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Abstract

This paper examines some of the characteristics of the foreign exchange market in the 1920s floating period. Nominal returns appear to exhibit properties consistent with asset prices on modern more well organized financial markets; i.e., they appear to be well described by martingales and possess persistent time dependent heteroskedasticity. In order to deal with the extreme kurtosis in the exchange rate series we use robust inferential methods to test for volatility spillovers and shocks that might effect subsequent mean returns. Apart from some particularly abnormal 'bear squeeze' episodes the markets appear remarkably efficient.

Keywords: Exchange Rates, Hyperinflation, Martingales, GARCH, Volatility, Market Efficiency, Robust Inference.

JEL Classification numbers - C22, E41, E31.

1. Introduction

Institutional and technological changes in the last decade would strongly suggest that the integration of financial markets is increasing. Indeed, a number of studies have examined different speculative auction markets, including exchange rates, stock prices and commodity prices and have found striking similarities in terms of the apparent widespread martingale property, volatility patterns and reactions to news. Also, several studies have now analyzed the reaction of volatility between and within different asset markets, either in terms of volatility spillovers across different geographical locations or different asset markets. In particular, Engle, Ito, and Lin (1990) and Baillie and Bollerslev (1991) looked at patterns of volatility between different exchange rates and market locations. Using data over the recent free floating period, these studies suggest that, while volatility may be temporally and geographically autocorrelated, the markets appear semi-strong efficient with price changes quickly incorporating news. Hamao, Masulis and Ng (1990) have also considered volatility spillovers between different equity markets; and find very interestingly that volatility was somewhat less important in the turbulent equity markets after the October 1987 crash.

This paper considers the structure of the foreign exchange market during an equally turbulent and interesting period of history, namely the era of widespread floating exchange rates in the 1920s. The foreign exchange market in this period was clearly less well organized than in the current float beginning in 1973. In particular the 1920s foreign exchange market lacked the sophisticated telecommunications systems, the organized trading structure and the range of financial instruments, such as options and futures, that exist in today's market place. Furthermore, the world economy was recovering from the devastating effects of World War I, with the turmoil of war reparations and hyperinflation in Germany. This also led to concerted speculative attacks on various currencies, most notably the French franc, which in turn prompted the French government to engage in a number of "bear squeezes" in the hope of deterring future speculation.

The analysis conducted in this paper finds that despite the severe disruptions that occurred and the relatively primitive market conditions, the 1920 foreign exchange markets were surprisingly efficient and in terms of the temporal dependencies very similar in character to today's market. However, in contrast to the general findings it does appear that some degree of volatility spillover did occur which was consistent with news on the French and Belgium currencies being transmitted to the Italian lire and Swiss franc. Part, but not all of this spillover effect seems to have occurred during the bear squeeze episode.

The plan of this paper is as follows. Section 2 provides a brief description of the foreign exchange market during this period and some of the relevant economic and political factors. Section 3 then discusses some of the temporal characteristics of the data, which turn out to be remarkably similar to exchange rates in the current float. While most of the spot and forward rates appear to be martingales, they also possess strong time dependence in their conditional variances which are well described by Generalized Autoregressive Conditional Heteroskedastic (GARCH) processes. Similarly to the experience following the breakdown of the Bretton Woods agreement in 1973 these GARCH processes, which are examined in section 4, also indicate a very high degree of persistence in the volatility process during the 1920s foreign exchange market.

In section 5 the effects of exchange rate innovations and volatility between and within other currencies are examined. While several of the political and economic events of this period were associated with extreme volatility, such episodes were generally short lived and do not appear to have led to predictable changes in mean returns. In summary, there is surprisingly strong evidence of apparent efficiency in the market with remarkably similar behavior to todays foreign exchange market. Due to the extreme degree of non normality in the returns data we rely throughout the paper on the Robust standard errors technique of Bollerslev and Wooldridge (1991). These Quasi Maximum Likelihood techniques allow for robust inference under quite general conditions.

