.65)	-0.1254 (1.10)	-	0.7675 (2.24)	-0.9394 (1.47)	0.8088 (1.69)	-	0.0285 (4.44)	"	19.72**	7.45**
RLA	0.0072 (1.54)	-0.3269 (2.56)	-	1.3804 (3.78)	-1.1306 (2.17)	-	0.8985 (2.69)	-	1971.50- 1985.31	98.88** (712)	161.13** (709)
RLA-Level	-0.0691 (3.77)	-0.3321 (2.63)	-	1.1558 (3.17)	-0.5591 (1.05)	-	0.0925 (0.24)	0.0097 (4.31)	"	18.55**	6.95**
SPA	0.0002 (5.98)	-0.1369 (1.09)	0.6553 (4.29)	-	-	-	-	-	1967.7- 1985.43	68.87** (976)	77.77** (932)

* Significant at 5 per cent level.
** Significant at 1 per cent level.
1 See footnote 1, Table 15.
2 See footnote 2, Table 15.
3 See footnote 3, Table 15.

TABLE 17 RESTRICTED ARCH VARIANCE EQUATIONS FOR GERMAN AND JAPANESE ASSET MARKET SERIES[1]

Series	Constant	Orders of Summation Variables (t values in parenthesis)[2]						Level Variable	Sample Period	ARCH Statistic[3]	
		Two	Three	Four	Seven	Twelve	Twenty-Three			Restricted	Unrestricted
RSG	0.3240 (4.24)	-	0.4862 (12.97)	-	-	-	-	-	1966.5 - 1985.17	144.36** (1,004)	195.31** (955)
RSG-Level	-0.0231 (1.20)	-	0.4551 (11.79)	-	-	-	-	0.0083 (3.14)	"	9.86**	138.90**
RLG[4]	0.0046 (4.22)	-	-	0.1005 (0.97)	-	0.4484 (3.30)	-	-	1969.14 - 1984.48	56.81** (755)	87.55** (719)
RLG-Level[4]	-0.0185 (3.53)	-	-	0.1215 (1.19)	-	0.2479 (1.75)	-	0.0031 (4.51)	"	20.32**	11.93**
SPG[4]	0.00027 (6.29)	-	-	-0.0282 (0.29)	-	0.1530 (0.96)	-	-	1966.4 - 1984.48	1.54 (907)	86.73** (867)
RSJ	0.0239 (3.57)	-	-	-	-	-	0.2688 (2.34)	-	1967.4 - 1985.13	5.46 (949)	80.95** (920)
RSJ-Level	-0.0269 (1.31)	-	-	-	-	-	0.0769 (0.56)	0.0074 (2.61)	"	6.80**	0.32
RLJ	0.0068 (2.66)	-	-	-0.2825 (1.67)	0.9466 (5.09)	-	-	-	1967.4 - 1985.13	157.70** (949)	187.83** (904)
RLJ-Level	-0.0436 (2.44)	-	-	-0.2686 (1.59)	0.8743 (4.68)	-	-	0.0061 (2.85)	"	8.14**	66.84**
SPJ	0.00023 (7.68)	0.2531 (6.30)	-	-	-	-	-	-	1967.3 - 1985.6	38.20** (943)	36.74** (893)

** Significant at 1 per cent level.
1 See footnote 1, Table 15.
2 See footnote 2, Table 15.
3 See footnote 3, Table 15.
4 There are only 48 observations per year for both RLG and SPG.

TABLE 18 RESTRICTED ARCH VARIANCE EQUATIONS FOR FRENCH AND ITALIAN ASSET MARKET SERIES[1]

Series	Constant	Orders of Summation Variables (t values in parenthesis)[2] One	Two	Three	Four	Eleven	Thirteen	Level Variable	Sample Period	ARCH Statistic[3] Restricted	Unrestricted
RSF	0.1213 (4.18)	-	-	0.3586 (8.41)	-	-	-	-	1967.49 - 1984.52	65.68** (891)	180.80** (842)
RSF-Level	0.0338 (0.38)	-	-	0.3489 (8.00)	-	-	-	0.0092 (1.05)	"	1.11	63.94**
RLF	0.0056 (3.10)	-	0.2649 (6.10)	-	-	-	-	-	1969.39 - 1984.52	34.63** (797)	41.21** (747)
RLF-Level	-0.0101 (1.28)	-	0.2495 (5.59)	-	-	-	-	0.0014 (2.05)	"	4.21*	31.27**
RSI	0.0565 (3.68)	0.1880 (4.87)	-	-	-	-	-	-	1971.50 - 1984.20	22.94** (649)	20.70** (598)
RSI-Level	0.0407 (0.90)	0.1873 (4.84)	-	-	-	-	-	0.0011 (0.37)	"	0.13	23.45**
RLI	0.0091 (2.95)	-	-	-	0.2452 (1.99)	-	0.2456 (1.37)	-	1977.14 - 1984.52	27.08* (404)	52.49** (365)
RLI-Level	-0.0566 (3.21)	-	-	-	0.3270 (2.65)	-	-0.1781 (0.85)	0.0044 (3.78)	"	14.31**	5.13**
SPI	0.00040 (5.17)	-	-	-	0.1786 (1.86)	0.3444 (2.71)	-	-	1968.13 - 1984.52	67.44** (875)	78.65** (834)

* Significant at 5 per cent level. The restricted ARCH statistic of 27.08 for RSI compares with a 1 per cent critical values of 27.86.

