Heterogeneity of Traders as a Source of Financial Volatility: The Case of the Foreign Exchange Market

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Abstract

We argue that exchange rate volatility can be explained in terms of the heterogeneity of traders who use differing trading strategies. These strategies are based on expectation formation mechanisms, trading rules or fundamentals. Within these broad categories traders are then classified into 19 different types. Each type is assigned a market weight that reflects the profitability of the underlying trading strategy, and these weights are used to simulate an exchange rate series. It is found that the actual and simulated series exhibit the same volatility patterns and that they belong to the same statistical distribution. It is concluded that trader heterogeneity can generate exchange rate volatility.

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Introduction

The causes and consequences of exchange rate volatility as well as the means whereby it can be reduced have been debated by economists and policy makers extensively. Yet, no consensus view has emerged out of these debates. This paper is a small contribution to these debates, a contribution that deals exclusively with the causes or sources of exchange rate volatility. Specifically, the objective of this paper is to argue for, and provide some evidence on, the view that exchange rate volatility can be attributed to the heterogeneity of traders who buy and sell currencies in the foreign exchange market.

Exchange rate volatility has been described as a puzzle, leading to the conclusion that fundamentals do not have any relevance for exchange rate determination. The inability of fundamental models to explain exchange rate volatility is verified by the casual observation that the volatility of exchange rates far exceeds the volatility of macroeconomic fundamentals. For example, Flood and Rose (1999, p F662) argue that “macroeconomics is an inessential part of the exchange rate volatility puzzle”. As a result of holding this and similar views, these economists have tried to come up with some fancy explanations for exchange rate volatility such as nonlinearities, chaos, news and “factors unknown to economists”.

The alternative explanation for exchange rate volatility that is proposed here and elsewhere is that of trader heterogeneity. This explanation can be found in studies of the microstructure of the foreign exchange market, in studies of survey data on expectation formation in the foreign exchange market and in studies of the profitability of foreign exchange trading. It is even found in the Post-Keynesian
writings on exchange rate determination. What is different about this paper is that it presents a simulation evidence on the effect of heterogeneity on volatility. By assuming that foreign exchange traders act on the basis of various trading strategies to buy and sell currencies (hence heterogeneity), we simulate an artificial exchange rate series from the actions of the traders. Then we test the hypothesis that the simulated exchange rate series and the actual series come from the same statistical distribution. The basic underlying idea is that heterogeneity of traders causes erratic shifts in the market’s excess demand function, hence creating the observed volatility. For the purpose of this exercise, we will use the exchange rate of the British pound versus the U.S. dollar.

**Heterogeneity and Volatility: An Overview**

Moosa (2000a) presents a simple theoretical model that is based on the micro foundations of exchange rate determination to illustrate the relationship between heterogeneity of traders and volatility. The model is based on the idea that observed exchange rate volatility can only result from erratic shifts in the market’s excess demand function that is made up of the excess demand functions of heterogenous traders. The heterogeneity of traders means that they have different sentiments and different expectations at any point in time. Hence, they are likely to react differently to new developments: some want to buy (thus raising excess demand) and some want to sell (thus reducing excess demand). The net effect of their actions is to shift the aggregate excess demand function by a certain amount in a certain direction. In describing the model, Moosa assumes that there are four kinds of traders: technicians
using filter rules, technicians using moving average rules, fundamentalists using rules, and fundamentalists using discretion.¹

Studies of the microstructure of the foreign exchange market seem to support this hypothesis. MacDonald (2000, p 87) argues that it seems impossible to explain the huge daily trading volume in the foreign exchange market in terms of standard open economy models using rational expectation, since this volume must rely on a dispersion of beliefs about the future path of exchange rates. The rational expectations hypothesis rules out the existence of heterogeneity, since it assumes that the true stochastic process generating exchange rates is unique. The market microstructure literature takes as its starting point that agents are heterogenous and seeks to build models that capture the interrelationships between information flows, heterogeneity, trading volume and price volatility (for example, Lyons, 1991, 1993). In Melvin and Yin (2000) exchange rate volatility is implicitly attributed to trader heterogeneity resulting from trading on the basis of public information, private information, noise or a combination thereof.