2. The Foreign Exchange Market in the 1920s

The early 1920s are an interesting period of history which, apart from the post 1973 era, constitute the other main source of information on the behavior of a system of floating exchange rates. This period is well documented from a data perspective and is interesting in terms of the exogenous economic and political events taking place.

The data used in this study are taken from Einzig (1937) and consist of 162 weekly Saturday observations on the London market from February 25, 1922 through March 25, 1925 on the exchange rates of Belgium (BL), Britain (BR), France (FR), Holland (HL), Italy (IT), and Switzerland (SW) vis a vis the US dollar. It should be noted that Einzig (1937) provides data beyond this period; however Britain, Holland and Switzerland returned to a gold standard in 1925 so all the data series are truncated at March 25, 1925 to facilitate comparability. Also, the original exchange rate data provided by Einzig (1937) was vis a vis the British pound but, in order to separate out news and shocks emanating on the pound we applied triangular arbitrage to obtain the exchange rates in terms of a numeraire US dollar.

One of the best known features of the early 1920s was the rapid depreciation of the German mark following the severe hyperinflation and explosion of the money supply process in Germany. In January 1922 there were approximately 800 marks to the pound; by May 1922 there were 1500 and by September 1923 the mark had depreciated to 45 million marks to the pound. At this point the market ceased to be quoted.

Considerable though less dramatic economic and political turbulence was simultaneously experienced by the six other European currencies analyzed in this study. Following World War I the French government substantially increased its expenditures to repair the regions of the country destroyed in the war. Subsequent domestic French inflation was compounded by the difficulty in collecting war reparations from Germany and finally, in the early 1920s, international confidence in the French franc began to deteriorate and by November 1923 heavy sales of the franc occurred in the Amsterdam market, which quickly led to similar activity in the London market. By March 1924 the French franc had depreciated almost 50% and on March 11, French Premier Raymond Poincaré launched a "bear squeeze" by negotiating secret loans from U.S. and British banks, who then purchased large quantities of francs. From a level of 117.00 francs to the pound on March 11, 1924, the franc then appreciated to 89.81 francs to the pound the following week. Similar events, leading to another bear squeeze, occurred in July 1926.

The events surrounding the French franc do not appear independent of events in other currency zones. In particular, the Belgian franc was also attacked by speculators in February and March 1924. This well documented event was explained by Shepherd (1936) and Einzig (1962) in terms of the Belgian and French francs sharing co-movements due to their similar economic and political situations while Einzig (1937) has suggested a linkage due to psychological factors. Also, Aliber (1962) argued that investors over this period were influenced by Purchasing Power Parity considerations.

3. Temporal Behavior of Exchange Rates

On denoting the logarithm of the spot exchange rate by s_t, the martingale property with respect to the information set Ω_t is given by

$$E(\Delta s_{t+1} | \Omega_t) = E_t \ (\Delta s_{t+1}) = 0$$

so that the price change is unpredictable. This condition implies the expected one period rate of return to be zero and is in accord with the concept of weak form efficiency and a time invariant risk premium; see Fama (1965). Consistent with the martingale property, several previous studies such as Meese and Singleton (1982), Baillie and Bollerslev (1989a, 1991) have documented the apparent existence of a unit root in weekly, daily and hourly exchange rates in the current float. The application of the unit root testing methodology of Phillips (1987) and Phillips and Perron (1988) also failed to reject the null hypothesis of a unit root in the logarithm of the 1920s exchange rates against a stationary alternative.[1] Details of these results are omitted from the paper for reasons of space, but are available from the authors on request.

