

A behavioural finance model of exchange rate expectations
within a stock-flow consistent framework

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Since the collapse of the Bretton Woods system in the early 1970s, economists have produced a vast pool of theories and models devoted to explaining exchange rate fluctuations. However, these models have been shown to perform very poorly in out-of-sample empirical studies. This suggests that they are either invalid or at the very least incomplete. Furthermore, as is the case with most areas of economic research, foreign exchange markets have been modeled as stand-alone processes rather than being modeled as part of a complete, self-contained, economic system. This limits the policy relevance of these models and often relegates them to being simple forecasting tools.

These two important weaknesses in the exchange rate literature are the main motivation for this paper. Here we will describe a model where the exchange rate is simply determined by the demand and supply of assets within a larger framework. The key to modeling exchange rate movements then becomes the specification of how the demands for financial assets are formed. This is where we will introduce speculator expectations of future exchange rate movements to examine the effects that different exchange rate expectations can have on different policy moves. To do this, we will add elements of behavioural finance, a promising new approach to modelling exchange rates, to a stock-flow consistent model, a tool most often used by Post-Keynesian economists to ensure a coherent and comprehensive account of all economic mechanisms at work.

By running simulations and experiments on this model, we will show that, under certain conditions, exchange rate expectations can have significant impacts on exchange rate movements without impacting the long run effects of policy decisions. Under other scenarios, we can show that, within this framework, speculation in foreign exchange markets can change the long-run impact of policy moves. This would suggest that exchange rate expectations and speculation can contribute to hysteresis, or path dependence.

We will begin in section 1 with a chronological review of the exchange rate literature. This will lead us to a brief survey of behavioural finance in section 2, after which we will present the exchange rate expectation specification used in this paper in section 3. The fourth section is devoted to a presentation of the stock-flow consistent model used in this paper. Finally, sections 5 through 9 will present the results obtained when running simulations and experiments on the model.

1. Exchange rate literature

In order to rebuild the international economic system at the end of the Second World War, the allies agreed on what would come to be known as the Bretton Woods system. Under this arrangement, every major world currency was pegged to the dollar. Thus, even though the dollar was convertible into gold in order to bolster faith in its strength, U.S. currency had effectively replaced gold in this new variant of the gold standard. During the Vietnam War, however, rising inflation forced the U.S. government to abandon the convertibility of the dollar into gold in 1971. This signalled the end of the Bretton Woods system. By 1976, all of the world's major currencies were floating. Under these regimes, currencies are essentially backed mostly by government debt, domestic or foreign, and the exchange rate is no longer the key monetary policy instrument. This new system of flexible exchange rates, which exists to this day, has proven to be a challenge for economists, theorists and forecasters alike.

Following the collapse of the Bretton Woods system, several economists built on the work of Mundell (1968) to form what they called the monetary approach to modelling the exchange rate. As is explained by Bailliu and King (2005), this monetary approach relied on the definition of the exchange rate as the relative price of two currencies to model the exchange rate as the relative demand and supply of those two currencies. One notable example of these monetary exchange rate models which gives special attention to the role played by expectations was developed by Frankel (1976). Under his formulation, given the foreign price level, P^* , the purchasing power parity (PPP) determines the ratio P/S , where P is the domestic price level and S is the spot exchange rate, to form the equation:

$$S = \frac{P}{P^*}$$

The price level is the one which clears the money market, given both the nominal money supply, M , and the expected level of inflation, π^e ¹. P is thus given by:

$$P = \frac{M}{\pi^e}$$

By normalizing the foreign price level to 1 and assuming it to be constant, Frankel then combines these two equations and log-linearizes them to get his formulation of the exchange rate determination mechanism:

$$\log(S) = a + b_1 \log(M) + b_2 \log(\pi) + u$$

¹ Here the inflation expectation is actually the difference between the anticipated domestic and foreign inflation rates. Frankel uses the forward rate premium as a proxy for this variable. The underlying assumption is thus that foreign exchange markets are efficient.

However, as Bailliu and King (2005) point out, this model, and monetary exchange rate models in general, rely on several questionable assumptions. These include perfectly flexible prices, perfectly substitutable domestic and foreign assets, absolute purchasing power parity holding at all times and the uncovered interest rate parity (UIP) holding at all times.

According to Lavoie (2000), the main issues with PPP are twofold. First, the theory has been subjected to extensive testing, most of which has concluded that the purchasing power parity can only help explain changes in exchange rates in the long run. Second, there is the issue of causality. It is not completely clear whether it is relative inflation rates that cause exchange rate fluctuations or the other way around.

Moosa (2004) articulates the problem with UIP by explaining that it can be decomposed into the covered interest rate parity (CIP) and the unbiased efficiency hypothesis. The CIP simply states that the interest rate differentials between domestic and foreign markets must equal the difference between the forward and spot exchange rate:

$$R - R^* = \log(F) - \log(S)$$

The unbiased efficiency hypothesis states that the forward rate represents the market's expectation of the future spot rate, incorporating all available information:

$$S^e = F$$

The Post-Keynesian view is that since banks set the forward rate by applying the CIP formula, it must hold, by definition. It is also easy to show that riskless arbitrage opportunities would be available in financial markets if this equation did not hold. Furthermore, the empirical evidence supports a contemporaneous relationship between the spot and forward exchange rate. Since the unbiased efficiency hypothesis would imply a lagged relationship between the spot and forward exchange rate, the evidence clearly points to the failure of unbiased efficiency and therefore, of UIP. As Lavoie (2000) puts it, “The forward exchange rate is not an expectational variable, but rather the result of a simple arithmetic operation.”

Several modifications have been made to the monetary models of exchange rates in light of the failure of many of their key assumptions. In a famous example, Dornbusch (1976) created a sticky-price version of the monetary exchange rate model where PPP only holds in the long run. By introducing jump variables, he showed that exchange rates can overshoot their long-run equilibrium levels.