The microstructural hypotheses have been tested by using survey data on exchange rate expectation. MacDonald and Marsh (1996) found very strong evidence for heterogeneity. They further examined the effect of heterogeneity, as measured by the standard deviation of the consensus expectation, on foreign exchange turnover and found the dispersion of expectations to be significantly positive, thus confirming the microstructural hypothesis. Chionis and MacDonald (1997) pushed the market microstructure test of MacDonald and Marsh further by testing for causality between

¹ The terms “rule” and “discretion” as used in this paper will be explained in a subsequent section.
Studies that are not directly concerned with the market microstructure also imply heterogeneity. Pilbeam (1995a, 1995b) based his study of the profitability of foreign exchange trading on the notion of trader heterogeneity. In Pilbeam (1995a) traders are supposed to follow three different exchange rate determination models (the flexible price monetary model, the sticky price monetary model and the sticky price portfolio model) in conjunction with six expectation formation mechanisms (static, extrapolative, adaptive, regressive, rational and heterogenous). In Pilbeam (1995b) traders are classified into chartists, fundamentalists and simpletons). The same idea forms the basis of the Post-Keynesian theory of exchange rate determination (see for example, Harvey, 1993).

Heterogeneity is supported by the evidence based on survey data on exchange rate expectation indicating that expectations have a distribution (Takagi, 1991). In addition to the distributional factor, heterogeneity in expectation may reflect systematic individual or group effects. Wakita (1989) and Ito (1990) found significant industry-specific bias in expectation. For example, they found that while exporters had expectations of greater yen depreciation (or smaller appreciation), importers expressed exactly the opposite expectation. The heterogeneity of market participants with respect to expectation formation mechanisms means that buy and sell signals arise in a more or less random manner, causing erratic changes in exchange rates. By using eight different expectation formation mechanisms, Moosa and Shamsuddin (2000) reach the conclusion that “the heterogeneity of market participants with
respect to expectation formation goes a long way towards explaining exchange rate behaviour and volatility”.

Trader heterogeneity has also found support in studies of the extent of the use of technical analysis, which show that traders use technical analysis, fundamental analysis or both. Allen and Taylor (1989, 1990) and Taylor and Allen (1992) present evidence on the use of technical analysis based on a survey of some 240 foreign exchange dealers in London. The survey revealed that traders give different weights to technical analysis at different time horizons. Lui and Mole (1998) conducted a similar survey involving 153 foreign exchange dealers in the Hong Kong market. This survey revealed that a very high proportion of the respondents placed some weight on both technical and fundamental analysis at all time horizons. By using an econometric model and proxies for the activities of technicians and fundamentalists, Moosa and Korszak (2000) found some evidence indicating that both technicians and fundamentalists play a role in exchange rate determination.

The Proposed Framework

This paper is based on a generalisation and extension of the ideas proposed by Moosa (2000a), Moosa and Shamsuddin (2000), as well as Pilbeam (1995a,b). We will assume that foreign exchange traders fall into three broad categories, depending on whether they base their buy-sell decisions on: (i) mechanical expectation formation mechanisms; (ii) technical trading rules, and (iii) fundamental analysis. Each of these categories is then subdivided into several types depending on a further classification of (i), (ii) and (iii). In all cases a buy decision is taken if the currency is expected to
appreciate and a sell decision is taken otherwise. Heterogeneity in this respect is due to differences in the criteria that generate buy and sell signals.

By adopting differing trading strategies, the buying and selling actions cause shifts in the excess demand function, leading to changes in the exchange rate. The contribution of each type of trader to the shift in the excess demand function, and hence to the change in the exchange rate, is determined by the weight assigned to each type. The weight is calculated on the basis of the profitability of the underlying strategy, such that the traders who conduct the most profitable operations are assigned the heaviest weight.

