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A fuzzy logic model for forecasting exchange rates

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ABSTRACT

This article is devoted to the issue of forecasting exchange rates. The objective of the conducted research is to develop a predictive model with the use of an innovative methodology – fuzzy logic theory – and to evaluate its effectiveness in times of prosperity (years 2005–2007) and during the financial crisis (years 2009–2011).

The model is based on sets of rules written by the author in the form of IF-THEN, where expert knowledge is stored. This model is the result of ten years of the author's research on this issue.

Empirically, this paper employs three currency pairs as experimental datasets: JPY/USD, GBP/USD and CHF/USD. From the model verification, it is demonstrated that refined processes are effective in improving the forecasting of exchange rate movements. The author's created model is characterised by high efficiency. These studies are among the world's first attempts to combine fundamental analysis with fuzzy logic to predict exchange rates.

1. Introduction

Exchange rates play an important role in international trade, investment determination, risk management in enterprises and the economic situation of a country by influencing its balance of payment. Many countries have implemented a freely floating exchange rate system that relies upon market mechanisms to adjust the value of their currencies. Currently, interventions of central banks in a currency market are rare and rarely successful when attempted. This ineffectiveness implies that market forces influence exchange rates. Exchange rates adjust over time, and a floating exchange rate system produces results which, in the long run, reflect the underlying economic fundamentals.

The fluctuation of exchange rates might not be understood completely due to a lack of information about factors affecting them. Additionally, in the real world, there are times when input variables cannot always be determined in the precise sense. Therefore, forecasting exchange rates is often uncertain and vague in a number of ways. The lack of models capable of providing reliable predictions of future exchange rates is therefore puzzling. This paper takes a novel perspective on the problem and finds an alternative way of improving the forecasting process by overcoming the drawbacks contained in statistical models and artificial neural networks. This paper should offer a good methodology that could be used more easily by investors. In the paper, the author assumes that there is an effective exchange rate adjustment mechanism operating in market-based economic systems that employ floating exchange rates, and Purchasing Power Parity (PPP) and Interest Rate Parity (IRP) are part of this mechanism. However, the approach taken in this paper is different from previously reported research. It brings together two research approaches – the use of fuzzy logic (the artificial intelligence method) in combination with a fundamental analysis. Fundamental analysis consists of evaluating the economic and political factors behind currency fluctuations and involves four theories (they are characterised in detail in Section 2): Purchasing Power Parity, Interest Rate Parity, the Balance of Payments Model and the Asset Market Model. The PPP theory states that exchange rates are determined by the relative prices of similar sets of goods. The IRP theory states that the fluctuation of one currency against another currency is neutralised by a change in the interest rate differential. While the Balance of Payments Model is mainly focused on stable current account balances, the Asset Market Model is based on financial assets, stating that exchange rates demonstrate a strong correlation with asset markets.

Fuzzy logic provides an appropriate tool for modelling this imprecise, uncertain and ambiguous phenomenon. Because the movement of exchange rates is affected by many factors (economic, political, psychological, etc.) that cannot be precisely and unambiguously defined, such an approach greatly enhances the predictive power of fundamental analysis and makes it an economically useful tool for exchange rate management. The purpose of this paper is to improve the forecasting effectiveness of exchange

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rates with the use of fundamental variables (relative inflation rates, relative interest rates, investments in fixed assets, country ratings, income levels, GDP growth, and trade balance) implemented in the fuzzy logic model.

The paper has the following contribution and innovation to the literature:

- implementation of fuzzy logic theory into fundamental analysis of the exchange rates,
- development of the fuzzy logic models for forecasting the exchange rates (based on economic factors),
- creation of an open application that can be easily updated and adopted for readers' needs,
- comparative analysis of effectiveness between developed fuzzy logic models and models of other research approaches (ARCH model, GARCH model and artificial neural networks).

Empirically, this paper employs three currency pairs as experimental datasets. From the model verification, it is shown that refined processes are effective in improving the forecasting of exchange rate movements.

The paper is organised as follows. Section 2 presents an overview of the main ways of forecasting exchange rate models. Section 3 recalls the technical background of the fuzzy logic model. Section 4 presents the research assumptions. Section 5 proposes forecasting models for the JPY/USD, GBP/USD and CHF/USD. Section 6 presents the conclusions.