Another strand of exchange rate modelling, called the portfolio-balance approach, drops the assumption of perfect substitutability of domestic and foreign assets to arrive at a much richer model where the exchange rate is determined by the demand and supply of all assets. These models also provide a description of the relationship between different sectors of the economy and the exchange rate which makes for much richer models. As is explained by Branson and Henderson (1985), these models also do away with the UIP assumption by introducing a home country bias which creates a currency risk premium.

However, an often cited paper by Meese and Rogoff (1983) has shown that these Macro-based models do very poorly in out-of-sample empirical investigations. In fact, these models were shown to perform worse than a random walk specification. These findings are supported by Obstfeld and Rogoff (2000) who show that there is a very weak relationship between exchange rate fluctuations and changes in macroeconomic fundamentals.

This disconnect between macroeconomic variables and the exchange rate has prompted economists to move towards micro-based models in which another crucial assumption is dropped, that of rational expectations. The three most important aspects of the rational expectations hypothesis are that agents are continuously maximizing their utility in an inter-temporal framework, forecasts take into account all relevant information and markets are efficient in the sense that prices reflect all relevant information. As De Grauwe and Grimaldi (2006) point out, the important testable consequence of the rational expectations hypothesis is that when there is no new information about fundamentals, prices shouldn't change. This prediction has, of course, been rejected by numerous studies.

Bailliu and King (2005) explain that another important component of these microstructure models is the heterogeneity of agents who trade according to different rules. These new models allow researchers to do away with assumptions such as homogeneity of agents, perfect information, costless trading, and the irrelevance of the trading process itself. In doing so, they are able to develop several alternative explanations for exchange rate movements. These include unobservable macroeconomic shocks, irrationality of market participants, speculative bubbles and herding behaviour. In order to model the trading rules used by these heterogeneous agents, researchers have called upon a relatively new field that borrows some of its concepts from psychology, behavioural finance.

2. Behavioral finance

The single most important contribution made by behavioural finance is the development of an alternative to the rational agent paradigm which is one of the building blocks of much of mainstream economics. As was described earlier, financial markets do not behave as they would if the agents trading financial assets were rational agents.

By conducting several psychology studies, Kahneman and Tversky (2000), two leading behavioural economists, have discovered how, and to some extent, why economic agents behave differently than they should under the rational agent hypothesis. They call these behavioural anomalies, heuristics.

One of these is called framing. In their experiments, Kahneman and Tversky find that the way in which an economic problem is presented will affect the choices made by the subjects.

Another example is that the subject's initial circumstance matters in his/her decision making. This finding strikes at the heart of expected utility theory which relies heavily on the rational agent tenets. Under expected utility theory, only the utility derived from the agent's final asset position will influence his decision. However, Kahneman and Tversky find that the agent's financial position is very relevant to their decision making in different situations. For example, a very poor person may be much more risk seeking (or less risk averse) than a very rich person, who has much more to lose. This finding explains behaviour such as purchasing lottery tickets or purchasing insurance. Both of these activities have negative expected values and are thus incompatible with the rational expectation hypothesis. In response to these findings, Kahneman and Tversky developed another theory of choice under uncertainty called prospect theory where it is the changes in wealth rather than the states of wealth which influence decision making. For example, a poor man with \$10 to his name is more likely to take on a gamble to win \$10 (+100%) than a rich man with \$100 (+10%) to his name presented with the same gamble.

The final heuristic example presented here is the anchoring effect. This behaviour is one where agents cannot possibly absorb and analyze all of the information relevant to a decision and so they choose, whether consciously or not, to concentrate on the most recent information. This heuristic seems particularly relevant to finance since financial asset prices have often been found to follow autoregressive processes.

As is explained by De Grauwe and Grimaldi (2006), proving that many economic agents do not behave according to the rational expectation hypothesis is not sufficient for invalidating models based on rational expectations. One could easily evoke the famous Milton Friedman argument that states that as long as some agents are rational, any deviations from fundamental prices will eventually be eliminated. Imagine, for example, that irrational noise traders exhibit the anchoring heuristic and base their exchange rate movement expectations on the most recent observed movements. The rational traders would recognize any deviation from fundamentals as a profit opportunity and bring the rate back to the fundamental rate by selling overpriced currencies and buying underpriced currencies.

This latest example has, in fact, been used as the basis for several microstructure exchange rate models where the noise traders are referred to as chartists and the rational traders are referred to as fundamentalists. A variation of one such model will be used in this paper. It is discussed in the next section.

3. Chartists and fundamentalists

In order to model the way in which agents form expectations on future exchange rate movements, we will slightly modify the simple model presented in Chapter 2 of De Grauwe and Grimaldi (2006). They define two types of simple forecasting rules which can be used by agents in the economy to form expectations about exchange rate movements. The first type, called fundamentalists, always trade in a manner that will put pressure on the exchange rate to go back to some exogenously defined fundamental rate². Fundamentalist trader expectations are therefore defined as:

$$dxr_{e,t}^{f} = -\psi \cdot (xr_t^{\$} - xr^{\$*})$$

where $dxr_{e,t}^{f}$ is the fundamentalist trader's expected change in the dollar per pound exchange rate at time t , ψ is a parameter which can be interpreted as a proxy for the expected speed of convergence to the fundamental exchange rate, $xr_t^{\$}$ is the dollar per pound exchange rate at time t and $xr^{\$*}$ is the exogenously determined fundamental exchange rate.

It is important to note that the fundamental rate here simply means the rate towards which the fundamentalists think the exchange rate should converge. Therefore, although $xr^{\$*}$ is referred to as the fundamental rate in this paper, it should really be thought of as the fundamentalist trader's assessment of where the exchange rate should be.

² De Grauwe and Grimaldi actually define the fundamental exchange rate as a stochastic process. However, it is more convenient to define it as an exogenously defined value for the purposes of this paper.