The relationship between profitability and the contribution to the actual change in the exchange rate may be explained as follows. Suppose that there are two types of traders, bulls and bears, and that the bulls dominate the market. The bulls believe that the currency will appreciate and so they buy it, while the bears sell it because they believe it will depreciate. Since the bulls dominate the market, the exchange rate will be forced upwards until the excess demand is eliminated. At this stage, the bulls will have made profit, while the bears will have made a loss. Hence, profitability and the contribution to the actual change in the exchange rate are related. The generalisation of this explanation to the case where there are more than two types of traders is straightforward.

Having described the framework adopted in this paper, we will now describe the various trading strategies and how they generate buy-sell signals. The following three sections describe the types of traders under the three broad categories: traders acting
on the basis of expectation formation mechanisms, those using trading rules, and those relying on fundamentals.

**Traders Acting on the Basis of Expectation Formation Mechanisms**

Five types of traders acting on the basis of expectation formation mechanisms are considered. The classification follows from the type of the underlying mechanism. These are: (i) extrapolative, (ii) adaptive, (iii) regressive, (iv) rational, and (v) heterogenous. Let $S$ be the exchange rate measured as the domestic currency price of one unit of the foreign currency. If $s$ is the logarithm of $S$ then $\Delta S_{t+1}^e$ is approximately the expected percentage change in the exchange rate. If we further assume that the buy and sell decisions pertain to the foreign currency then a buy signal is indicated by $\Delta S_{t+1}^e > 0$, while a sell signal is indicated by $\Delta S_{t+1}^e < 0$.

In this paper we will not follow the conventional specifications of these expectation formation mechanisms as found, for example, in Moosa (1999) and Frankel and Froot (1987). Rather we follow the definitions adopted by Pilbeam (1995a), which are easier to implement in this exercise. Using the conventional specifications requires the assigning of numerical values to the coefficients. The coefficients cannot be estimated statistically from observed exchange rate data because these reflect the behaviour of the whole market, and not that of the traders using a particular expectation formation mechanism. The second alternative is to assign arbitrary values to the coefficients, which we find inappropriate and unacceptable.
According to Pilbeam (1995a), the extrapolative expectations hypothesis implies that a rise in the exchange rate is followed by a rise and vice versa. Formally, extrapolative expectations are represented by

$$\begin{align*}
\Delta s_{t+1}^e > 0 \quad \text{if} \quad \Delta s_t > 0 \\
\Delta s_{t+1}^e < 0 \quad \text{if} \quad \Delta s_t < 0
\end{align*}$$

which means that for a trader basing his or her decisions on extrapolative expectations, a buy signal is given by $\Delta s_t > 0$, while a sell signal is given by $\Delta s_t < 0$.

Adaptive expectations, on the other hand, mean that if the exchange rate rises in at least two of the latest three periods then it should be expected to rise in the coming period. Formally, adaptive expectations have the following representation

$$\begin{align*}
\Delta s_{t+1}^e > 0 \quad \text{if} \quad \Delta s_{t-i} < 0 \\
\Delta s_{t+1}^e < 0 \quad \text{if} \quad \Delta s_{t-i} > 0
\end{align*}$$

for at least two values of $i = 0, 1, 2$.

Regressive expectations are the opposite of extrapolative expectations. In this case the exchange rate is expected to rise if it falls in the current period and vice versa. Formally, regressive expectations have the representation

$$\begin{align*}
\Delta s_{t+1}^e > 0 \quad \text{if} \quad \Delta s_t < 0 \\
\Delta s_{t+1}^e < 0 \quad \text{if} \quad \Delta s_t > 0
\end{align*}$$

Rational expectations mean that expectation is formed on the basis of all available information. The assumption used by Pilbeam is that all of the market information is reflected in the forward spread, such that if a currency is selling at a premium, then it
should be expected to appreciate and vice versa. Therefore, rational expectations have the representation

\[
\begin{align*}
\Delta s_{t+1}^e > 0 \quad & \text{if} \quad f_t - s_t > 0 \\
\Delta s_{t+1}^e < 0 \quad & \text{if} \quad f_t - s_t < 0
\end{align*}
\]  

(4)

where \( f \) is the logarithm of the forward rate.