As previously mentioned, several authors such as Shepherd (1936) and Einzig (1962), have suggested common comovement between currencies in the 1920s. Since all the six series, appear to be well described as I(1) processes, it is appropriate to examine this issue in terms of the concept of cointegration, which allows for the possibility of long-run stationary cointegrating relationships between the nominal rates. To that end we implemented the trace test due to Johansen (1988) and Johansen and Juselius (1989) but were unable to reject the null hypothesis of six distinct stochastic trends. Hence no evidence of cointegration between the exchange rates in the early 1920s was discerned. This result is contrary to the results presented by Baillie and Bollerslev (1989a) for the 1980s, who found evidence for one cointegrating vector in a system of seven daily spot exchange rates.[2] Since this result could be driven by any subset of the exchange rates, and since several of the currencies were in the EMS, the apparent cointegration of exchange rates in the 1980s might not be that surprising. However, the 1920s era possessed no such deliberate policy coordination and it seems reasonable for the various currencies to be determined by quite different sets of fundamentals.

From a statistical point of view the apparent lack of any cointegrating relationship also justifies the specification of a set of univariate time series of the martingale variety. Based on the preliminary results in Table 1 all the estimated models apart from BL, appear to provide a reasonable description of the series; however as noted by Diebold (1987) and Cumby and Huizinga (1988) the presence of heteroskedasticity and/or excess kurtosis will bias the Ljung and Box (1978) portmanteau statistic towards rejecting the null hypothesis of uncorrelated returns too often. Thus in order to provide robust inference in the presence of the extreme kurtosis, the subsequent statistics presented in the paper all rely on the robust standard errors technique due to Bollerslev and Wooldridge (1991) and is briefly described in the Appendix.

Returning to Table 1, the Ljung Box statistics on the squared residuals are suggestive of time dependent heteroskedasticity in the returns data. This phenomenon was originally noted by Mandelbrot (1963) and Fama (1965) and is consistent with the systematic occurrence of tranquil and volatile periods that are typical of data from modern speculative markets. The returns data also exhibits substantial excess kurtosis which have been well chronicled for exchange rate data in the recent float; see Westerfield (1977), McFarland, Pettit and Sung (1982), and Hsieh (1989).

A number of authors including Milhøj (1987), McCurdy and Morgan (1987), and Baillie and Bollerslev (1989b) have all found the basic ARCH process, introduced by Engle (1982), and the Generalized ARCH (GARCH) process of Bollerslev (1986), to be very successful in describing the time dependent heteroskedasticity present in exchange rate returns data in the recent float.

Consequently we estimated the following GARCH (1,1) model for all six returns series:

$$100\Delta s_t = \mu + \varepsilon_t \quad (1)$$

$$\varepsilon_t | \Omega_{t-1} \sim N(0, \sigma^2_t) \quad (2)$$

$$\sigma^2_t = \omega + \alpha\varepsilon^2_{t-1} + \beta\sigma^2_{t-1}. \quad (3)$$

where $N(\cdot)$ defines the conditional normal density. All models were estimated using the Berndt, Hall, Hall, and Hausman (1974) algorithm with robust Quasi

Maximum Likelihood based standard errors as described in the Appendix. All the exchange rates appear to be well characterized by the above simple model, and the results compare closely with Baillie and Bollerslev (1989a) who report similar models estimated on weekly 1980s data. The shocks to the conditional variances as represented by $(\alpha + \beta)$ are very persistent. Also, the standardized residuals for all of the six rates show substantial excess kurtosis, thus necessitating the robust inference procedures.[3] In summary, though the exchange rates all exhibit substantial autocorrelation and persistence in their volatility, there is little or no evidence of any own temporal dependence in the mean of returns.

4. Cross Country Volatility Effects of the Exchange Rate

This section explores the possibility of spillover effects among the currencies. Spillover effects have recently been examined by Engle, Ito and Lin (1990) and Baillie and Bollerslev (1991), both of whom use data on several different currencies and market locations in the current floating period. Since the 1920s data are only available from one market location it is not possible to directly determine how news or volatility is transmitted from one market location to another. However, the key idea of seeing how volatility spills over from one currency to another, either contemporaneously, or with a lag, remains the same.

