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Yu Cai
Michigan Technological University, cai@mtu.edu

Howard Qi
Michigan Technological University, howardqi@mtu.edu

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A Computational Analysis of Exchange Rate Time Series

Yu Cai and Howard Qi

School of Business and Economics, Michigan Technological University, United States of America.

Corresponding Author: Yu Cai

Abstract

International trade and its expansion with the rise of modern global economies create a need for buying, selling or borrowing a multiplicity of foreign currencies. A key aspect of currency exposures is that a company might add extra risk due to selling or buying foreign currency due to the volatile exchange rate influenced by a variety of exogenous and endogenous factors. We have conducted a fairly comprehensive computational investigation of the exchange rate using time series based on econometric analysis. We choose the exchange rate between the US dollar and the British pound because of the pounds influential position in the US economy. It is important for a manager to understand the exchange rate movement for his / her strategic decision-making. This study performs an empirical time series analysis of the exchange rate movements, and serves as a basic exploratory effort on the understanding of the exchange rate risk. We hope our empirical investigation may provide some guidance or information that is useful for further theoretical research endeavors.

Keywords: exchange rate, time series, econometric analysis, US dollar, British pound

INTRODUCTION

With market globalization, a growing number of U.S. corporations have crossed geographical boundaries and become truly multinational in nature. Therefore, this type of globalization of commerce creates a need for buying, selling or borrowing foreign currencies. On the other hand, international trade also takes place when two countries have supplementary industries or there exists a pricing disparity. To put it fairly, exposing to exchange rate risk becomes an ever-growing challenge to more and more firms in the modern world (see, for example, Coyle, 2000). A key aspect of currency exposures is that although a company might wish to make a planned profit, certain costs from its international selling or buying and exchange rate movements can put the plan at risk. Profits or losses can become more dependent on exchange rate changes than on the inherent profitability of the underlying trade in goods or services. This has encouraged us to conduct an exploratory analysis of the correlation of exchange rate between the US dollar and the British pound because of the pounds influential position in the US economy. For example, the LIBOR (London Inter-bank offered rate) has been used widely in the U.S. as a benchmark rate for setting the terms for many interest rate financial products. Besides, it is likely important for a manager to understand the exchange rate movement for his / her strategic decision making in this ever growing globalization environment.

Historical efforts regarding the exchange rate are more focused on the effect from announcement. For example, the paper by Anderson et al (2002) used a newly constructed dataset consisting of six years of real-time exchange rate quotations, macroeconomic expectations, and macroeconomic realizations. They characterized the conditional mean of the US dollar spot exchange rate for the German mark, British pound, Japanese yen, Swiss franc, and the euro. The important finding indicated conditional mean adjustments of exchange rates to news occur quickly compare to conditional variance adjustment. Besides an announcement's impact depends on its timing relative to other related announcement, on whether the announcement time is known in advance. Moreover, the adjustment response pattern is characterized by a sign effect. The sign effect refers to the fact that the market reacts to news in an asymmetric fashion. In general, bad news has greater impact than good news.

Multiple Regression Models

We used a variety of economic factors to understand the exchange rate movement. The linear relationship [1] between different economic factors and the exchange rate can be determined using the multiple regression models which also may help to identify the major contributors influencing the exchange rate between the US dollar and the British pound. Details of building the regression models were based on the following multiple regression models

[1] *For simplicity, we assume linearity as the first order of approximation. On the other hand, many nonlinear relationships may be converted into linear ones after certain algebraic transformations.*

$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + ... + \beta_k x_{ki} + e_i$ (i = 1, ... , n) where e_i's are iid with random N($0, \sigma^2$) errors. The variables are explained as follows.

(1) **Response Variable (y) - Exchange rate (XRate)**: The exchange rate between the two currencies.

(2) **Predictor Variables (x_1, x_2, …, x_{10})**: Various factors that are related to the performance of the US and the UK economies are used in the study. Due to different reporting system between the US and the UK, all data are quarterly based so as to maintain consistency in the available information. We choose quarterly data because of a few reasons. First, they are readily available. Second, they are less messy than daily data but provide more information than annual data in terms of sample size and movements.

(3) **XRate_1**: The preceding exchange rate between the US dollar and the British pound.

(4) **% d_GDP**: The percentage change of Gross Domestic Product (GDP). GDP is defined as the value of the final goods and services produced in the economy during the course of a period of time.

(5) **% d_PPI**: Refer to the percentage change of Producer Price Indexes (PPI). PPI is based on the selling prices reported by establishment(S) of all sizes selected by probability sampling, with the probability of selection proportional to size. PPI measures the average change in prices received by domestic producers of commodities in all stages of processing.

(6) **% d_IR**: The percentage change of the Interest Rate (IR). IR is an annual percentage rate associated with transferring, borrowing or lending, money for a period of time.

(7) **% d_BI**: The percentage change of the Broad Index (BI). BI is a weighted average of the foreign exchange values of the U.S. dollar against the currencies of a large group of major U.S. trading partners. The index weights, which change over time, are derived from U.S. export shares and from U.S. and foreign import shares.