Finally, heterogeneous expectations mean that the trader follows the majority signal (out of extrapolative, adaptive, regressive and rational expectations). If two of the four mechanisms give a buy signal and the other two give a sell signal then the signal generated by heterogeneous expectations can be determined in one of two ways. The first is to take no action (no buy or sell decision). The second is to disregard rational expectations and adopt the majority signal of the other three mechanisms. This is because there is a substantial body of evidence indicating that the hypothesis of rational expectations is not valid for the foreign exchange market (for example, Moosa, 1999 and Takagi, 1991).

**Traders Acting on the Basis of Trading Rules**

We assume that traders use either a filter rule or a moving average rule. The working of the filter rule depends on the recognition of peaks and troughs (ex post) in the exchange rate series. Assume that the exchange rate is observed at points in time \( t-m, t-m+1, \ldots, t-1, t, t+1 \). The value of the exchange rate at time \( t \), \( S_t \), defines a trough if

\[
\begin{align*}
S_{t+1} - S_t > 0 \\
S_{t-i} - S_{t-i-1} < 0
\end{align*}
\]  \( \forall i = 0,1,\ldots,m-1 \)  

(5)

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2 This in fact is a prediction of the version of the flexible price monetary model that incorporates
Equation (5) implies that for \( S_t \) to define a trough the necessary condition is that \( \Delta S_{t+1} > 0 \), while the sufficient condition is that \( \Delta S_{t-i} < 0 \) for \( i = 0,1,...,m-1 \). On the other hand, \( S_t \) defines a peak if

\[
\begin{align*}
S_{t+1} - S_t < 0 \\
S_{t-i} - S_{t-i-1} > 0
\end{align*}
\] \( \forall i = 0,1,...,m-1 \) (6)

which implies that for \( S_t \) to define a peak the necessary condition is that \( \Delta S_{t+1} < 0 \), while the sufficient condition is that \( \Delta S_{t-i} > 0 \) for \( i = 0,1,...,m-1 \).

We will use two filters: an \( x \) per cent filter an \( x-y \) per cent filter. In the case of the former the buy and sell signals are identified as follows. If there is a trough at \( S_t \), then a buy signal emerges at \( S_{t+j} \) if

\[
S_{t+i} \geq (1 + x)S_t
\] (7)

On the other hand, if there is a trough at \( S_t \), then a sell signal emerges at \( S_{t+i} \) if

\[
S_{t+i} \leq (1 - x)S_t
\] (8)

The representation of the \( x-y \) filter rule is similar. A buy signal emerges when the exchange rate rises by \( x \) per cent from the trough as represented by equation (7). A sell signal, on the other hand, emerges when the exchange rate falls by \( y \) per cent from its most recent peak. This is represented by equation (8) with \( y \) replacing \( x \).

The moving average rule is a mechanical trading rule that is based on buy-sell signals derived from the behaviour of the exchange rate relative to one or more moving averages. According to the single moving average rule, buy and sell signals are covered interest parity. See, for example, Moosa (2000b), chapter 4.
indicated by the intersection of the time paths of the exchange rate and a moving average of some order. If the moving average at time $t$ is $M_t$, then a buy signal is generated when

$$
\begin{align*}
S_t \geq M_t \\
S_{t-1} < M_{t-1}
\end{align*}
$$

(9)

while a sell signal is generated when

$$
\begin{align*}
S_t \leq M_t \\
S_{t-1} > M_{t-1}
\end{align*}
$$

(10)

A double moving average rule works in the same way except that the short moving average replaces $S_t$, while the long moving average replaces $M_t$ in equations (9) and (10).