The second type of trader, called chartists, always expect the latest change in the exchange rate to be repeated in the next period. It is easy to see the link to the anchoring heuristic described in the behavioural finance section. These traders can also be interpreted as being trend-following speculators who continuously push the price up after an initial price increase and continuously push the price down after an initial price decrease. This type of trend following behaviour is at the root of financial bubbles and is typical of traders who rely on technical analysis, or chart analysis, thus the name, chartist. Chartist exchange rate expectations are formed by the following equation:

$$dxr_{e,t}^{\$,c} = \beta \cdot dxr_{t-1}^{\$}$$

where $dxr_{e,t}^{\$,c}$ is the chartist trader's expected change in the dollar per pound exchange rate at time t , β is a parameter governing the magnitude of the autoregressive process and $dxr_{t-1}^{\$}$ is the change in the dollar per pound exchange rate at time $t-1$.

Market expectations about future exchange rate movements are simply a weighted average of both types of traders who make up the speculative segment of the foreign exchange market. We thus get the following equation for market expectations of future exchange rate movements:

$$dxr_{e,t}^{\pounds} = w_c \cdot dxr_{e,t}^{\pounds,c} + w_f \cdot dxr_{e,t}^{\pounds,f}$$

or

$$dxr_{e,t}^{\pounds} = w_c \cdot dxr_{t-1}^{\pounds} - w_f \cdot \psi \cdot (xr_t^{\pounds} - xr^{\pounds*})$$

where $dxr_{e,t}^{\pounds}$ is the market's expected change in the dollar per pound exchange rate at time t , w_c is the proportion of chartists in the speculative segment of the foreign exchange market and w_f is the proportion of fundamentalists in the speculative segment of the foreign exchange market. Also note that since both β and w_c are exogenously defined for our purposes here, the β parameter was simply dropped from the equation (or set to 1).

The first thing to notice in the equation above is that chartists and fundamentalists will not necessarily expect the currency to move in opposite directions. If the exchange rate is moving upwards but is still below the fundamental rate, both types of traders will expect the exchange rate to increase. Similarly, if the exchange rate is moving downwards but is still above the fundamental rate, both types of traders will expect the exchange rate to decrease.

However, if the exchange rate is moving upwards and is already above the fundamental rate, whether or not the market expectation of future exchange rate movements is positive or negative will depend on the size of the last upward move and on the distance of the exchange rate from the fundamental value, for a given set of ψ , w_c and w_f parameters. As the exchange rate moves further and further away from the fundamental value, the magnitude of the fundamentalist's expectation increases relative to that of the market as a whole until the movement in the exchange rate reverses.

For example, if an exchange rate starts increasing above the fundamental rate, the move will be fuelled by the chartists' belief that it will continue. However, the upward move cannot continue indefinitely since the fundamentalists' belief that it must come down is putting downward pressure on the market expectation. To illustrate, think of a ball being thrown straight up in the air. The ball first rises at a decreasing speed and then falls at an increasing speed. In the up move, the chartists can be thought of as the ball's momentum, continuously willing it to go higher and higher. The fundamentalists can be thought of as gravity, slowing the ball down until it comes to a complete stop in mid-air. After that critical point has been reached, the ball heads towards the ground at an increasing speed as both its momentum (chartists) and gravity (fundamentalists) are pulling it down.

This simple model of exchange rate expectations will be added to the equations governing the demand for financial assets in a much larger model where the exchange rate is determined by the demand and supply of financial assets. The stock-flow consistent framework used in the rest of the paper is presented in the next section.

4. Stock-flow consistent framework

The stock-flow consistent framework used in the rest of this paper was spawned by the belief that for economic models to provide true insights, they must be comprehensive and fully coherent. To do this, stock-flow consistent models are constructed from a series of transaction flow and balance sheet matrices. As is explained by Godley and Lavoie (2007), the transaction flow matrices describe the changes in stock variables between the beginning and end of a given period. The balance sheet matrices measure the levels of all stock variables at a given point in time. The relationships between these matrices are described by a series of equations and accounting identities which ensure that the model is fully consistent. This accounting framework ensures that everything comes from somewhere and goes somewhere. These accounting laws also impose a kind of discipline on the researcher which could be compared to the laws of physics for a natural science theorist. The framework also provides a much richer analysis since the properties of a complete, self-contained, economic system are studied as opposed to considering one aspect at a time and simply assuming that the rest of the system stays in place while we do so.

Working with these stock-flow consistent models involves attributing initial values to all stock and flow variables as well as defining the values of all behavioural parameters. Numerical simulation is then used to check that the accounting framework is consistent and that the model converges to a steady state. We then shock the model by changing some parameter(s) and/or variable(s) and see how the variables of interest react to these shocks.

The specific model used in the rest of this paper is presented in chapter 12 of Godley and Lavoie (2007). The key features specific to this model are the ability of agents to trade for foreign assets, the dependence of international trade on both national output and relative prices and the possibility of speculation on financial asset markets through price expectation variables. In order to work with a stationary model, domestic and foreign investment in both fixed and working capital is omitted from the model. In addition, firms do not hold financial assets, there are no banks and there is no credit money.

This brief description of stock-flow consistent modelling only scratches the surface. However, an in depth explanation is beyond the scope of this paper. The reader is thus referred to Godley and Lavoie (2007) for a complete description of stock-flow consistent modelling and, more specifically, of the model used in the rest of this paper. We now turn to the two key links between stock-flow consistent modelling, Post-Keynesian economics and the behavioural finance inspired microstructure models described in previous sections.

First, the budget constraints which determine the demand for financial assets in these stock-flow consistent models are very similar to the framework used in the portfolio-balance exchange rate models described in section 2. Of course, the rigid accounting framework of stock-flow consistent models extends to other sectors of the economy while the portfolio equations of the portfolio balance models treat the agents' decision as being isolated, thus making the stock-flow consistent models much richer and more comprehensive.