** Significant at 1 per cent level.

1 See footnote 1, Table 15.

2 See footnote 2, Table 15.

3 See footnote 3, Table 15.

TABLE 19 MEANS OF QUARTERLY AVERAGED ARCH VARIANCE SERIES

Series	Mean of Quarterly Averaged Series (x 1000)	Sample Period
UK		
VRSB	145.89	1968.1-1985.3
VRLB	45.62	1968.2-1985.3
VSPB	0.6938	1968.1-1985.3
VER$£	0.5815	1974.1-1985.3
US		
VRSA	153.0	1971.4-1985.2
VRLA	37.62	1972.1-1985.2
VSPA	0.4110	1967.2-1985.3
Germany		
VRSG	63.53	1966.2-1985.1
VRLG	10.45	1970.4-1984.4
VSPG	0.3038	1966.2-1984.4
Japan		
VRSJ	32.70	1967.2-1985.1
VRLJ	20.44	1967.2-1985.1
VSPJ	0.3036	1967.2-1984.4
France		
VRSF	189.6	1968.1-1984.4
VRLF	7.625	1969.4-1984.4
Italy		
VRSI	69.54	1972.1-1984.1
VRLI	18.00	1977.3-1984.4
VSPI	0.8359	1968.2-1984.4

TABLE 20 WITHIN COUNTRY CROSS-MARKET CORRELATION COEFFICIENTS FOR QUARTERLY AVERAGED ARCH VARIABLE SERIES[1]

	Short Rate	Long Rate	Share Prices
UK			
Long Rate	0.1948	-	-
Share Prices	0.1714	0.6375**	-
Exchange Rate	0.1967	-0.2974*	-0.1642
US			
Long Rate	0.8630**	-	-
Share Prices	0.1866	0.1349	-
Exchange Rate	0.3243*	0.3256*	-0.1314
Germany			
Long Rate	0.2159	-	-
Share Prices	-0.0018	-0.0228	-
Japan			
Long Rate	0.8109**	-	-
Share Prices	-0.1185	-0.0809	-
France			
Long Rate	0.7810**	-	-
Italy			
Long Rate	0.3843*	-	-
Share Prices	0.0012	0.2613	-

* Significant at the 5% level.
** Significant at the 1% level.

1 Each correlation coefficient (R) is calculated over the full overlapping date set (n) available for each pair of series. Significance is adjudged by the test statistic: $T = R\sqrt{n-2}/\sqrt{1-R^2}$, where T is distributed as t with n-2 degrees of freedom.

TABLE 21 WITHIN MARKET CROSS-COUNTRY CORRELATION COEFFICIENTS FOR QUARTERLY AVERAGED ARCH VARIANCE SERIES[1]

Short Rates	UK	US	Germany	Japan	France
US	0.1269	-	-	-	-
Germany	0.1809	0.2800*	-	-	-
Japan	0.2021	0.3158*	0.0500	-	-
France	-0.0190	0.2647*	0.0604	-0.0358	-
Italy	-0.0440	0.0384	-0.0421	0.0183	0.3519**
Long Rates					
US	0.0365	-	-	-	-
Germany	0.0427	0.7630**	-	-	-
Japan	0.1729	0.2918*	0.4796**	-	-
France	0.0506	0.2832*	0.4332**	0.1239	-
Italy	-0.0607	0.5179**	0.6391**	-0.0808	0.4637**
Share Prices					
US	0.3929**	-	-	-	-
Germany	0.3715**	0.6929**	-	-	-
Japan	0.1431	0.2800*	0.2269[2]	-	-
Italy	0.1625	-0.0615	-0.0845	-0.0969	-

* Significant at the 5% level.
** Significant at the 1% level.

1 Each correlation coefficient (R) is calculated over the full overlapping date set (n) available for each pair of series. Significance is adjudged by the test statistic: $T = R\sqrt{n-2}/\sqrt{1-R^2}$, where T is distributed as t with n-2 degrees of freedom.

2 Not quite significant at 5% level. Calculated value of 1.94 compared to critical value 1.96.

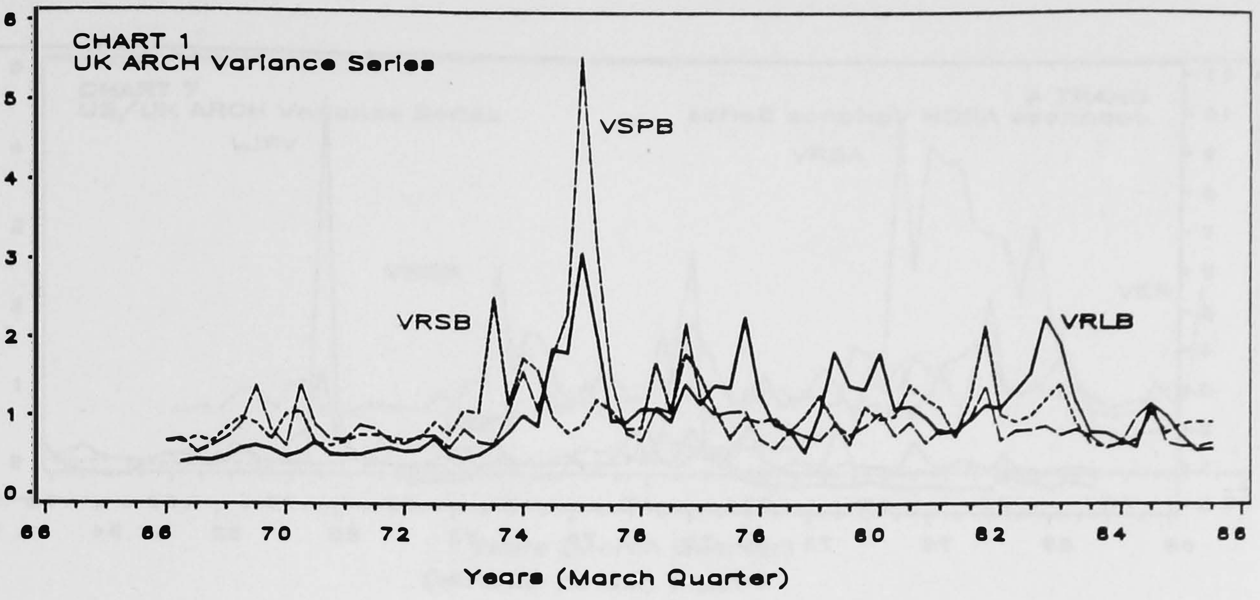
CHART 1
UK ARCH Variance Series
VSPB
VRSB
VRLB
0
1
2
3
4
5
6
66
68
70
72
74
76
78
80
82
84
86
Years (March Quarter)