Many authors have discussed the role of news on the behavior of exchange rates in the recent float. For example, Cornell (1983) and Ito and Roley (1987) have considered news on money supply announcements, while Ito (1987) has examined the effect of policy regime changes. We shall not attempt to explicitly model the news arrival process to the market. Instead, Table 3 contains a series of Robust Wald statistics for the hypothesis that the lagged surprise of its own and other exchange rates do not influence mean returns. It can be seen from Table 3 that there is virtually no evidence that lagged returns Granger causes mean returns, either individually or collectively for any of the currencies.

While it is reasonable for volatility to be autocorrelated across time and space, as in the "heat wave" and "meteor shower" hypotheses set forward in Engle, Ito and Lin (1990), an efficient market should quickly incorporate volatility caused by news into its mean price. Hence, the possibility of lagged volatility Granger causing mean prices or mean returns, would violate the notion of strong form efficiency. A test for this form of market inefficiency is equivalent to testing for GARCH in the mean (GARCH-M) effects, where the lagged conditional standard deviations are used to explain mean returns. The original ARCH-M model introduced by Engle, Lilien, and Robins (1987) is the model used for this purpose, where interest focuses on whether lagged conditional standard deviations significantly causes mean returns. Table 4 presents a series of Robust Wald statistics to test this proposition. Again the evidence is generally supportive of market efficiency with no systematic effects of news or volatility on one currency being useful in predicting returns on another for 30 of the 36 possible relationships. The exceptions to this are the mean returns of Italy and Switzerland that strongly react to volatility on the Belgium and French currencies. However, a considerable amount of these significant relationships appear to be due to events around the time of the Bear Squeeze in March 1924 when volatility peaked on the French and Belgium francs. In order to isolate the degree of dependence that is due to the highly abnormal bear squeeze period we included two dummy variables in the French and Belgium conditional variance equations for the weeks of March 11 and 18, 1924 and then used these adjusted conditional standard deviations in the model presented in Table 4. For Italy, for example the Robust Wald statistics were reduced from 14.916 to 11.304 for Belgium volatility and from 13.351 to 11.977 for the effect of French volatility. Thus although the bear squeeze appears to be an important factor, it is by no means the only occasion when news on the French and Belgium currencies was related to subsequent mean returns on the Italian and Swiss currencies. Similar results can also be seen from Table 5 where lagged volatility on the Belgium and French francs are related to volatility on the Italian and Swiss currencies.

5. Conclusions

The 1920s provide an interesting experiment on the success of a floating exchange rate system and despite the relatively primitive conditions compared with todays markets, the 1920s exchange rate returns appear remarkably similar in pattern to todays markets, with a highly persistent volatility process. In general little evidence is available to question the efficiency of these markets: although lagged news and volatility on the French and Belgium currencies appear to be transmitted to future returns on the Italian lira and the Swiss Franc. While a certain amount of this "inefficiency" appears due to the events surrounding the famous Bear Squeeze of March 1924 there are probably other periods as yet unaccounted for when this causal flow of information occurred. For the other currencies, no such departure from efficiency could be found.

Table 1

QMLE of the model:

$$100\Delta \log s_t = \mu + \varepsilon_t$$

$$\varepsilon_t | \Omega_{t-1} \sim N(0,\omega)$$

	Belgium	Britain	France	Holland	Italy	Switzerland
μ	0.321 (.0269)	-0.051 (.048)	0.354 (.283)	-0.026 (.038)	0.130 (.144)	0.008 (.054)
ω	11.970 (2.538)	0.381 (.067)	13.941 (4.648)	0.304 (.073)	3.369 (.478)	0.438 (.081)
Log L	-431.229	-151.795	-443.730	-133.107	-328.137	-163.228
Q(10)	27.139	8.592	14.624	5.521	9.928	15.721
$Q^2(10)$	39.652	17.754	18.650	61.005	74.381	27.854
m_3	-.971	-.427	-2.165	-.039	0.161	0.205
m_4	8.233	6.038	18.769	10.477	4.266	6.572

Key: All countries were estimated for T = 162 weekly observations from February 25, 1922 through March 28, 1925.