Second, the departure of stock-flow consistent models and of Post-Keynesian economics more generally, from the rational expectations hypothesis is, as was described at length earlier, central to behavioural finance inspired models. In these stock-flow consistent models, there is no need to rely on assumptions of profit and utility function maximization nor is there a need to assume perfect information. The procedural rationality described by Godley and Lavoie, on which these models are based, is thus very much compatible with behavioural economics.

5. Further changes made to the Godley-Lavoie model

We begin by describing how the Godley-Lavoie stock-flow consistent model will be modified in order to incorporate the De Grauwe-Grimaldi behavioural finance exchange rate model. It must be pointed out that the stock-flow consistent model already has exchange rate expectations built into its structure. The authors simply decided to set all exchange rate expectations to 0. This is tantamount to assuming that expectations about the probability of appreciation and of depreciation are balanced which means that the expectation of the future change in the exchange rate is 0. This assumption will serve as a base case for the experiments that follow.

The key equations which will be affected by changing exchange rate equations are the six equations governing how agents in both countries choose to allocate their wealth between the three different asset types, namely, domestic bills, foreign bills and domestic currency:

$$B_{\pounds d}^{\pounds} = V^{\pounds} \cdot (\lambda_{10} + \lambda_{11} \cdot r^{\pounds} - \lambda_{12} \cdot (r^{\$} + dxr_e^{\$})),$$

$$B_{\pounds d}^{\$} = V^{\pounds} \cdot (\lambda_{20} - \lambda_{21} \cdot r^{\pounds} + \lambda_{22} \cdot (r^{\$} + dxr_e^{\$})),$$

$$H_d^{\pounds} = V^{\pounds} - B_{\pounds d}^{\pounds} - B_{\pounds d}^{\$},$$

$$B_{\$ d}^{\pounds} = V^{\$} \cdot (\lambda_{40} + \lambda_{41} \cdot r^{\$} - \lambda_{42} \cdot (r^{\pounds} + dxr_e^{\pounds})),$$

$$B_{\$ d}^{\$} = V^{\$} \cdot (\lambda_{50} - \lambda_{51} \cdot r^{\$} + \lambda_{52} \cdot (r^{\pounds} + dxr_e^{\pounds}))$$

and

$$H_d^{\$} = V^{\$} - B_{\$ d}^{\pounds} - B_{\$ d}^{\$}$$

where $B_{\pounds d}^{\pounds}$ is the demand for U.K. bills in the U.K., $B_{\pounds d}^{\$}$ is the demand for U.S. bills in the U.K., H_d^{\pounds} is the demand for U.K. currency, $B_{\$ d}^{\pounds}$ is the demand for U.S. bills in the U.S., $B_{\$ d}^{\$}$ is the demand for U.K. bills in the U.S., $H_d^{\$}$ is the demand for U.S. currency, V^{\pounds} is wealth in the U.K., $V^{\$}$ is wealth in the U.S., r^{\pounds} is the interest rate in the U.K., $r^{\$}$ is the interest rate in the U.S. and $dxr_e^{\$}$ & dxr_e^{\pounds} are the speculative sector of the exchange rate market's expectation of future changes for U.S. and U.K. currencies, respectively.

As was explained earlier, both dxr_e^s and dxr_e^f are set to 0 in our base case. When introducing our behavioural finance model, these variables are governed by the following two equations from the behavioural finance section, which are replicated here for the reader's convenience:

$$dxr_{e,t}^f = w_c \cdot dxr_{e,t}^{f,c} + w_f \cdot dxr_{e,t}^{f,f}$$

and

$$dxr_{e,t}^s = w_c \cdot dxr_{e,t}^{s,c} + w_f \cdot dxr_{e,t}^{s,f}$$

or

$$dxr_{e,t}^f = w_c \cdot dxr_{t-1}^f - w_f \cdot \psi \cdot (xr_t^f - xr^{f*})$$

and

$$dxr_{e,t}^s = w_c \cdot dxr_{t-1}^s - w_f \cdot \psi \cdot (xr_t^s - xr^{s*})$$

Because adding exchange rate fluctuation expectations to the six equations describing wealth allocation decisions creates more of a tendency to shift bill demands from one country to another, some of the lambda parameters in those equations had to be modified in order to get convergence in our simulations. We change parameters λ_{10} , λ_{20} , λ_{40} , λ_{50} and λ_{12} , λ_{22} , λ_{42} & λ_{52} to 0.5. At first glance, the first set of parameter changes seems to eliminate the home country bias in the decision to buy foreign or domestic bills. However, the second set of parameter changes reduces the impact of foreign asset returns on domestic residents' bill portfolio decisions. Since the lambda parameters that multiply the domestic interest rates are left untouched at much larger values, the home country bias is restored when interest rates are stable. These changes therefore make speculators less responsive to changes in returns abroad and, therefore, much less likely to shift their bill holdings wildly. The changes give the model the stability needed for convergence when speculator expectations are modeled without taking too much away from the realism of the model. It is also important to note that these modifications to the lambda parameters still respect Tobin's principle for the portfolio adding up conditions. It is easy to show that the sum of the constants is equal to one and the sum of the coefficients of each remaining column is equal to zero.

One final important thing to be made aware of before discussing simulations and experiments is that the dollar per pound exchange rate is determined by the supply and demand for U.K. bills:

$$xr^{\pounds} = \frac{B_{\pounds S}^s}{B_{\pounds d}^s}$$

where xr^{\pounds} is the dollar per pound exchange rate, $B_{\pounds S}^s$ is the supply of U.S. bills to the U.K. and $B_{\pounds d}^s$ is the demand for U.S. bills in the U.K.. Since the money supply is endogenous in this model, the bond supply is a function of the government surplus or deficit, which, itself, is a function of a variety of factors throughout the economy. At the same time, bond demand is a function of the six equations governing the allocation of wealth, of which exchange rate expectations are only a small part. These six equations, of course, are a function of the wealth accumulated in each country which, itself, is a function of a variety of factors throughout the economy. The point here is that within this larger framework, the exchange rate expectations are not meant to determine movements in the exchange rate but rather to have an influence on how the exchange rate and other variables react to different shocks.