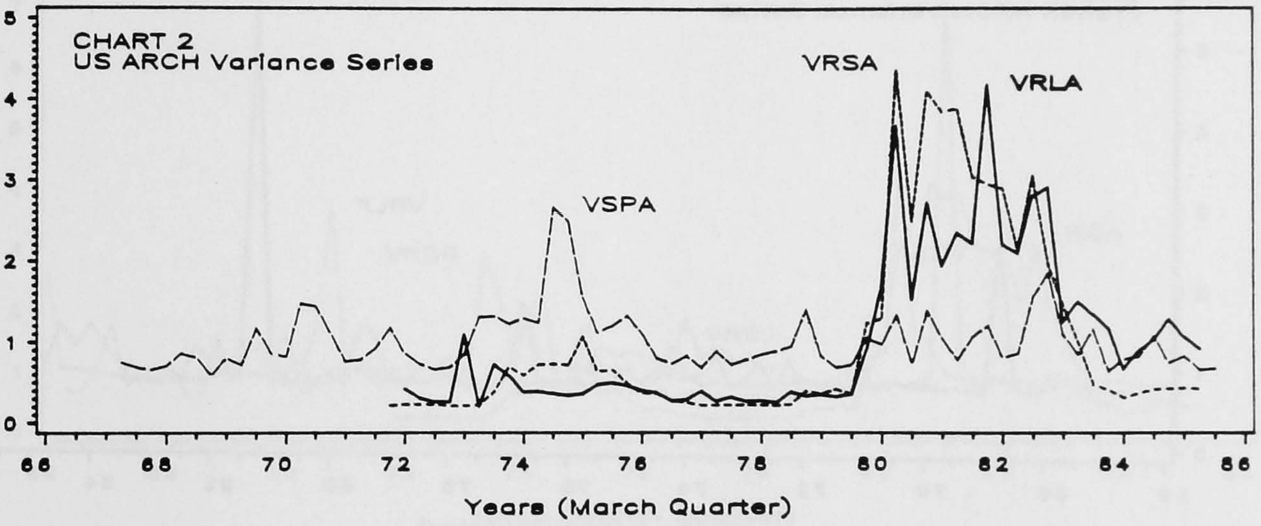
CHART 2
US ARCH Variance Series
VRSA
VRLA
VSPA
0
1
2
3
4
5
66
68
70
72
74
76
78
80
82
84
86
Years (March Quarter)

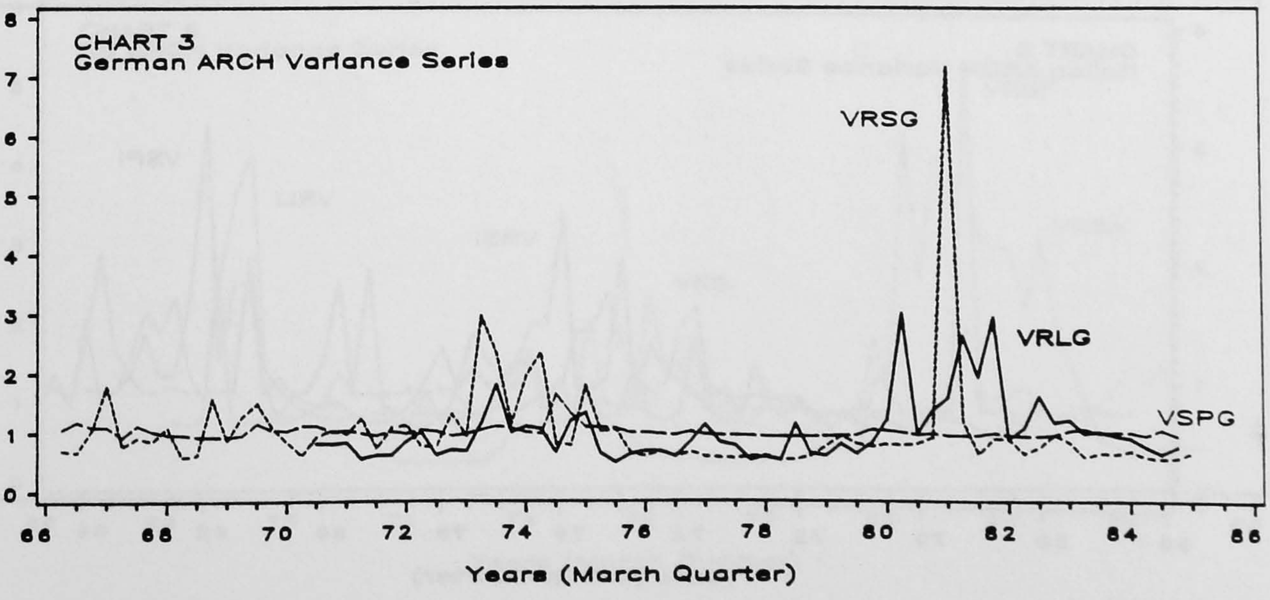
CHART 3
German ARCH Variance Series
VRSG
VRLG
VSPG
0
1
2
3
4
5
6
7
8
66
68
70
72
74
76
78
80
82
84
86
Years (March Quarter)

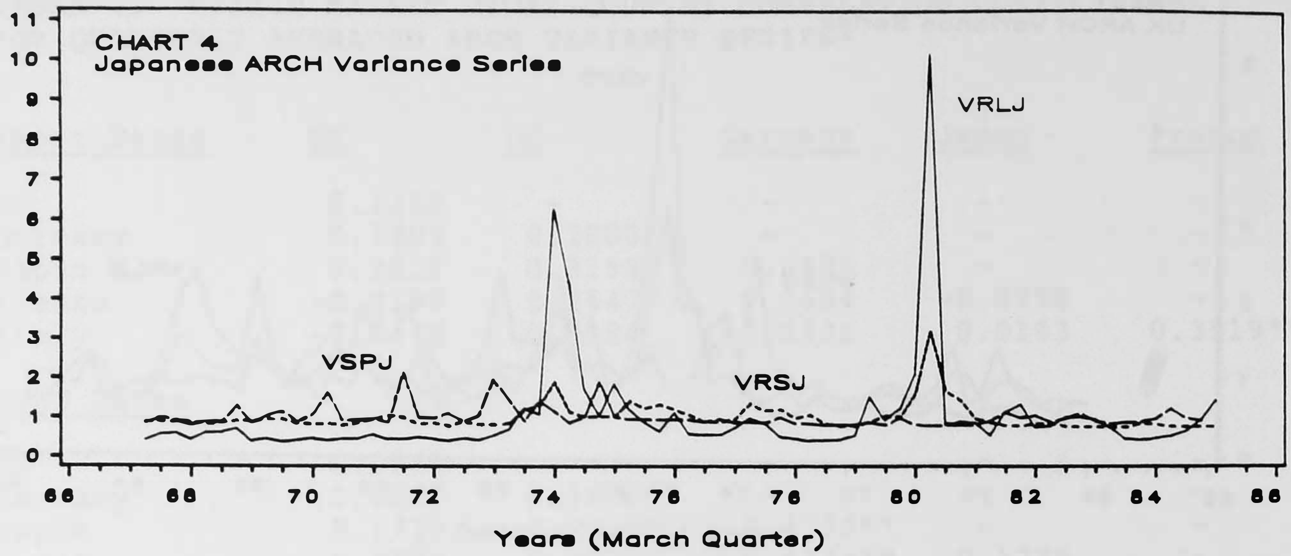
CHART 4
Japanese ARCH Variance Series
VRLJ
VSPJ
VRSJ
0
1
2
3
4
5
6
7
8
9
10
11
66
68
70
72
74
76
78
80
82
84
86
Years (March Quarter)