Robust standard errors appear in parenthesis below corresponding parameter estimates; m_3 and m_4 are respectively the sample skewness and kurtosis coefficients of the standardized residuals. Under the assumption of normality $m_3 \sim N(0,6/T)$ and $m_4 \sim N(3,24/T)$ asymptotically. Q(10) and $Q^2(10)$ are the Ljung Box statistic based on the first 10 lags of the autocorrelations of the standardized residuals, and squared standardized residuals respectively.

Table 2

QMLE with Robust Standard Errors of the model:

$$100\Delta \log s_t = \mu + \epsilon_t$$

$$\epsilon_t | \Omega_{t-1} \sim N(0, \sigma_t^2)$$

$$\sigma_t^2 = \omega + \alpha\epsilon_{t-1}^2 + \beta\sigma_{t-1}^2$$

	Belgium	Britain	France	Holland	Italy	Switzerland
μ	0.013 (.129)	-.060 (.049)	.203 (.143)	.004 (.022)	.152 (.083)	.031 (.036)
ω	0.268 (.184)	.076 (.042)	.763 (.462)	.014 (.009)	.201 (.193)	.140 (.072)
α	.517 (.168)	.394 (.137)	.429 (.191)	.484 (.184)	.215 (.087)	.414 (.222)
β	.591 (.094)	.473 (.181)	.586 (.117)	.533 (.113)	.728 (.124)	.287 (.250)
Log L	-398.987	-141.489	-404.873	-90.143	-310.921	-146.477
Q(10)	12.839	15.218	7.119	16.043	7.875	18.533
$Q^2(10)$	6.979	10.519	13.045	6.734	13.821	2.718
m_3	.027	-.766	.177	.031	.361	.066
m_4	4.122	5.920	4.333	3.709	3.855	4.663

Key: As for Table 1.

Table 3

Robust Wald Tests for Causality in Mean:

$$100\Delta\log s_{it} = \mu_i + \epsilon_{it} + \gamma_j \hat{\epsilon}_{jt-1}$$

$$\epsilon_{it}|\Omega_{t-1} \sim N(0,\sigma^2_{it})$$

$$\sigma^2_{it} = \omega_i + \alpha_i\epsilon^2_{it-1} + \beta_i\sigma^2_{it-1}$$

Effect of lagged innovations $\hat{\epsilon}_{jt-1}$:

	BL	BR	FR	HL	IT	SW
$\hat{\epsilon}_{BL\ t-1}$	1.000	0.074	0.314	0.141	1.586	0.132
$\hat{\epsilon}_{BR\ t-1}$	0.050	0.000	0.880	0.500	0.000	0.545
$\hat{\epsilon}_{FR\ t-1}$	0.169	0.250	0.088	0.020	0.911	0.141
$\hat{\epsilon}_{HL\ t-1}$	0.427	0.844	0.017	.027	0.013	0.000
$\hat{\epsilon}_{IT\ t-1}$	0.391	0.790	0.496	0.128	1.235	0.479
$\hat{\epsilon}_{SW\ t-1}$	0.238	0.629	0.045	1.111	3.104	5.219*
$\Sigma\hat{\epsilon}_{j\ t-1}$	8.655	3.224	9.341	3.768	3.945	1.805

Key: All the elements in the first six rows have an asymptotic χ^2_1 distribution under the null and the elements in the final row are asymptotically χ^2_5 distributed. One asterisk denotes significance at the .05 level and two asterisks indicates significance at the .01 level. The final row of the table denotes the Wald test statistic when all five other lagged conditional residuals are included in the equation for mean returns. Own lagged returns are not included.