**Traders Acting on the Basis of Fundamentals**

Traders who base their buy-sell decisions on fundamentals can use rules or discretion. Those using discretion react to changes in individual fundamental variables. Thus, if the change in a fundamental variable is perceived to have a positive effect on the exchange rate, the underlying currency will be bought and vice versa. Whether the effect of the change in a fundamental variable on the exchange rate is positive (hence a buy signal) or a negative (hence a sell signal) depends on the fundamental model to which the trader subscribes. This is because economic theory can be used to show that a change in a certain fundamental variable can be good or a bad for a particular currency.\(^3\)

\(^3\) A rise in income may be interpreted to be a bullish signal since growth means profitability and a thriving stock market, but it can be interpreted to be a bearish signal since it leads to growth of imports and hence a deterioration in the current account. Likewise, a rise in interest rate may be taken to be a bullish signal since it implies that domestic assets have become more attractive or as a bearish signal
Five models of exchange rate determination are used for this purpose: the flow model, the flexible price monetary model, the sticky price monetary model, the real interest differential model and the Hooper-Morton (1982) model. These models are represented respectively by the following functional relationships:

\[ s_t = f_1(y_t - y_t^*, \pi_t^*, \pi_t^*, i_t, i_t^*) \]  
\[ s_t = f_2(m_t - m_t^*, y_t - y_t^*, i_t, i_t^*) \]  
\[ s_t = f_3(m_t - m_t^*, y_t - y_t^*, i_t, i_t^*) \]  
\[ s_t = f_4(m_t - m_t^*, y_t - y_t^*, \pi_t^*, \pi_t^*, r_t, r_t^*) \]  
\[ s_t = f_5(m_t - m_t^*, y_t - y_t^*, \pi_t^*, \pi_t^*, i_t, i_t^*, c_t, c_t^*) \]

where \( y \) is the logarithm of real output, \( \pi \) is the inflation rate, \( i \) is the interest rate, \( m \) is the logarithm of the money supply, \( r \) is the real interest rate and \( c \) is the current account. The superscript \( e \) indicates the expected value (such that the expectation is made at time \( t \) for \( t+1 \)) and an asterisk indicates the corresponding foreign variable. The signals indicated by a change in each fundamental variable according to each model are shown in Table 1. For example, a rise in relative output, \( y_t - y_t^* \), is a buy signal for a trader who believes in the flow model and a sell signal for a trader who follows the flexible price monetary model.

On the other hand, traders who act on the basis of fundamentals by using a rule behave as follows: they buy when the actual exchange rate is below its equilibrium value (when the currency is undervalued by \( x \) per cent) and sell when the actual

---

4 For a description of these models, see Moosa (2000b), chapter 4.
exchange rate is above its equilibrium value (when the currency is overvalued) by \( x \) per cent. Formally a buy signal is given when

\[
S_i \leq \overline{S}_i (1 - x)
\]

(16)

and a sell signal is given when

\[
S_i \geq \overline{S}_i (1 - x)
\]

(17)

The equilibrium value of the exchange rate, \( \overline{S}_i \), is taken to be the value estimated from a fundamental model or from a trend. For this purpose the equilibrium exchange rate is taken to be the in-sample predicted value based on one of the following models: the flow model, the monetary model, the real interest differential model and the Hooper-Morton model. The monetary model is either the sticky price model or the flexible price model, because once equations (12) and (13) are estimated they will be indistinguishable. Alternatively, the equilibrium value of the exchange rate is taken to be the trend estimated by the applying the HP filter to the exchange rate series.

**Data and Empirical Results**

Monthly data are used covering the period 1982:6-1999:12. The exchange rate is the dollar/pound exchange rate with the pound taken to be the foreign currency such that the profitability of exchange rate trading is measured in dollar terms. The definitions of the fundamental variables appear in Table 2. The data were obtained from the DX database (OECD Main Economic Indicators).

