

Change in Unconditional Exchange Rate Volatility: GBP and USD Price of the Euro 2002-2003

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Abstract

Unconditional foreign exchange rate variance is generally assumed to be constant in analysis of foreign exchange rates. We note that there is evidence of a change in unconditional foreign exchange rate variance during the two-year period surrounding the Iraq war, January 2002 to December 2003 for the GBP price of the Euro though not for the USD price of the Euro. This has implications for the indiscriminate use of models that assume constant unconditional variance, such as the GARCH family of models, in analysis of foreign exchange rates.

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Does Unconditional Foreign Exchange Rate Volatility Change Over Time?

1. Introduction

Foreign exchange rates are often argued to be best modelled using a GARCH process. Yet, an important assumption that underlies the GARCH model is the assumption of constant unconditional volatility. It is difficult to predict what might cause a change unconditional volatility though we argue that the period from 1 January 2002 through to 31 December 2003 might provide a situation where there were events of sufficient magnitude to generate a change in unconditional volatility at least for the currencies of the USA and the UK relative to Europe currencies. The importance of Middle East oil for the world economy, the political fallout that surrounded the invasion of Afghanistan and the invasion of Iraq for the USA, together with the acknowledgement of the possibility of a drawn out conflict in Iraq for both the USA and the UK all point to a fundamental change in the relationship between the USA and the UK with Europe. We focus on this two-year period, using the USA dollar price of the euro (USD) and the Great Britain Pound price of the euro (GBP) because of the reasonably strong experimental setting provided by the refusal of key European countries to take part in the Iraq invasion.

The single break point and multiply break point forms of the Kokoszka and Leipus (1998, 2000) (KL) test are used to identify the existence breaks in the unconditional volatility of the USD and GBP relative to the euro in this study. We use five-minute foreign exchange rate returns based on data supplied by Olsen Financial Technologies to estimate daily variance and the KL test is then applied to these daily variance estimates to test for change in unconditional variance. We find evidence of a statistically significant increase in variance for the GBP price of the euro around

December 2002. The following section provides a brief literature review with data description in section 3, analysis in section 4 and summary and conclusions reported in section 5.

2. A Test for Change in Unconditional Variance

The foreign exchange volatility literature has burgeoned over the last few years though much of the research is based on ARCH type models with a focus on describing time variation in volatility (Anderson and Bollerslev, 1997 and 1998, Ballie and Bollerslev, 1989, and Harvey and Huang, 1991). With the availability of microstructure data we are able to better estimate daily volatility with a view to more carefully studying the possibility of changes in unconditional variance. Anderson et al (2001) define several measures of variation using tick-by-tick data including the realised variance for a day, $\text{var}_t = \sum_{n=1}^N R_{t,n}^2$, with R being the change in the average log bid and log ask price across the observation interval and N being the number of return observations available for the day.¹

Given the abundant evidence for the existence of ARCH effects in foreign exchange rates it is critical that any method that is used to test for change in unconditional variance is adjusted for ARCH effects. Andreou and Ghysels (2002) compare three possible tests for change in unconditional variance and find that the Kokoszka and Leipus (1998, 2000) test (KL), which specifically adjusts for ARCH effects, performs well in financial data applications. As a result we use the KL test to test for change in unconditional foreign exchange rates variance. This test uses the cumulative sum of

¹ We also calculate the Anderson et al (2001) standard deviation estimates for our data though there is little change in the results and so they are not reported here.

squares where the underlying variable is an estimate of the foreign exchange rate variance, X_j . The KL test is defined as:

$$KL = \sup\{|U_T(k)|\}/\hat{\sigma} \quad (1)$$

The parameter, T , is the sample size, k is the possible break point that is the subject of the test and:

$$U_T(k) = \left[1/\sqrt{T}\right] \sum_{j=1}^k X_j - \left[k/(T\sqrt{T})\right] \sum_{j=1}^T X_j \quad (2)$$

The standard deviation estimate, $\hat{\sigma}$, is estimated using the VARHAC estimator (Den Haan and Levin, 2000, Bollen and Inder, 2003). The critical values for these tests are 1.628 (1.358) for the 1% (5%) level of significance. The KL test is also used to identify multiple change dates following the procedure described in Inclan and Tiao (1994). We also use a 5% level of significance in the multiple change date form of the test.