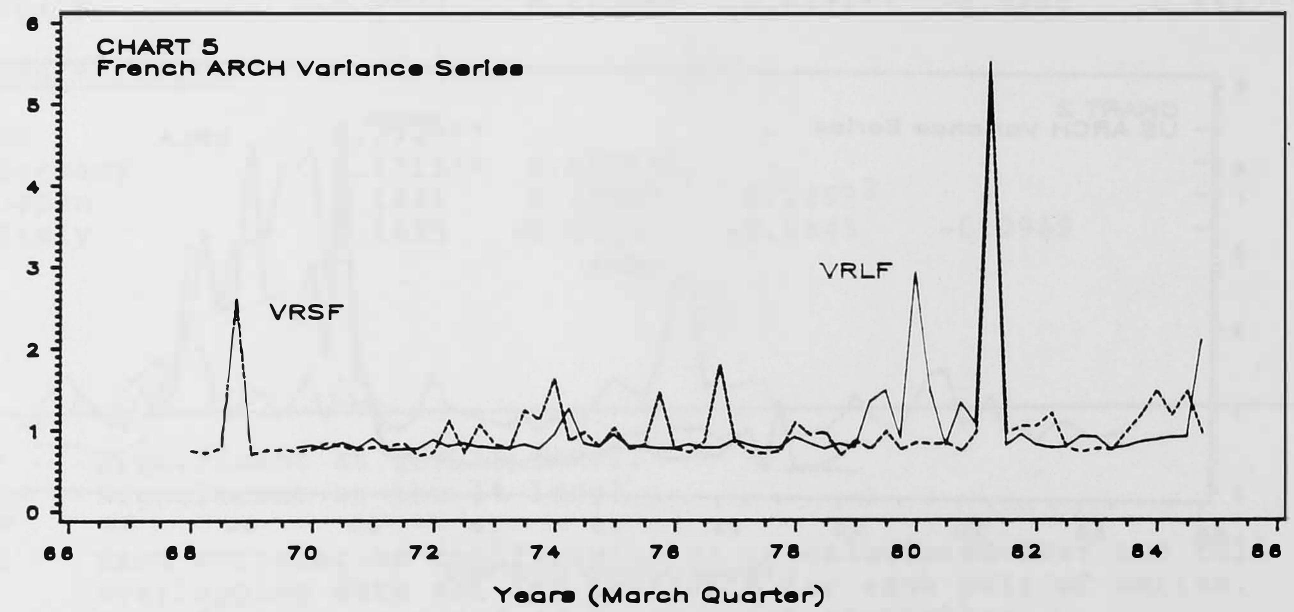
CHART 5
French ARCH Variance Series
VRLF
VRSF
0
1
2
3
4
5
6
66
68
70
72
74
76
78
80
82
84
86
Years (March Quarter)

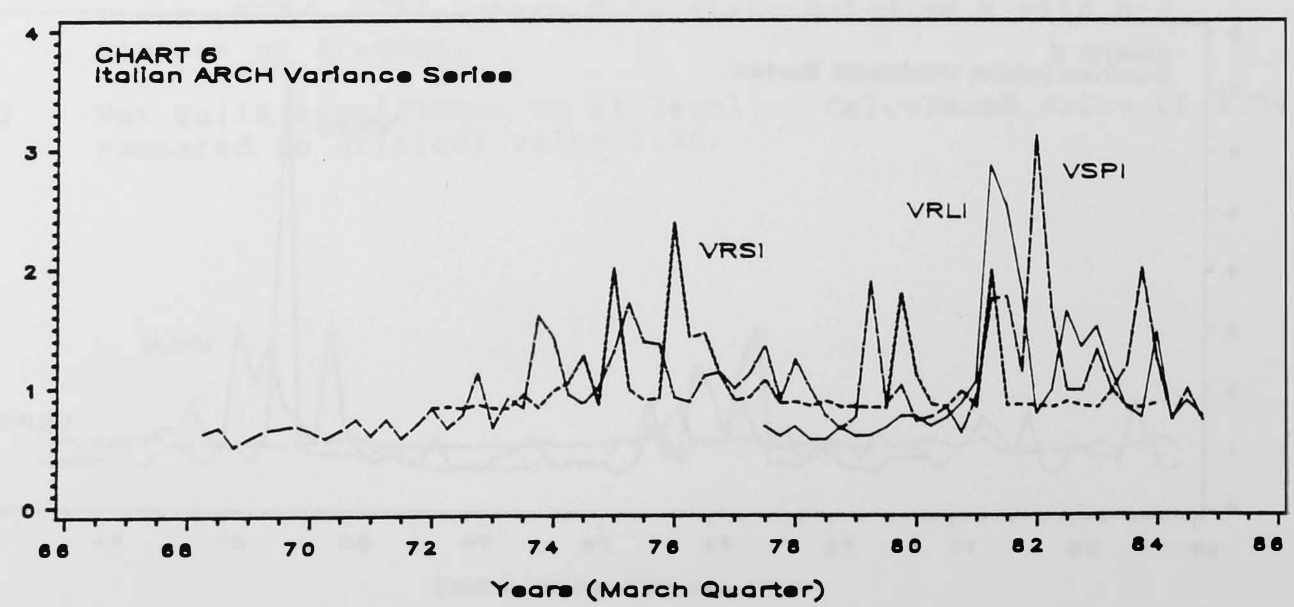
CHART 6
Italian ARCH Variance Series
VSPI
VRLI
VRSI
0
1
2
3
4
66
68
70
72
74
76
78
80
82
84
86
Years (March Quarter)