To start with, we calculate the profitability of the trading operations of various types of traders. For this purpose, each trader is given an initial capital of 100,000 U.S. dollars to buy and sell pounds according to the signals generated by the underlying
trading strategy. Table 3 reports the net profit generated by each trader. It is obvious that the filter rules provide the most successful trading strategy, while loss is incurred by trading on the basis of adaptive expectations, regressive expectations, a double moving average rule and the flow model (using discretion). Also reported in the table are the weights assigned to each type of trader. These are calculated on the basis of profitability as explained earlier.

The weights are subsequently used to simulate an exchange rate series. The period-to-period change in the exchange rate is calculated as follows. We use an indicator that takes a value of +1 for a buy signal, -1 for a sell signal and 0 for a hold signal. We then calculate the simulated percentage change in the exchange rate as a weighted average by applying the weights to a two-month moving sum of the actual absolute percentage change such that the indicator determines the sign of each component of the weighted average.

The actual and simulated percentage changes in the exchange rate are shown in Figure 1 and Figure 2 respectively. The two series behave in remarkably similar manners although the turning points of the two series do not necessarily coincide. This is a trivial matter, however, because this is not meant to be a forecasting model. All that we want to show is that the simulated series is as volatile as the actual series: this must be the impression one gets by observing Figure 1 and Figure 2.

To find out if the two series come from the same statistical distribution we apply the Wald-Wolfowitz (1940) test. This is a nonparametric test designed to find out if two samples are from the same population. Consider two samples, $x_i$ and $y_i$, where
To find out if these two samples come from the same population, the two samples are merged and the observations are arranged in ascending order. Then a complementary dummy sequence to the one obtained is constructed such that 0’s correspond to \( x_i \) and 1’s correspond to \( y_i \). Each set of 0’s and 1’s is called a run. Let \( R_0 \) and \( R_1 \) be the number of runs whose elements are 0’s and 1’s respectively. The test is based on the statistic

\[
R = R_0 + R_1
\]  

Wald and Wolfowitz (1940) derive the exact distribution of \( R \) under the null hypothesis that \( x_i \) and \( y_i \) come from the same distribution. They show that the mean and variance of \( R \) are given by

\[
E(R) = \frac{2n_x n_y}{n_x + n_y} + 1
\]

\[
\sigma^2_R = \frac{2n_x n_y (2n_x n_y - n_x - n_y)}{(n_x + n_y)^2(n_x + n_y - 1)}
\]

They also show that

\[
\frac{R - E(R)}{\sigma_R} \sim N(0,1)
\]

which means that the null hypothesis is rejected if \( [R - E(R)]/\sigma_R \) is greater than the critical value of the standard normal distribution (1.96 at the 5 per cent significance level). The calculated value of the test statistic is –0.506, which means that the null that the two series come from the same population cannot be rejected. This formal evidence reinforces the impression obtained from Figure 1 and Figure 2 that the simulated series based on the assumption of trader heterogeneity behaves in a similar manner to what is observed in reality.
Conclusion

The main conclusion that can be derived from this paper is that exchange volatility can indeed be explained in terms of the heterogeneity of traders. This conclusion is based on empirical evidence showing that an artificial exchange rate series that is simulated on the assumption of trader heterogeneity exhibits a similar volatility pattern to that of the actual series.

In this paper heterogeneity is represented by differences in the trading strategies used by various traders. In all, 19 different strategies were used falling in one of three categories: those based on expectation formation mechanisms, those based on mechanical trading rules, and those based on fundamentals. On the basis of the profitability of each trading strategy a weight was assigned to different traders, and these weights were subsequently used to simulate an artificial exchange rate. Statistical testing showed that the actual and simulated exchange rate series belonged to the same statistical distribution. The conclusion reached in this paper supports the microstructural approach to exchange rate determination and volatility.