While the KL test provides a statistical test for change in unconditional variance, it is useful to provide a simpler, though perhaps less statistically sound, graphical approach to help draw out the intuition underlying the test. We use the Inclan and Tiao (1994) cumulative sum for this purpose. This is defined as:

$$IT = \sum_{j=1}^k X_j / \sum_{j=1}^T X_j - k/T \quad (3)$$

The parameter, k , is the number of observations to the current observation and T is the total number of observations. With this graphical approach it is possible to differentiate between increases in variance (positive sloped segment of the cumulative sum curve) and decreases in variance (negative sloped segment of the cumulative sum

curve) as well as to get an idea of the relative importance of the break points (changes in slope of the curve) that are identified by the KL tests.

3. Data

We select five-minute bid and ask quotes for the USD and the GBP for the period 1 January 2002 through to 31 December 2003 from data provided by Olsen Financial Technologies.² The average of the log bid and log ask price available at the end of each five-minute period is calculated and where there are two consecutive five-minute observations these are differenced to obtain a return.³ Further, due to low levels of trading that occurred on 1 January 2002, 25 December 2002, 1 January 2003, 25 December 2003 and on Saturdays and Sundays we dropped these days from the study, leaving 518 trading day variance observations for analysis. These filter rules ensure that each daily variance estimate is based on a large sample of observations gathered from trading that occurred during a normal trading day.

Descriptive statistics are reported in Table 1 for the variance estimates based on the sum of the five-minute squared returns. The variance per day estimates suggest annual foreign exchange return standard deviations of approximately 9.4% per annum for the GBP and 10.4% per annum for the USD. Thus the USD is around 10% per annum more volatile than the GBP over this period. While the average GBP variance is lower it is important to note that the standard deviation, skewness and kurtosis values of the daily variance estimates are considerably greater for the GBP than for the USD. Finally, the average covariance is around 47%, suggesting that the GBP and the USD were fairly highly correlated over the period.

² The web site for this data provider is www.olsendata.com.

³ No return is calculated for five-minute periods unless there are fresh quotes at the beginning and the end of the five-minute period.

[Insert Table 1 about here]

4. Analysis

The KL test breakpoint dates are reported in Table 2 for both of the USA and GBP. The tests are conducted under the assumption of a single break point and also under the assumption a multiple break points. Under the assumption of a single break point there is evidence of change in unconditional volatility on the 16 December 2002 though there is no evidence of statistically significant change in the USD variance. Nor is there evidence of a statistically significant change in the covariance between GBP and USD over the period.

The multiple break points KL test identifies two break points in the GBP based on five-minute returns, 16 December 2002 and 21 July 2003. Consistent with the single break-point test there are no break points identified for the USD or the covariance between the GBP and the USD. Given the adjustment for ARCH effects inherent in the KL test, the results provide fairly strong evidence that the unconditional GBP variance changed during the period, 1 January 2002 to 31 December 2003.

[Insert Table 2 about here]

Figure 1 provides an indication of the direction of the change in variance as this plots the cumulative sum of squares for the GBP, the USD and the covariance between the

two.⁴ The GBP variance shows much greater visual evidence of a break around December 2002 with a fairly rapid increase in variance evident around this month. From Figure 1 it can be seen that the variance is relatively low for the GBP until December 2002 when there is an increase in the level of variance that remains in effect until July 2003 after which the GBP variance returns to the average for the period.

[Insert Figure 2 about here]

The question that remains is why we see evidence of unconditional change in the GBP variance but not in the USD or in the covariance between the two? While we cannot make conclusive statements there are certainly important decisions made late in 2002 that had dramatic implications for the UK/Europe relations. The greater volatility of the USD captures the open approach that the USA took with respect to the invasion of Afghanistan and Iraq, even to the point of President Bush gaining congressional approval to use force if necessary in its dealings with Iraq in October 2002. It could be argued that there were few surprises in the USA actions and thus we might expect the unconditional variance to remain fairly stable over the period. While there is clear movement in the cumulative sum over the period it is not statistically significant. Such a conclusion is supported by the findings of Andersen et al (2003) with regard to impacts of expected news on forex markets

⁴ It should be noted that periods of comparatively low variance are reflected with a downward sloping line and periods of higher variance are indicated by an upward sloping line.