Table 4

Robust Wald Tests for Causality of Conditional Standard Deviation:

$$100\Delta \log s_{it} = \mu_i + \epsilon_{it} + \lambda_j \hat{\sigma}_{jt}$$

$$\epsilon_{it}|\Omega_{t-1} \sim N(0, \sigma^2_{it})$$

$$\sigma^2_{it} = \omega + \alpha_i \epsilon^2_{it-1} + \beta_i \sigma^2_{it-1}$$

Effect of conditional variances $\hat{\sigma}_{jt}$:

	BL	BR	FR	HL	IT	SW
$\hat{\sigma}_{BLt}$	0.898	1.000	1.128	2.116	14.916**	9.434**
$\hat{\sigma}_{BRt}$	0.560	1.054	0.055	0.000	1.359	0.183
$\hat{\sigma}_{FRt}$	0.336	2.678	2.384	0.826	13.351**	5.556*
$\hat{\sigma}_{HLt}$	0.699	2.589	0.007	0.184	0.498	1.032
$\hat{\sigma}_{ITt}$	0.474	1.214	0.084	2.028	9.620	1.588
$\hat{\sigma}_{SWt}$	4.386*	0.286	0.046	4.054*	3.340	0.885
$\Sigma\hat{\sigma}_{jt}$	7.487	10.162	4.302	6.517	31.935**	15.216**

Key: As for Table 3.

Table 5

Robust Wald Tests for Causality in Variance:

$$100\Delta\log s_{it} = \mu_i + \epsilon_{it}$$

$$\epsilon_{it}|\Omega_{t-1} \sim N(0,\sigma^2_{it})$$

$$\sigma^2_{it} = \omega_i + \alpha_i\epsilon^2_{it-1} + \beta_i\sigma^2_{it-1} + \gamma_j\,\hat{\sigma}^2_{jt}$$

	BL	BR	FR	HL	IT	SW
$\hat{\sigma}^2_{BL\ t}$	--	20.25**	4.514*	0.563	1.000	0.111
$\hat{\sigma}^2_{BR\ t}$	1.250	--	0.142	1.591	8.869**	29.566**
$\hat{\sigma}^2_{FR\ t}$	0.0003	1.000	--	0.444	4.000*	0.442
$\hat{\sigma}^2_{HL\ t}$	0.857	1.000	0.028	--	9.990**	5.760*
$\hat{\sigma}^2_{IT\ t}$	1.700	0.640	1.846	0.444	--	0.000
$\hat{\sigma}^2_{SW\ t}$	3.642	0.016	0.307	0.009	1.313	--
$\Sigma\hat{\sigma}^2_{j\ t}$	4.922	26.542	8.291	3.476	5.838	26.865**

Key: As for Table 3.

Appendix

This appendix describes the robust standard error procedure developed in Weiss (1986), Bollerslev and Wooldridge (1988), and Wooldridge (1990). Let,

$$\mu_t(\theta) = E_{t-1}(y_t)$$
$$\sigma_t^2(\theta) = \mathrm{var}_{t-1}(y_t)$$

denote the conditional mean and the variance for y_t as a function of the unknown parameters θ. It is also convenient to define

$$\epsilon_t(\theta) = y_t - \mu_t(\theta).$$

Following Bollerslev and Wooldridge (1990), if the model for y_t correctly parameterizes $\mu_t(\theta)$ and $\sigma_t^2(\theta)$, the Quasi Maximum Likelihood Estimator (QMLE) for θ, say $\hat{\theta}_T$, obtained under the auxiliary assumption of conditional normality, will under fairly general regularity conditions be $\sqrt{T}$ consistent for the true parameters, θ_0, and asymptotically normally distributed. Furthermore, a consistent estimate for the asymptotic covariance matrix for $\hat{\theta}_T$ is readily available, as

$$\sqrt{T}(\hat{A}_T^{-1}\hat{B}_T\hat{A}_T^{-1})^{-\frac{1}{2}}(\hat{\theta}_T - \theta_0) \xrightarrow{D} N(0,I) \tag{A1}$$

where

$$\hat{A}_T = T^{-1}\cdot\sum_{t=1}^{T} [\nabla_\theta\mu_t(\hat{\theta}_T)'\nabla_\theta\mu_t(\hat{\theta}_T)\sigma_t^{-2}(\hat{\theta}_T) + .5\nabla_\theta\sigma_t^2(\hat{\theta}_T)'\nabla_\theta\sigma_t^2(\hat{\theta}_T)\sigma_t^{-4}(\hat{\theta}_T)] \tag{A2}$$