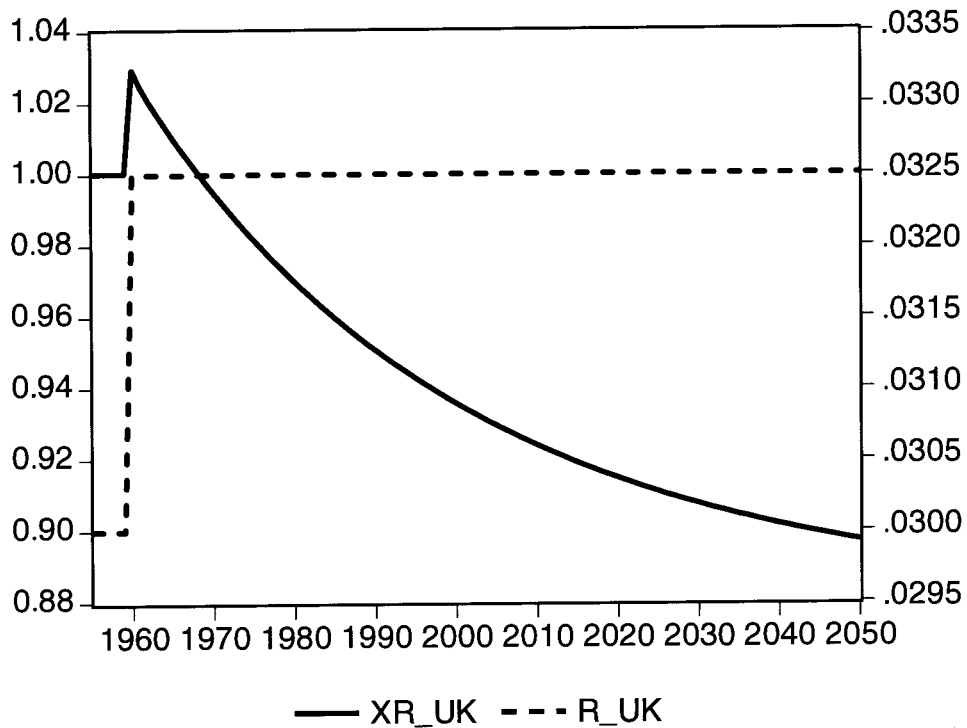
All numerical simulations and experiments described in the sections that follow were conducted using an Eviews version of the stock-flow consistent model developed by Gennaro Zezza³.

³ All stock flow consistent models presented in Godley and Lavoie (2007) are available, in Eviews version, on Gennaro Zezza's website at <http://gennaro.zezza.it/software/eviews/gl2006.php>.

6. Simulations with the Baseline Model

We are now ready to begin with our baseline experiment in which we will increase the U.K. interest rate by 25 basis points, from 3% to 3.25%.

Figure 1: An increase in the U.K. interest rate (right axis) and the U.K. exchange rate (Baseline)



The behaviour of the exchange rate in Figure 1 can better be understood by looking at the demand for U.K. financial assets.

Figure 2: Demand and supply (right axis) of U.K. bills in the U.S. (Baseline)

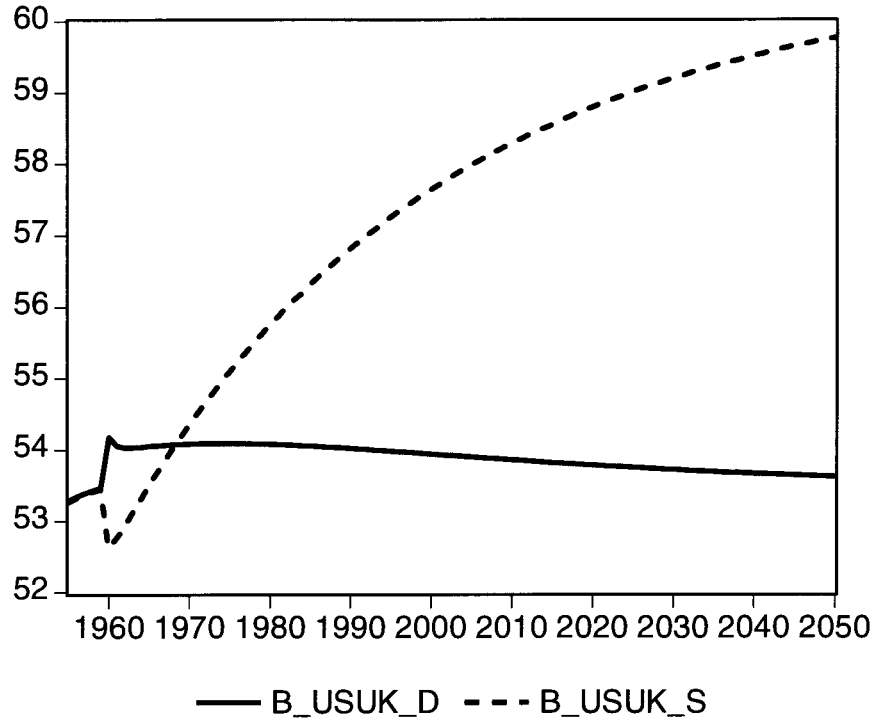


Figure 2 clearly shows an increase in the demand for U.K. bills following the increase in the U.K. interest rate. What is less obvious is why the supply of U.K. bills subsequently increases. To understand this, we must note that the supply of bills is determined by the government's budget deficit or surplus. An increase in the supply of bills would suggest a deficit. Figures 3, 4 and 5 help us tell the story.