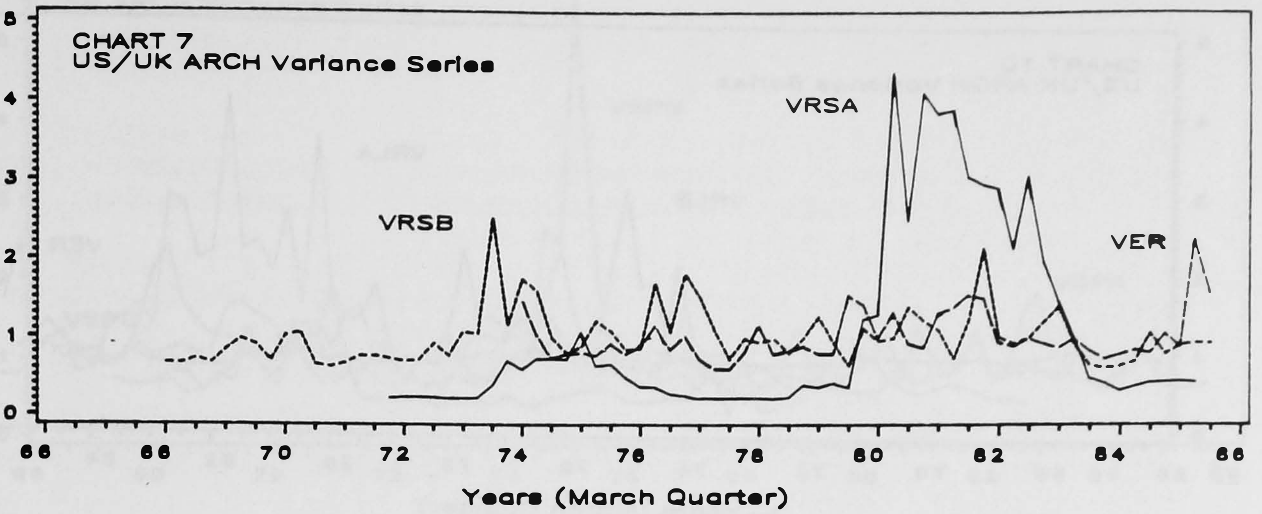
CHART 7
US/UK ARCH Variance Series
VRSA
VRSB
VER
Years (March Quarter)

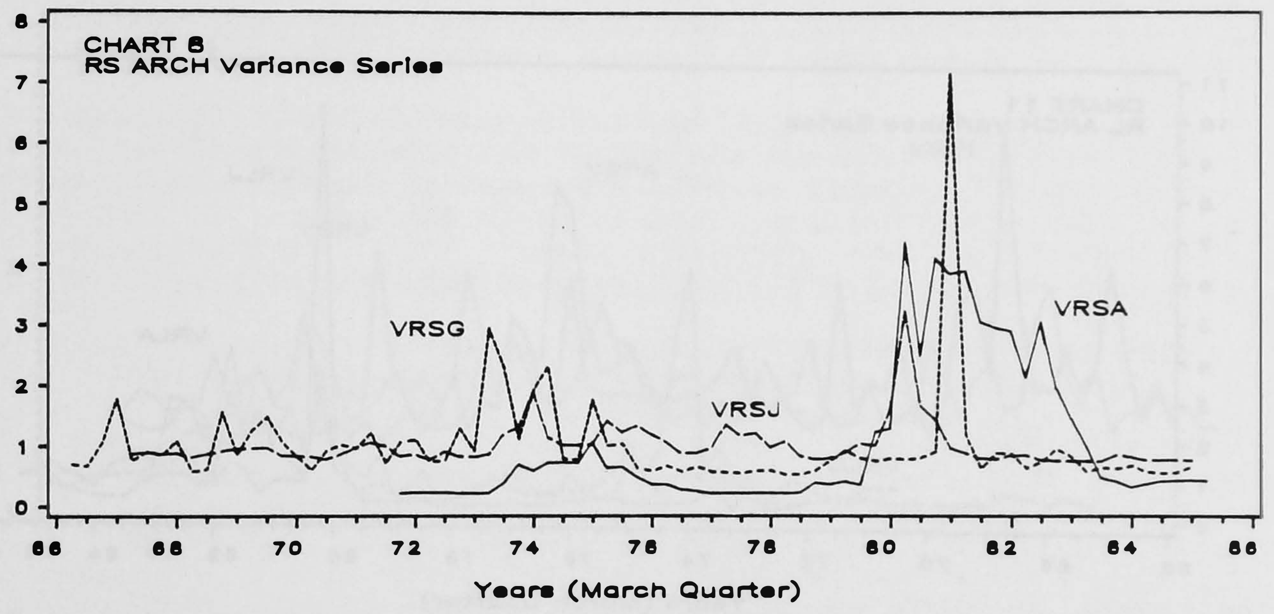
CHART 8
RS ARCH Variance Series
VRSG
VRSJ
VRSA
Years (March Quarter)