$$\hat{B}_T = T^{-1} \bullet \sum_{t=1}^{T} [\nabla_\theta \mu_t(\hat{\theta}_T)' \nabla_\theta \sigma_t^{-2}(\hat{\theta}_T) \epsilon(\hat{\theta}_T) + .5 \nabla_\theta \sigma_t^2(\hat{\theta}_T)' \sigma_t^{-4}(\hat{\theta}_T)(\epsilon_t^2(\hat{\theta}_T) - \sigma_t^2(\hat{\theta}_T))]$$

$$[\nabla_\theta \mu_t(\hat{\theta}_T)' \nabla_\theta \sigma_t^{-2}(\hat{\theta}_T) \epsilon(\hat{\theta}_T) + .5 \nabla_\theta \sigma_t^2(\hat{\theta}_T)' \sigma_t^{-4}(\hat{\theta}_T)(\epsilon_t^2(\hat{\theta}_T) - \sigma_t^2(\hat{\theta}_T))]' \quad \text{(A3)}$$

It should be noted that, the expressions in (A2) and (A3) involve first derivatives of the conditional mean and variance functions only. This is particularly appealing when numerical derivatives are being used. Also, when the assumption of conditional normality is satisfied, the usual equalities hold true; i.e., $E(\hat{A}_T^{-1}\hat{B}_T \hat{A}_T^{-1}) = E(\hat{A}_T^{-1}) = E(\hat{B}_T^{-1})$. The limiting distribution available from A3 is then used to construct the robust Wald statistics used throughout this paper.

Notes

1. For the German mark, not analyzed any further here, the unit root hypothesis can be rejected in favor of an explosive alternative.

2. Restricting the analysis to France, Belgium and Italy in order to increase the potential power of the test does not alter this conclusion. The findings of Baillie and Bollerslev (1989a) and the implications concerning the predictability of at least one of the nominal rates have recently been challenged by Diebold and Yilmaz (1990) in the context of an expost forecasting experiment.

3. An alternative to the QMLE based robust standard errors would be to estimate models with fat tailed conditional densities such as the student t density, as in Baillie and Bollerslev (1989b). Experience with this data in this study indicated the robust standard errors was a more tractable procedure.

References

Aliber, R. Z., "Speculation in the Foreign Exchanges: The European Experience, 1919-1926", Yale Economic Essays, 1962, **2** :171-245.

Baillie, R.T. and T. Bollerslev, "Common Stochastic Trends in a System of Exchange Rates", Journal of Finance, March 1989, **44**: 167-181 (1989a).

Baillie, R.T. and T. Bollerslev, "The Message in Daily Exchange Rates: A Conditional Variance Tale", Journal of Business and Economic Statistics, July 1989, **7**: 297-305.

Baillie, R.T. and T. Bollerslev, "Intra-Day and Inter-Market Volatility in Foreign Exchange Markets", Review of Economic Studies, May 1991, **58**: 565-585.

Berndt, E.K., B.H. Hall, R.E. Hall and J. Hausman, "Estimation and Inference in Nonlinear Structural Models", Annals of Economic and Social Measurement, 1974, **4**: 653-665.

Bollerslev, T., "Generalized Autoregressive Conditional Heteroskedasticity", Journal of Econometrics, April 1986, **31**: 307-327.

Bollerslev, T. and J. Wooldridge, "Quasi-Maximum Likelihood Estimation of Dynamic Models with Time Varying Covariances", forthcoming Econometric Reviews, 1991.

Cornell, B., "The Money Supply Announcement Puzzle: Review and Interpretation", American Economic Review, 1983, 73: 644-657.

Cumby, R.E. and J. Huizinga, "Testing the Auto-Correlation Structure in Disturbances in Ordinary Least Squares and Instrumental Variables Regression", University of Chicago, unpublished manuscript, 1988.