Figure 3: Real wealth and real output (right axis) in the U.K. (Baseline)

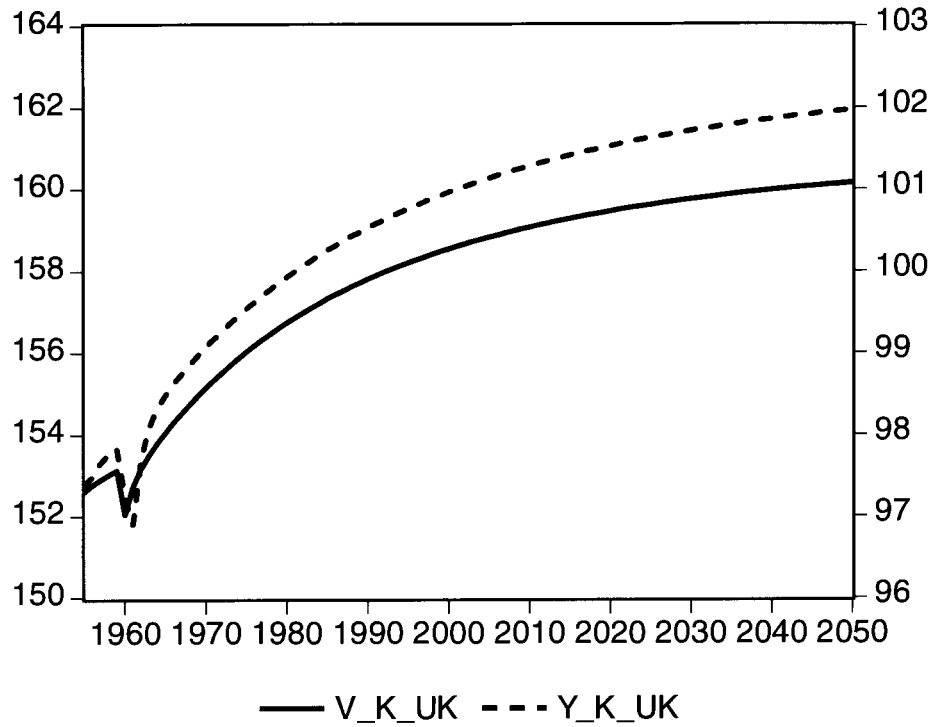


Figure 4: Price index of domestic sales in the U.K. (Baseline)

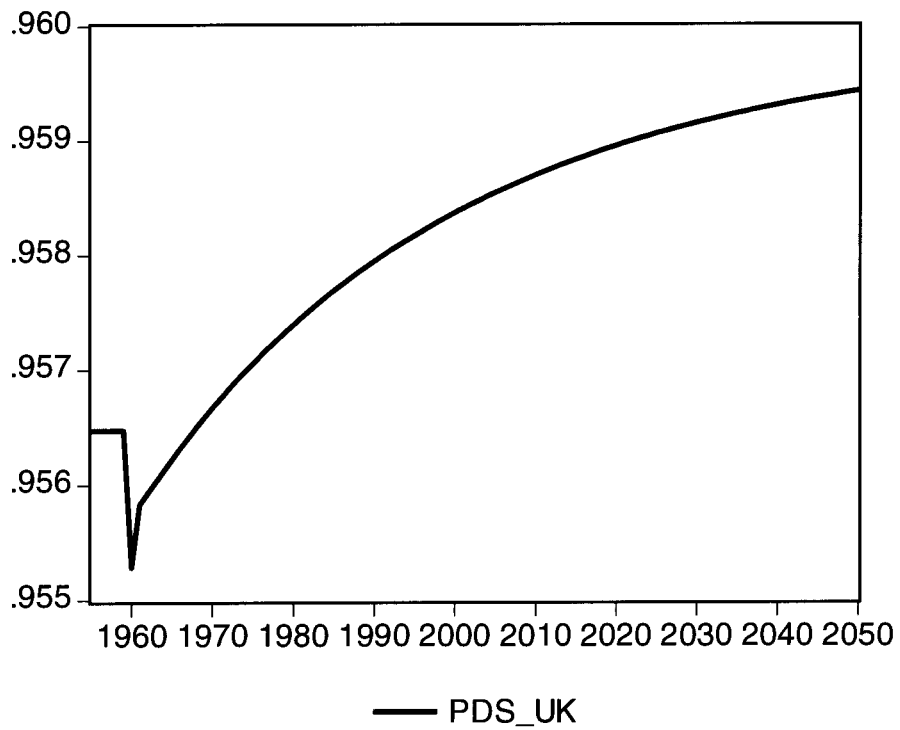
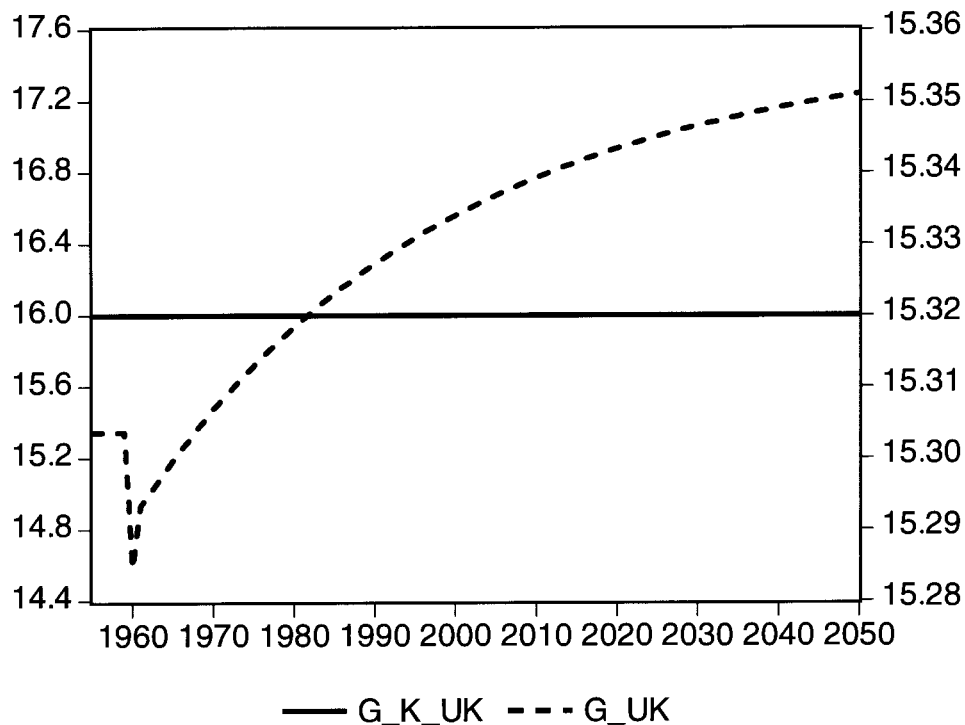