2. Types of forecasting exchange rate models in the literature

The problem of predicting the movement of foreign exchange rates has attracted increasing attention. There are three main approaches to forecasting exchange rates in the literature:

(1) The majority of research efforts are devoted to standard models, where volatility is a key parameter used with time-dependent conditional heteroskedasticity. These models belong to the well-known ARCH (autoregressive conditional heteroskedasticity) and GARCH (generalised autoregressive conditional heteroskedasticity) approaches initiated by Engle [15] and Bollerslev [4]. The ARCH/GARCH framework has proven to be successful in predicting volatility changes. Those models describe the time evolution of the average size of squared errors, that is, the evolution of the magnitude of uncertainty Engle et al. [16]. Despite the empirical success of ARCH/GARCH models, there is no real consensus on the economic reasons why uncertainty tends to cluster. Therefore, the models tend to perform better in some periods and worse in other periods. The example of such research is the study conducted by Brandt and Jones [7], which shows that there is substantial predictability in volatility at horizons of up to 1 year, which is in contrast with earlier studies, such as those by West and Cho [46] and Christoffersen and Diebold [13], both of which conclude that volatility predictability is essentially a short-horizon phenomenon. Additionally, the application of ARCH models may be problematic according to Lamoreux and Lastrapes [28] because ARCH estimates are seriously affected by structural changes.

(2) Less popular models are those that use a fundamental analysis. These models are based on the information of the supply and demand and of domestic currency compared with a foreign currency. The following factors are the most commonly listed factors in the literature (for example, [52,31]):

(a) Relative inflation rates – changes in relative inflation rates can affect international trade, which influences the supply and demand of currencies and therefore affects exchange rates. A higher inflation rate in country A than in country B will cause the increase of the import of cheaper products from B to A (*ceteris paribus*[1]). This will result in a higher demand for the currency of country B. At the same time, a higher relative inflation rate in country A will lead to the reduction of the supply of its currency because the export of products will decrease in such circumstances. The higher demand and smaller supply of country A's currency will lead to the appreciation of country B's currency. Such findings are consistent with the conclusions derived from previous studies, for example, those by Parsley and Wei [38] and Qiu et al. [35].

(b) Relative interest rates – changes in relative interest rates affect investment in securities, which influences the supply and demand of currencies. Higher relative interest rates in country A will lead to a higher supply of currency of country B in exchange for the currency of country A because investments in securities in country A will be more profitable for investors (*ceteris paribus*). On the other hand, the demand for currency B should decrease due to less profitable securities. The increase of the supply and the decrease of the demand of country B's currency will cause its depreciation. Gruen and Wilkinson [19] find that the real interest rate differential is qualitatively more important than the balance of trade in forecasting the exchange rate. Similar conclusions can be found in recent studies conducted by Chen [10].

(c) Gross domestic product – a country characterised by a high growth of GDP should attract foreign investors that will seek to use the opportunities for profit in such an economy. A booming economy in country A would lead to a higher demand for its currency (*ceteris paribus*), thereby influencing its appreciation. Karfakis and Phipps [25] and Bergvall [3] report that GDP has a significant influence on exchange rates.

(d) Trade balance – because exports and imports are the elements of GDP, the assumption will be connected to the above assumption. Increasing the exports of country A means that the demand for its currency is increasing, causing its appreciation. Increasing the imports as an opposite to increasing exports will lead to the depreciation of the currency due to a higher supply of the currency of this country (*ceteris paribus*). For example, De Gregorio and Wolf [14] demonstrate that an improved balance of trade will lead to an appreciation of the exchange rate.

(e) Income level – higher GDP accompanies high income levels. However, high-income societies tend to increase their demand for imported goods. According to this assumption, the growth of the income level in the country will lead to the depreciation of its currency (*ceteris paribus*) due to higher imports. Miyakoshi [34] reveals that the variation in the exchange rate is attributable to the productivity and income level.

Fundamental analysis has a few drawbacks in forecasting exchange rate movements. Firstly, besides describing the main economic variables affecting the supply and demand of the domestic currency and foreign currencies, there are many other psychological and political factors that may lead to speculative trading. Secondly, different factors can have different impacts on the exchange rate at different times. There is also empirical

[1] In reality the actual demand and supply of currency depends on several factors simultaneously. The point of holding all other factors constant is to logically present the mechanics how each individual factor influences the exchange rates. Each factor assessed one at a time allows to describe separate influence of each factor on exchange rates. Then, all factors can be tied together to the forecasting model.