Diebold, F.X., "Testing for Serial Correlation in the Presence of ARCH", Proceedings of the American Statistical Association, Business and Economic Statistics Section, 1986, 323-328.

Diebold, F.X. and K. Yilmaz, "Cointegration and Exchange Rates: Is the Martingale Model Dead?", University of Pennsylvania Working Paper, 1990.

Einzig, P., "The Theory of Forward Exchange, 1937, London; MacMillan.

Einzig, P., "The History of Foreign Exchange, 1962, New York; St. Martin's Press.

Engle, R.F., "Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of UK Inflation", November 1982, 50: 987-1008.

Engle, R., D.M. Lilien and R.P. Robins, "Estimating Time Varying Risk Premia in the Term Structure: The ARCH-M Model", Econometrica, March 1987, 55: 391-407.

Engle, R.F., T. Ito, and W. Lin, "Meteor Showers or Heat Waves? Heteroskedastic Intra-Daily Volatility in the Foreign Exchange Market", Econometrica, 1990, **58**: 525-542.

Fama, E., "The Behavior of Stock Market Prices", Journal of Business, January 1965, **38**: 34-105.

Hamao, Y., R. Masulis and V. Ng, "The Effects of the Stock Market Crash on Financial Integration", No.2, 1990, Review of Financial Studies, **3**: 281-307.

Hsieh, D.A., "Modeling Heteroskedasticity in Daily Foreign-Exchange Rates, Journal of Business and Economic Statistics, July 1989, **7**: 307-317.

Ito, T., "The Intra-daily Exchange Rate Dynamics and Monetary Policies After the G5 Agreement", Journal of Japanese and International Economies, 1987, **1**: 275-298.

Ito, T., and V. V. Roley, "News form the U.S. and Japan: Which Moves the Yen/Dollar Exchange Rate", Journal of Monetary Economics, 1987, **19**: 255-277.

Johansen, S., "Statistical Analysis of Cointegration Factors", Journal of Economic Dynamics and Control, 1988, **12**: 231-254.

Johansen, S. and K. Juselius, "The Full Information Maximum Likelihood Procedure for Inference on Cointegration - with Applications", 1989, Institute of Mathematical Statistics, University of Copenhagen.

Ljung, G. M. and G. E. P. Box, "On a Measure of Lack of Fit in Time Series Models", Biometrika, March 1978, **65**: 297-303.

Mandlebrot, B., "The Behavior of Stock Market Prices, Journal of Business, **38**: 34-105.

McCurdy, T. and G.I. Morgan, "Test of the Martingale Hypothesis for Foreign Currency Futures with Time Varying Volatility", International Journal of Forecasting, 1987, **3**: 131-148.

McFarland, J.W., R.R. Pettit and S.K. Sung, "The Distribution of Foreign Exchange Price Changes: Trading Day Effects and Risk Measurement", Journal of Finance, June 1982, **37**: 693-715.

Messe, R.A. and K.J. Singleton, "On Unit Roots and the Empirical Modeling of Exchange Rates", Journal of Finance, September 1982, **37**: 1029-1035.

Milhøj, A., "A Conditional Variance Model for Daily Deviations of an Exchange Rate", January 1987, Journal of Business and Economic Statistics, **5**: 99-103.

Phillips, P.C.B., "Time Series Regression with a Unit Root", Econometrica, March 1987, **55**: 335-346.

Phillips, P.C.B. and P. Perron, "Testing for a Unit Root in Time Series Regression", Biometrika, 1988, **75**: 335-346.

Shepherd, H., The Monetary Experience of Belgium, 1936, Princeton, Princeton University Press.

Weiss, A., "Asymptotic Theory for ARCH Models: Estimation and Testing", Econometric Theory, 1986, **2**, 107-131.

Wooldridge, J.M., "A Unified Approach to Robust Regression-Based Specification Tests, 1990, Econometric Theory, **6**: 17-43.

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