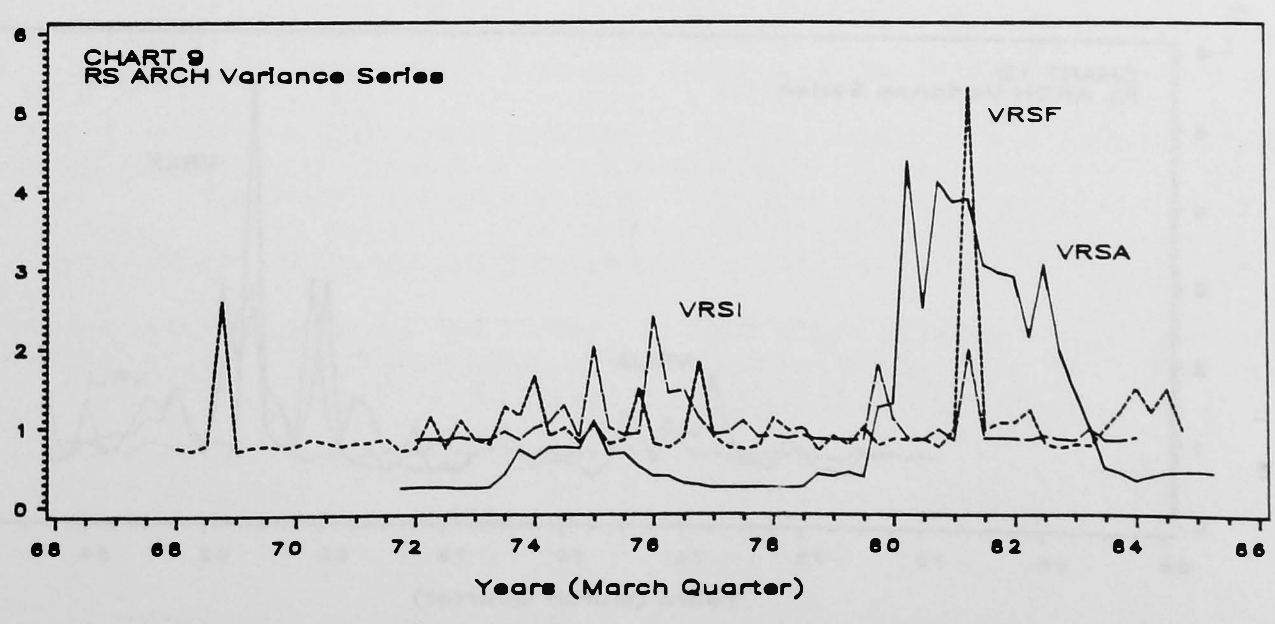
CHART 9
RS ARCH Variance Series
VRSF
VRSA
VRSI
Years (March Quarter)

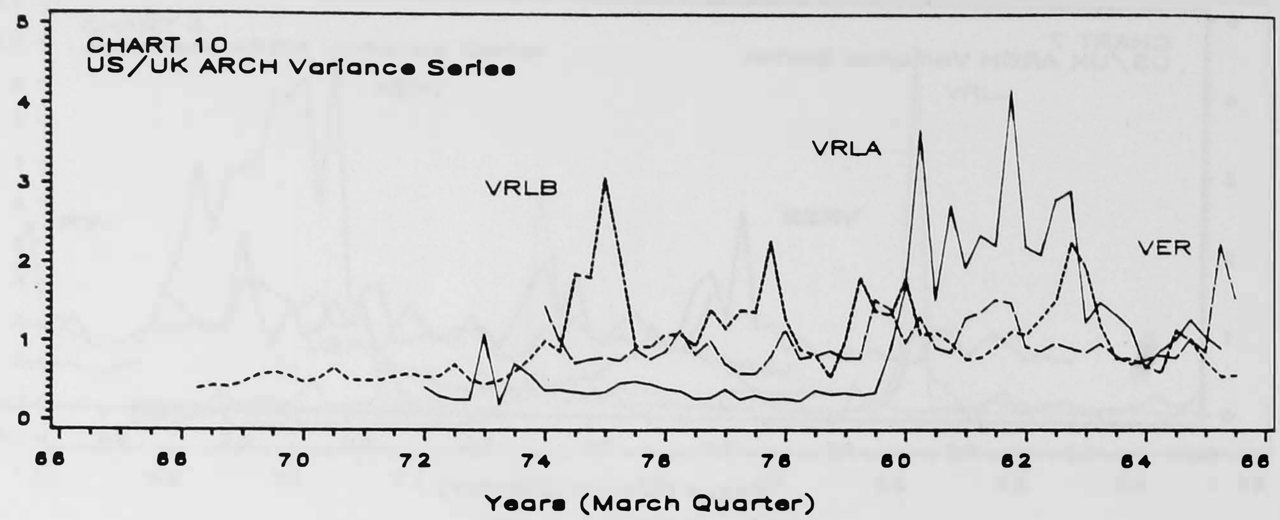
CHART 10
US/UK ARCH Variance Series
VRLB
VRLA
VER
Years (March Quarter)

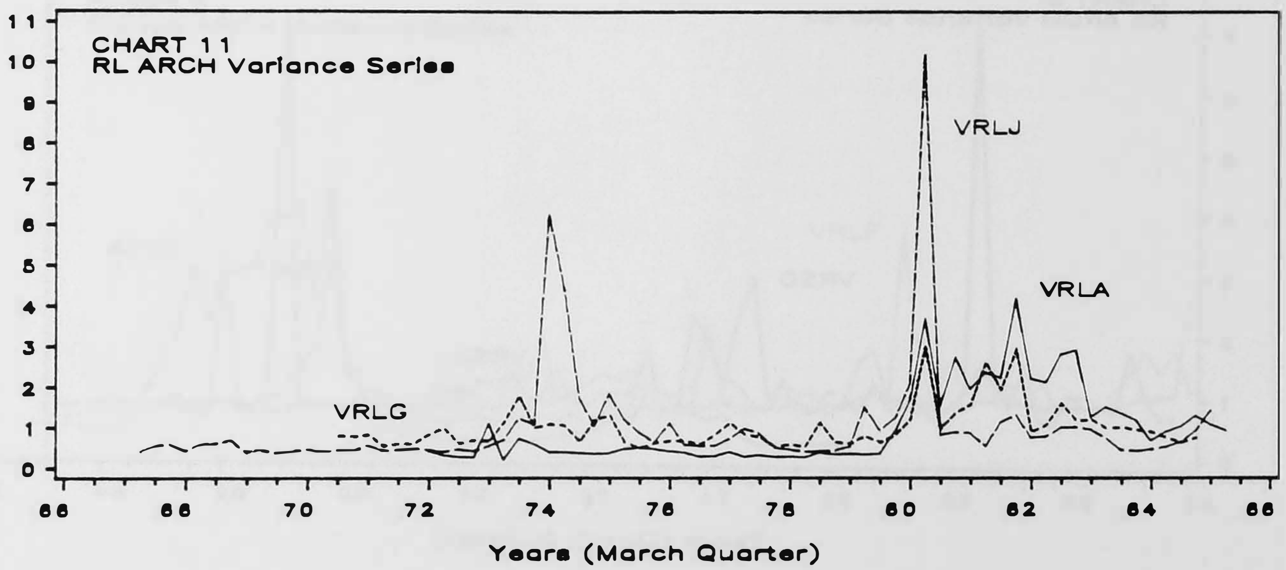
CHART 11
RL ARCH Variance Series
VRLJ
VRLA
VRLG
Years (March Quarter)

