A computational analysis of exchange rate time series

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A Computational Analysis of Exchange Rate Time Series

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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 pound's 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 pound's 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 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

\[ \text{Exchange Rate} = \beta_0 + \beta_1 \text{Economic Factor}_1 + \beta_2 \text{Economic Factor}_2 + \cdots + \beta_k \text{Economic Factor}_k + \epsilon \]

\[ \text{For simplicity, we assume linearity as the first order of approximation. On the other hand, many nonlinear relationships may be converted into linear ones after certain algebraic transformations.} \]
The regression results are as follows.
\[
Xrate = 1.63 - 0.0144 \text{UK-\%d\_GDP} + 0.0611 \text{UK-\%d\_PPI} + 0.00212 \text{UK-\%d\_IR} + 0.0143 \text{USA-\%d\_GDP} - 0.0048 \text{USA-\%d\_PPI} - 0.00959 \text{USA-\%d\_IR} + 0.0264 \text{\%d\_BI} - 0.0282 \text{\%d\_NMC} - 0.00760 \text{\%d\_OITP}
\]

**Analysis:** 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 multicollinearity 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.
\[
Xrate = 1.63 - 0.00878 \text{USA-\%d\_IR} - 0.0138 \text{\%d\_NMC}
\]

**Analysis:** 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,
\[
X_{rate} = 1.62 + 0.0291 \ \text{UK-\%d\_PPI} - 0.00855 \ \text{USA-\%d\_IR} - 0.0127 \ \text{\%d\_NMC}
\]

**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.
\[
X_{rate} = 0.310 + 0.814 \ \text{Xrate-lag} - 0.0158 \ \text{\%d\_NMC} + 0.00423 \ \text{UK-\%d\_IR} - 0.00311 \ \text{USA-\%d\_IR}
\]

**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 Xrate-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**

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

**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

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

![Fitted Value vs. Actual Value](image)

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.

\[ Xrate = 0.310 + 0.814 \times Xrate_{-\text{lag}} - 0.0158 \times \%d\_NMC + 0.00423 \times \text{UK-\%d\_IR} - 0.00311 \times \text{USA-\%d\_IR} \]

This model interprets the exchange rate movement between US dollars and British pounds based on the preceding exchange rate. Besides, \%d\_NMC, UK-\%d\_IR, and USA - \%d\_IR also play a 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:

\[
\text{change} = -0.0228 - 0.0178 \times \%d\_NMC + 0.00429 \times \text{UK-\%d\_IR} - 0.00172 \times \text{USA-\%d\_IR} + 0.0226 \times \text{UK-\%d\_GDP}
\]

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 of 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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