(8) **% d_NMC**: The percentage change of the Nominal Major Currencies (NMC). NMC is a weighted average of the foreign exchange values of the U.S. dollar against a subset of currencies in the broad index that circulate widely outside the country of issue.

(9) **% d_OITP**: The percentage change of the Other Important Trading Partners Index (OITP). OITP is a weighted average of the foreign exchange values of the U.S. dollar against a subset of currencies in the broad index that do not circulate widely outside the country of issue. Choosing these variables in our model has a few reasons. First, they are available. Second, since this study has the nature of exploration. We are not sure whether these variables cast an influence on exchange rate or not, therefore it is worthwhile to investigate whether there is a statistically significant role may play. If the answer is more confirmatory, then it provides a stronger justification and motivation for further theoretical investigations.

Data Overview and Model Building

It is well documented that there is a sizable drop in the exchange rate between the US dollar and the British pound in the past 13 years at the fourth quarter of 1992 because British announced to withdraw from the Euro Currency Proposal at the end of 1992. Comparing the descriptive statistics between 80% of sample and 20% of sample, the lower exchange rate in two groups are roughly same, which was 1.4462 and 1.4212 respectively. But the highest exchange rate in 80% of sample (1.9439) is much higher than in 20% of sample (1.6183). It indicated the currency fluctuation from Q1 1990 to Q4 2000 are much more than from Q1 2001 to Q3 2003. The techniques we implement in carrying out the investigative data analysis are fairly standard and widely available, Hamilton (1994), Tsay (2002), and Wei (1990)

Model 1: A Simple Time Series Regression. Using our data, we identified the following regression model and the parameters.

Xrate = 1.63 − 0.0144 UK-%d_GDP + 0.0611 UK-%d_PPI + 0.00212 UK-%d_IR + 0.0143 USA-%d_GDP − 0.0048 USA-%d_PPI − 0.00959 USA-%d_IR+ 0.0264 %d_BI − 0.0282 %d_NMC − 0.00760 %d_OITP

<u>Analysis:</u> Overall model 1 is significant with p-value is 0.001. The normality plot is close to a straight line except for several points. The residual analysis was good without any pattern in the residual plot versus the fitted value. However R-Square 53.8% is not high, and also the model contains too many predictor variables. Besides, there is multicolleaniarity problem in the model 1 because VIF value for %d_BI and %d_NMC was 16.1 and 15.2, which were greater than 10. So we tried other models.

Model 2: Stepwise Regression

The regression results are as follows.

Xrate = 1.63 − 0.00878 USA-%d_IR − 0.0138 %d_NMC

<u>Analysis:</u> In general, the model has a good normality and clear residuals. All the variables in model 2 are significant. However, the R-Sq (46.9%) reduced. Besides, Durbin-Waston statistics = 0.80 < 1.39, based on 5% significant level, it indicated there is autocorrelation

problem in the model 2, which is also shown from autocorrelation graph.

Model 3: Best Subsets Regression

The regression results are given below,

Xrate = 1.62 + 0.0291 UK-%d_PPI − 0.00855 USA-%d_IR − 0.0127 %d_NMC

Analysis: Overall, the model 3 has a good normality and clear residuals. All the variables in model 3 are significant except for UK-%d_PPI (when we deleted the insignificant term, we got the same model as model 2), and the R-Sq (49.4%) was low. Besides, Durbin-Waston statistics = 0.79 < 1.34 , based on 5% significant level, it indicates there is autocorrelation problem in the model 3, which is also shown from autocorrelation graph.

Model 4: Addressing the Autocorrelation Issue

Since in model 2 and model 3, there are autocorrelation problems and usually in time series, this indicates we lose one important predictor in the model. Since in time series data, people consider the lagged value of the response variable as one of the predictors. So we add the lag 1 term into the regression model and we get the same model using best subset regression method and stepwise regression method. The regression results are as follows.

Xrate = 0.310 + 0.814 Xrate-lag − 0.0158 %d_NMC + 0.00423 UK-%d_IR − 0.00311 USA-%d_IR

Analysis: After adding the lag term into the model, the R-square is greatly increased (from 46% to 87.6%), it also has a good normality and clear residuals. All the variables in model 4 are significant and the overall model is also significant. Besides, Durbin-Waston statistics= 1.86 > 1.72 , based on 5% significant level, it indicates there is no autocorrelation problem in the model 4, which is also shown from autocorrelation graph.

Test of Seasonal Pattern

Since our data are quarterly time series data, we add a Xrate-lag4 term into the model to see whether there is a seasonal effect. If there is significant seasonal pattern, then the seasonal term Xrage-lag4 should be significant. Using stepwise method, the regressors only contain Xrate-lag1, %d_NMC,UK-%d_IR, USA-%d_IR.