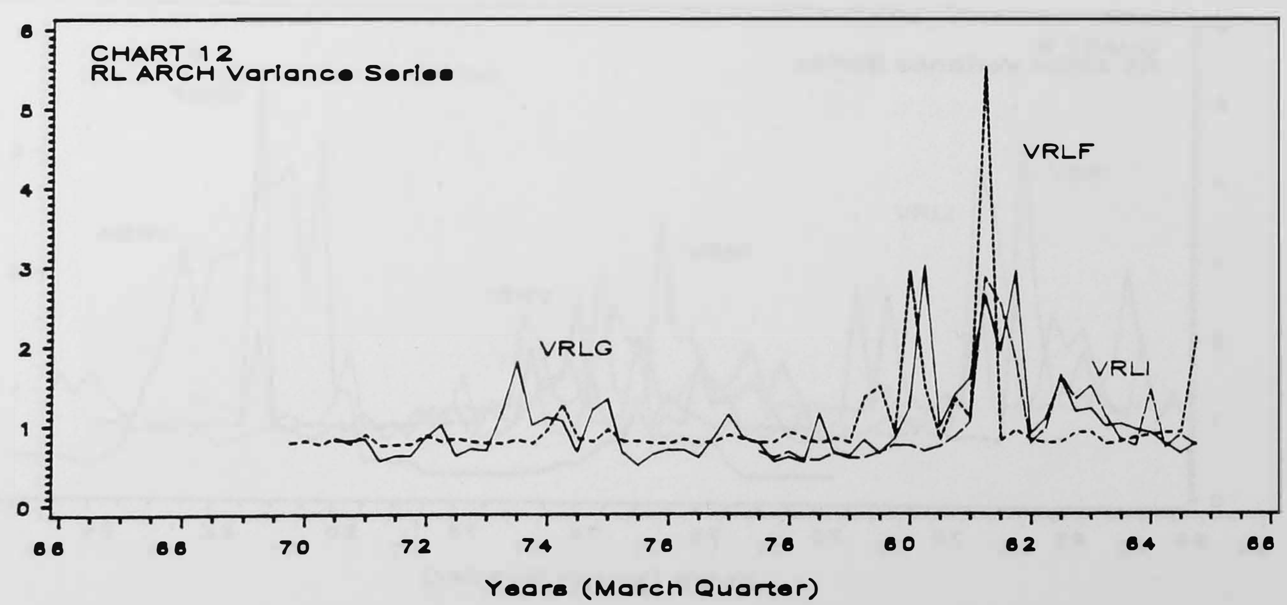
CHART 12
RL ARCH Variance Series
VRLF
VRLG
VRLI
Years (March Quarter)

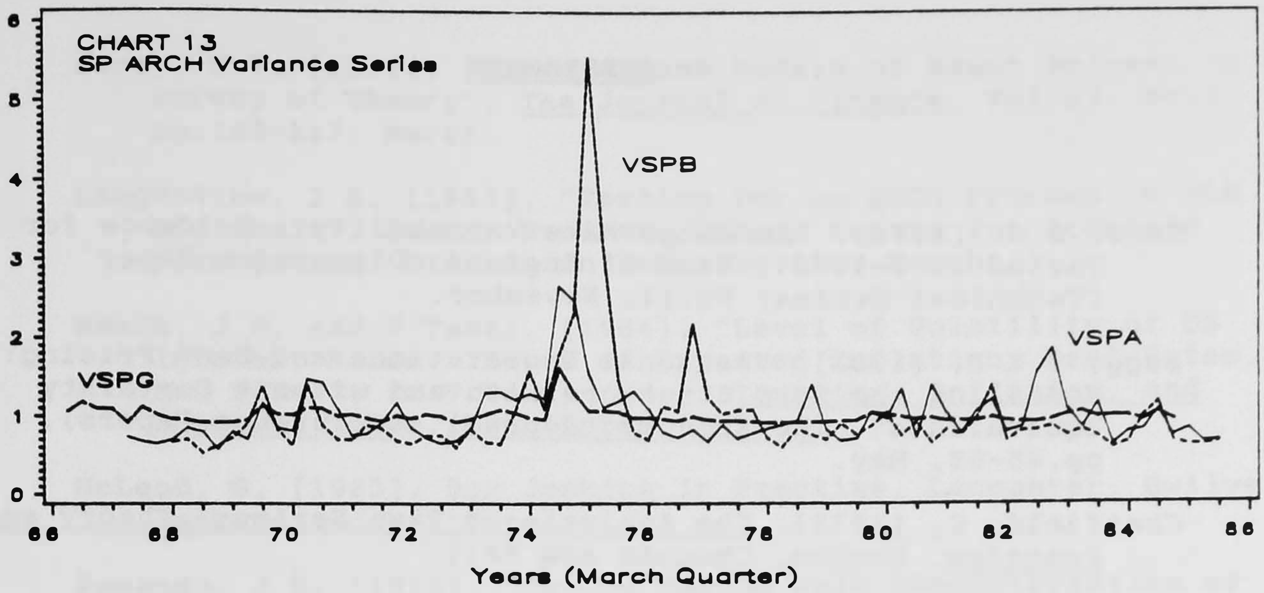
CHART 13
SP ARCH Variance Series
VSPB
VSPA
VSPG
0
1
2
3
4
5
6
66
68
70
72
74
76
78
80
82
84
86
Years (March Quarter)