The situation for the UK was quite different. There were changes in interest rates in 2002 and in particular the European Central Bank interest rate cut, the first time in over 12 months, on 5 December 2002 and these would have had an impact on the GBP price of the euro. Further, the UK relations with the rest of Europe soured with the cessation of Anglo/French discussions late in 2002 because of differences over Iraq. Finally, while the USA was fairly clear with its decision on Iraq through 2002, there was no clear indication that the UK would take part in the invasion of Iraq until December 2002 where Blair is quoted in the *Financial Times* (21 December 2002, p.9) as saying that Britain's forces should prepare for war and by the 24 December 2004 it was noted in the *Financial Times* (24 December 2002, p.13) that British troops were moving towards the Middle East with predictions of war in the Middle East in 2003. These are important announcements and it is apparent, in hindsight, that these announcements had substantial effects on the relationship that exists between the UK and Europe.

5. Summary

This paper applies the KL test for change in unconditional variance to show that there is evidence of a major change in the GBP variance late in 2002, lasting almost seven months. This is an important result because it suggests that changes in the unconditional foreign exchange variance can be maintained for considerable periods of time, even after adjustment for GARCH effects. Perhaps the propensity for dramatic shifts in the underlying foreign exchange rate variance provides one reason why it has is so difficult to forecast foreign exchange variance in practise and it also highlights the need to check for stability of GARCH model parameters, as the assumption of constant unconditional variance may not hold.

References

- Andersen, T. G., and T. Bollerslev, 1997, "Heterogeneous Information Arrival and Return Volatility Dynamics: Uncovering the Long-Run in High Frequency Returns", *Journal of Finance* 52, 975-1005.
- Andersen, T. G., and T. Bollerslev, 1998, "Deutsche Mark-Dollar Volatility: Intraday activity Patterns, Macroeconomic Announcements, and Longer Run Dependencies", *Journal of Finance* 53, 219-265.
- Andersen, T. G., T. Bollerslev, F.X. Diebold, and C.Vega, 2003, "Micro Effects of Macro Announcements: Real-Time Price Discovery in Foreign Exchange", *The American Economic Review* 93, 38-62.
- Andersen, T. G., T. Bollerslev, F.X. Diebold, and P. Labys, 2001, "The Distribution of Realized Exchange Rate Volatility", *Journal of the American Statistical Association* 96, 42-55.
- Andreou, E., and E. Ghysels, 2002, "Detecting Multiple Breaks in Financial Market Volatility Dynamics", *Journal of Applied Econometrics* 17, 579-600.
- Ballie, R. T. and T. Bollerslev, 1989, "The Message in Daily Foreign Exchange Rates: A Conditional Variance Tale", *Journal of Business and Economic Statistics* 7, 297-305.

Bollen, B. and B. Inder, 2003, "A Comparison of Estimators Daily Realised Volatility", *Finance Letters* 1, 29-34.

Den Haan, W. J. and A.T. Levin, 2000, "Robust Covariance Matrix Estimation with Data-Dependent VAR Prewhitening Order", Discussion Paper 11, Department of Economics, University of California, San Diego.

Harvey, C. R. and R. D. Huang, 1991, "Volatility in the Foreign Currency Futures Market", *Review of Financial Studies* 4, 543-69.

Inclan, C. and G. C. Tiao, 1994, "Use of Cumulative Sums of Squares for Retrospective Detection of Changes of Variance", *Journal of the American Statistical Association* 89, 913-923.

Kokoszka, P and R. Leipus, 1998, "Change-point in the mean of dependent Observations", *Statistics and Probability Letters* 40, 385-393.

Kokoszka, P and R. Leipus, 2000, "Change-point Estimation in ARCH Models", *Bernoulli* 6, 513-539.

Lavielle, M. and E. Moulines, 2000, "Least-Squares Estimation of an Unknown Number of Shifts in a Time Series", *Journal of Times Series Analysis* 21, 33-59.

Table 1
Descriptive Statistics Variance and Covariance Estimates
Five Minute Squared Returns

	GBP Variance	USD Variance	USD and GBP Covariance
Average	0.3512	0.4271	0.1820
Standard Deviation	0.2292	0.1696	0.0969
Skewness	7.2174	1.3997	2.0433
Kurtosis	76.1343	4.2335	8.8604

Table 2
Kokoszka and Leipus (1998, 2000)
Tests for Unconditional Change in Variance of FX Rates

Panel A: Test for One Unconditional Change Date

	Five Minute Returns
GBP Variance	16 Dec 2002
USD Variance	-
GBP, USD Covariance	-

Panel B: Test for Multiple Unconditional Change Dates

	Five Minute Returns
GBP Variance	16 Dec 2002 21 Jul 2003
USD Variance	-
GBP, USD Covariance	-

Figure 1
CUM SUM for GBP Variance, USD Variance and Covariance
Based on Five-Minute Returns