Our regression results show that there is not a significant seasonal effect. This conclusion is based on the p-value of Xrate-lag4 which is 0.043, a number very close to 0.05; in other words, there is only a very weak seasonal effect in the data. This agrees with the fact that when we add the seasonal term Xrate-lag4 into the regressors, the model selected by using stepwise and best subset methods is the same as the one where we don't consider the seasonal term as the predictors, i.e., the model still doesn't contain the seasonal term-Xrate-lag4. Therefore, model 4 is still the best model we tried.

Model Comparison and Conclusions

From all 4 models, we decided to select model 4 because of the high R-Square, low standard deviation, and no autocorrelation problem. Please refer to the comparison table for the detail. (*means that term is significant in the regression model).

Table 1. Summary of Model Regression Results

Predictors	Model 1	Model 2	Model 3	Model 4
Constant	1.63*	1.63*	1.62*	0.310*
UK-%d_GDP	-0.0144			
UK-%d_PPI	0.0611		0.0291	
UK-%d_IR	0.00212			0.00423*
USA-%d_GDP	0.0143			
USA-%d_PPI	-0.0048			
USA-%d_IR	-0.00959*	-0.00878*	-0.00855*	-0.00311*
%d_BI	0.0264			
%d_NMC	-0.0282	-0.0138*	-0.0127*	-0.0158*
%d_OITP	-0.0076			
Xrate-lag				0.814*
R-Sq	53.80%	46.90%	49.40%	87.60%
S	0.09133	0.08915	0.08806	0.04468
Autocorrelation	NA	Yes	Yes	No

Model Validation

20 percent (11 data) of sample were used to test the model validation. The graph below indicated the difference between the fitted value and actual value. The ratio of the MSPE and the MSE (0.0018544/0.002) was 0.927214, which is much less than 4. It indicates the model is valid.

Table 2. Model Predictive Power

Xrate	Predicted	Residual
1.4581	1.5131	-0.055
1.4212	1.49683	-0.07563
1.4373	1.46702	-0.02972
1.4426	1.48052	-0.03792
1.4261	1.48368	-0.05758
1.4421	1.47145	-0.02935
1.5497	1.48464	0.065061
1.5714	1.57205	-0.00066
1.5784	1.59026	-0.01186
1.6183	1.59585	0.022448
1.6107	1.62739	-0.01669

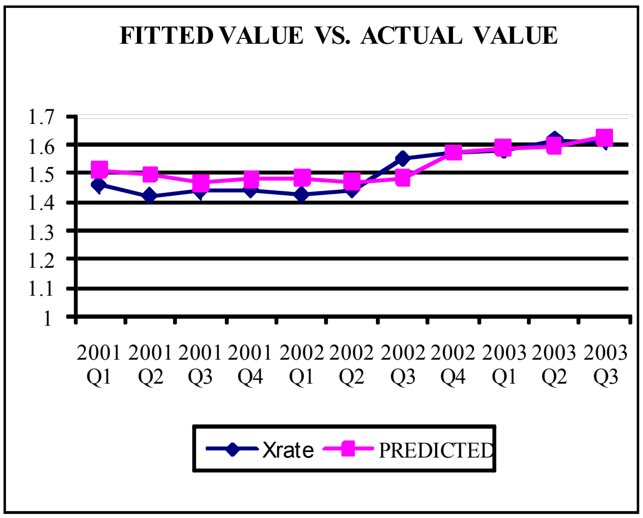

Figure 1. Model-Predicted Value versus Actual Value:

Model 4's performance. The closeness of these two curves presents visual evidence in support of Model 4's performance.

INTERPRETATION AND CONCLUSIONS

The final model selected with the regression results is given below.

Xrate = 0.310 + 0.814 Xrate-lag – 0.0158 %d_NMC + 0.00423 UK-%d_IR– 0.00311 USA-%d_IR

This model in terprets the exchange rate movement between US dollars and British pounds were based on the preceding exchange rate. Besides, %d_NMC, UK-%d_IR, and USA - %d_IR also play significant role to the exchange rate. However, this research has its limitation including the difficulty of increasing the sample size due to some variables only available on a quarterly basis. Overall, this study has its merit on providing a reasonable sense of the exchange rate movement between US dollars and British Pounds to the management, and helping the management to better understand the movement of the exchange rate between US dollars and British Pounds. Since the coefficient of Xrate-lag term is very close to 1, we also investigated the regression equation for the change of the exchange rate using stepwise regression method. Our overall model is significant as follows:

change = – 0.0228 – 0.0178 %d_NMC + 0.00429 UK-%d_IR – 0.00172 USA-%d_IR + 0.0226 UK-%d_GDP

In this study, we performed computational time series analysis of exchange rate movements. We pick the exchange rate between the British pound and the US dollar because the availability of the data and the relative importance of their roles in the modern business world. We tested a few time series models in an ad hoc fashion aimed at investigating the time series characteristics of the exchange rate. Our hope is to reveal what factors may be playing an important role and what factors are not so relevant. Our study serves as a basic exploratory effort on the understanding of the exchange rate risk. We hope our empirical investigation may provide some guidance or information that is useful for further theoretical research endeavors.

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