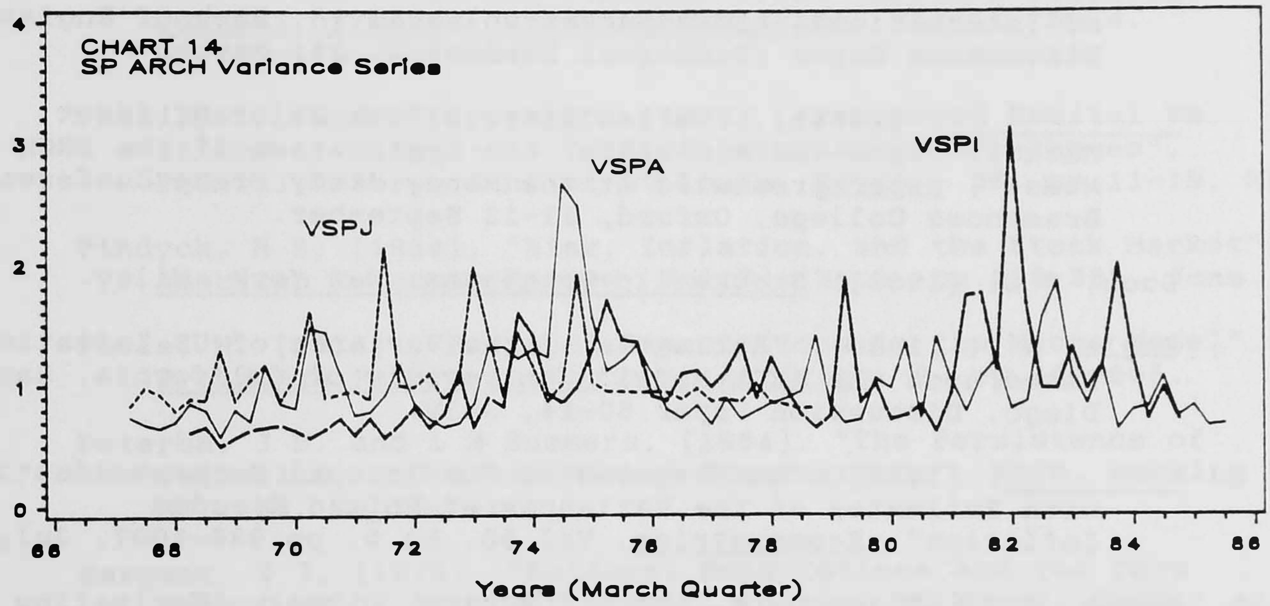
CHART 14
SP ARCH Variance Series
VSPI
VSPA
VSPJ
0
1
2
3
4
66
68
70
72
74
76
78
80
82
84
86
Years (March Quarter)

REFERENCES

Barr, D G, [1984], "Exchange Rate Variability: Evidence for the Period 1973-1982", Bank of England, Discussion Paper (Technical Series) No.11, November.

Begg, D K H, [1983], "Rational Expectations and Bond Pricing: Modelling the Term Structure with and without Certainty Equivalents", The Economic Journal (Conference Papers), pp.45-58, May.

Chatfield, C, [1975], The Analysis of Time Series: Theory and Practice, London, Chapman and Hall.

Dickens, R R, [1986a], "The ARCH Model as Applied to the Study of International Asset Market Volatility", Bank of England, Discussion Paper (Technical Series) No.13, March.

____________, [1986b], "Variability in Some Major UK Asset Markets since the mid-1960s: An Application of the ARCH Model", paper presented at the Money Study Group Conference, Brasenose College, Oxford, 11-13 September.

Doob, J L, [1953], Stockastic Processes, New York, Wiley.

Engle, R F, [1980], "Estimates of the Variance of US Inflation Based upon the ARCH Model", University of California, San Diego, Discussion Paper 80-14, July.

_________, [1982], "Autoregressive Conditional Heteroscedasticity with Estimates of the Variances of United Kingdom Inflation", Econometrica, Vol.50, No.5, pp.989-1007, July.

Engle, R F, Lilien, D M, and R P Robins, [1984], "Estimating Time Varying Risk Premia in the Term Structure: The ARCH-M Model", University of California, San Diego, Discussion Paper, 85-17, December (Second Revision).

Engle, R F, Hendry, D F, and D Trumble, [1985], "Small-sample Properties of ARCH Estimators and Tests", Canadian Journal of Economics, Vol.18, No.1, pp.66-93, February.

Fama, E F, [1977], Foundations of Finance, Oxford, Blackwell.

Goodhart, C A E, and D H Gowland, [1977], "The Relationship Between Yields on Short and Long-Dated Gilt-Edged Stocks", Bulletin of Economic Research, Vol.29, pp.96-111.

Johnson, D, [1981], "Interest Rate Variability Under the New Operating Procedures and the Initial Response in Financial Markets", paper written for Federal Reserve Staff Review of Monetary Control Procedures, January.

Kmenta, J, [1971], Elements of Econometrics, New York, MacMillan.

Leroy, S F, [1982], "Expectations Models of Asset Prices: A Survey of Theory", The Journal of Finance, Vol.37, No.1, pp.185-217, March.

Longbottom, J A, [1984], "Testing for an ARCH Process in OLS Residuals", London Business School Centre for Economic Forecasting, Discussion Paper No.122, March.

Makin, J H, and V Tanzi, [1984], "Level of Volatility of US Interest Rates: Rates of Expected Inflation, Real Rates, and Taxes", in V Tanzi (ed.), Taxation, Inflation, and Interest Rates, Washington, IMF.

McLeod, G, [1983], Box Jenkins in Practise, Lancaster, Gwilym Jenkens and Partners.

Pesando, J E, [1979], "On the Random Walk Characteristics of Short- and Long-term Interest Rates in an Efficient Market", Journal of Money, Credit and Banking, Vol.11, No.4, pp.456-466, November.

Phillips, L and J Pippenger, [1976], "Preferred Habital Vs. Efficient Market: A Test of Alternative Hypotheses", Federal Reserve Bank of St Louis, Review, 58, pp.11-19, May.

Pindyck, R S, [1984], "Risk, Inflation, and the Stock Market", American Economic Review, Vol.74, No.3, pp.335-351, June.

Poole, W, [1976], "Rational Expectations in the Macro Model", Brookings Papers on Economic Activity, 2, pp.463-505.

Poterba, J M, and L H Summers, [1984], "The Persistence of Volatility and Stock Market Fluctuations", NBER, Working Paper No.1462, September.

Sargent, T J, [1972], "Rational Expectations and the Term Structure of Interest Rates", Journal of Money, Credit and Banking, Vol.4, No.1, pp.74-97, February.

Sims, C A, [1984], "Martingale-Like Behaviour of Prices and Interest Rates", University of Minnesota, Centre for Economic Research Department of Economics, Discussion Paper No.205, October.

Taylor, S J, [1985], "The Behaviour of Futures Prices Over Time", Applied Economics, 17, pp.713-734.

Yule, G U, and M G Kendall, [1965], An Introduction to the Theory of Statistics (fourteenth edition), London, Griffin.

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