Figure 5: Real government expenditures and nominal government expenditures
(right axis) (Baseline)



Since more U.K. bills are held in the U.K. than in the U.S., the wealth effects from the higher interest rate are greater in the U.K.. Since there is no credit in this economy, the wealth effects created by the higher interest dominate the story. This wealth gives the U.K. economy a boost which fuels inflation. Though real government expenditures are held constant, growing nominal government expenditures, coupled with higher interest payments on government debt creates a government deficit which increases the supply of U.K. bills. The supply of U.K. bills therefore overtakes the demand as the U.K. economy grows following the wealth effects of the higher interest rate. This, of course, forces a depreciation of the U.K. currency, which further fuels U.K. exports and, consequently, positive growth in the U.K. economy and negative growth in the U.S. economy. This causes further prices increases which lead to more government deficits.

7. Simulations with Chartist and Fundamentalist expectations

Now that we have analyzed the effects of the U.K. interest rate increase on the dollar per pound exchange rate in the baseline case, let us replicate the experiment, this time with a model augmented by the De Grauwe-Grimaldi behavioural finance exchange rate model.

Let us begin by defining the ψ parameter which governs how quickly fundamentalists expect the exchange rate to come back to the fundamental rate. For example, a ψ parameter of 1 would mean that fundamentalists expect any deviation from the fundamental rate to be retraced immediately in the following year. We will set this parameter to 0.2. This would be interpreted as meaning that fundamentalists expect a deviation from the fundamental rate to be retraced by 20% every year.

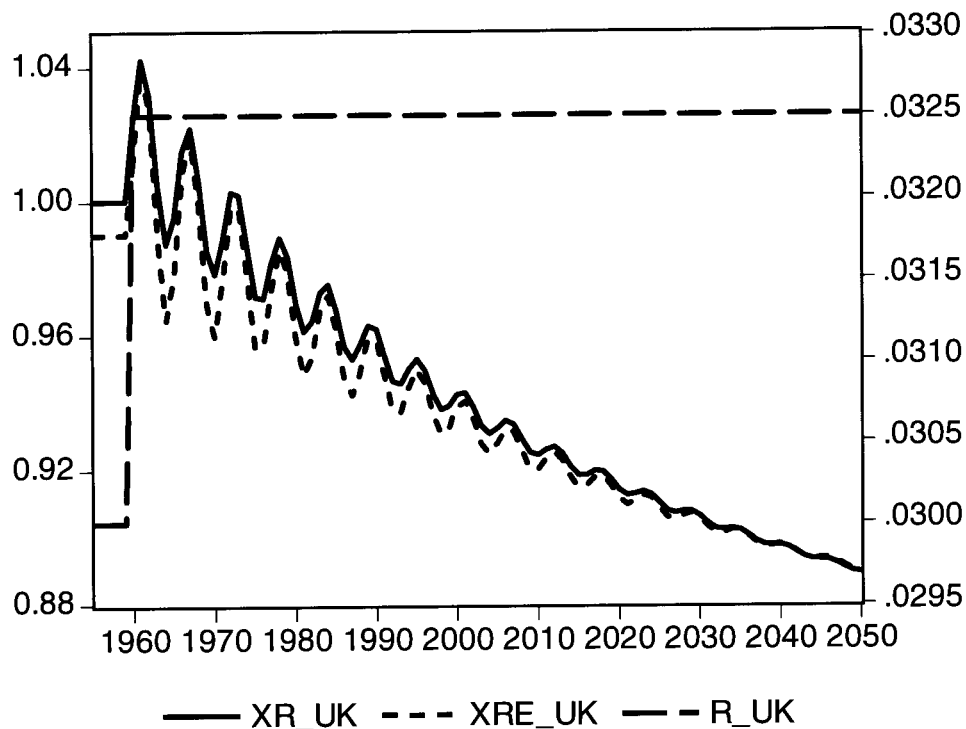
We also need to define the parameters identifying the proportion of the speculative segment of the foreign exchange market made up of each type of traders. We will set both the w_c and w_f parameters to 0.5. This would mean that there are an equal number of chartists and fundamentalists in the market or that chartists and fundamentalists control and trade the same amount of capital.

7A. Experiment 1

Another key variable of the model which, for the purposes of this paper, we have defined as being exogenously determined, is the fundamental exchange rate. Let us first assume that the fundamentalists know what the exchange rate should converge to following a 25 basis point increase in the U.K. interest rate. Looking at Figure 1, we see that this rate is around 0.9. We therefore set the xr^* variable, the fundamental exchange rate, to 0.9.