Furthermore, the results shed some light on the question of whether or not fundamentals do matter for exchange rate determination. Some economists would argue that fundamentals do not matter because fundamental models have failed to outperform a simple random walk model. Some also argue that fundamentals cannot explain volatility because fundamental variables are less volatile than exchange rates. Based on the results presented in this paper we argue that fundamentals do matter in the sense that some traders act upon them, leading to changes in the forces of supply and demand and therefore in exchange rates. The fact that exchange rates are more
volatile than fundamentals is due to heterogeneity. The exchange rate is not determined solely by the actions of fundamentalists. Moreover, the empirical failure of exchange rate determination models is due to the fact that not all fundamentalists subscribe to the same model. Even if they did they would not obey it like an iron law. Heterogeneity, it seems, is a simpler and more plausible explanation for exchange rate volatility than nonlinearities, chaos, “factors unknown to economists” or aliens from outer space.
References


<table>
<thead>
<tr>
<th>Model</th>
<th>Fundamental Variable</th>
<th>Signal</th>
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</thead>
<tbody>
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<td><strong>Flow Model</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(y, ( - y_i^* ))\uparrow\downarrow</td>
<td>Buy/Sell</td>
<td></td>
</tr>
<tr>
<td>(( \pi, - \pi_i^* ))\uparrow\downarrow</td>
<td>Buy/Sell</td>
<td></td>
</tr>
<tr>
<td>(i, ( - i_i^* ))\uparrow\downarrow</td>
<td>Sell/Buy</td>
<td></td>
</tr>
<tr>
<td><strong>Flexible Price Monetary Model</strong></td>
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<td>Buy/Sell</td>
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<tr>
<td>(y, ( - y_i^* ))\uparrow\downarrow</td>
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<td>(i, ( - i_i^* ))\uparrow\downarrow</td>
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<td><strong>Sticky Price Monetary Model</strong></td>
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<tr>
<td>(y, ( - y_i^* ))\uparrow\downarrow</td>
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<td>(i, ( - i_i^* ))\uparrow\downarrow</td>
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<td><strong>Real Interest Differential Model</strong></td>
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<tr>
<td>(y, ( - y_i^* ))\uparrow\downarrow</td>
<td>Sell/Buy</td>
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<tr>
<td>(( \pi, - \pi_i^* ))\uparrow\downarrow</td>
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<td>(r, ( - r_i^* ))\uparrow\downarrow</td>
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<td><strong>Hooper-Morton Model</strong></td>
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<td>(y, ( - y_i^* ))\uparrow\downarrow</td>
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<td>(( \pi, - \pi_i^* ))\uparrow\downarrow</td>
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<td>(c, ( - c_i^* ))\uparrow\downarrow</td>
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### Table 2: Definition of Fundamental Variables

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<th>Variable</th>
<th>U.S.</th>
<th>U.K.</th>
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<td>Industrial production</td>
<td>Industrial production excluding</td>
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<td></td>
<td>construction</td>
</tr>
<tr>
<td>$\pi$</td>
<td>Percentage change in CPI (all items)</td>
<td>Percentage change in CPI (all items)</td>
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<tr>
<td>$i$</td>
<td>Three month certificates of deposit</td>
<td>Three month interbank loans</td>
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<td>$m$</td>
<td>Broad money supply (M3)</td>
<td>Broad money supply (M4)</td>
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<td>$c$</td>
<td>Current account balance</td>
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<tr>
<td>Basis of Trading Strategy</td>
<td>Profit (Loss)</td>
<td>Weight (%)</td>
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<td>Two Per Cent Filter Rule</td>
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<td>Two Per Cent-Three Per Cent Filter Rule</td>
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<td>Single Moving Average Rule (6 Months)</td>
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<td>Double Moving Average Rule (6 and 18 Months)</td>
<td>(542)</td>
<td>2.35</td>
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<tr>
<td>Fundamentals (Discretion)</td>
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<td></td>
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<tr>
<td>Flow Model</td>
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<td>Sticky Price Monetary Model</td>
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<td>3.03</td>
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<td>Hooper-Morton Model</td>
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Figure 1: Actual Percentage Changes in Dollar/Pound Exchange Rate

Figure 2: Simulated Percentage Changes in Dollar/Pound Exchange Rate