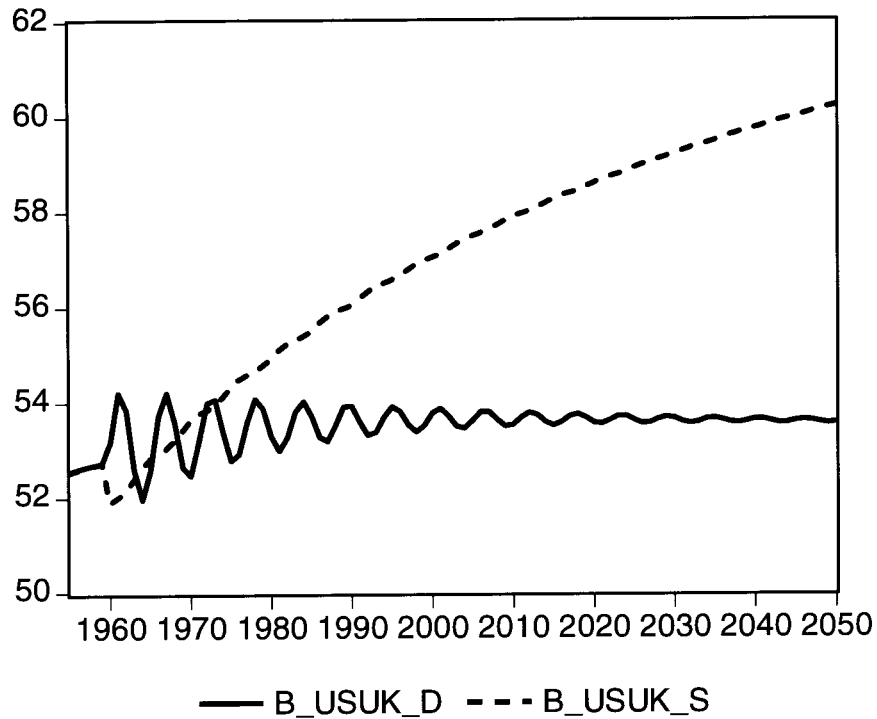
We now run the experiment where we increase the U.K. interest rate by 25 basis points, from 3% to 3.25%, as we did in the baseline case. We call this Experiment 1.

Figure 6: An increase in the U.K. interest rate (right axis), U.K. exchange rate and expectations about the U.K. exchange rate (Experiment 1)



The first thing to note when looking at Figure 6 is that the general movement of the exchange rate is very similar to that described in the baseline case. The exchange rate first rises and then converges to a lower level. This should not be a big surprise since all of the dynamics which made the exchange rate behave this way are still true, even though the exchange rate expectations have changed. This is illustrated in Figure 7.

Figure 7: Demand and supply (right axis) of U.K. bills in the U.S. (Experiment 1)

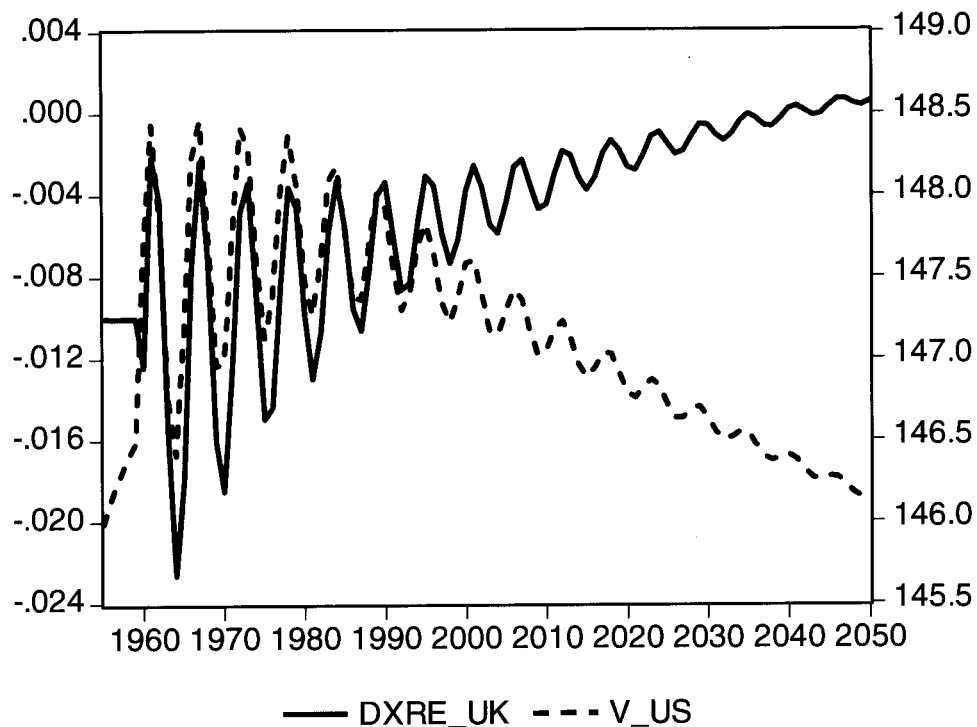


We clearly see that the demand for U.K. bonds is much more volatile because of changing dollar per pound exchange rate expectations. However, the demand still converges to a level above its initial steady state. As for the supply of bonds, the same story of increased wealth, economic output and exports fuelling inflation and leading to a government deficit is the same as in the baseline case. Though the exchange rate expectations clearly have a material impact on the model, they do not dominate the story. This is why the use of the stock-flow consistent framework to analyze the behavioural finance model adds realism to the conclusions.

Looking at Figure 6, the exchange rate expectations add a significant amount of volatility to the exchange rate without completely taking over and changing the exchange rate's general long-term direction. This behaviour is consistent with the findings of Flood and Rose (1995) who found that exchange rates tend to be much more volatile than macroeconomic fundamentals. The speculators described by the behavioural finance exchange rate model are meant to represent only a segment of the foreign exchange market. Many other forces, such as those described in our analysis of the baseline case, determine exchange rate movements.

We now turn to explaining this volatility. In order to understand the dynamics which cause the oscillating pattern, it is best to turn to Figure 7 since the exchange rate is directly related to the supply and demand of U.K. bills in the U.S.. We see that the oscillating behaviour is coming from the demand side and we know that everything but V^s , the wealth of U.S. households, and dxr_e^{\pounds} , speculator expectations about future exchange rate movements, is constant in the equation for the U.S. demand of U.K. bills.

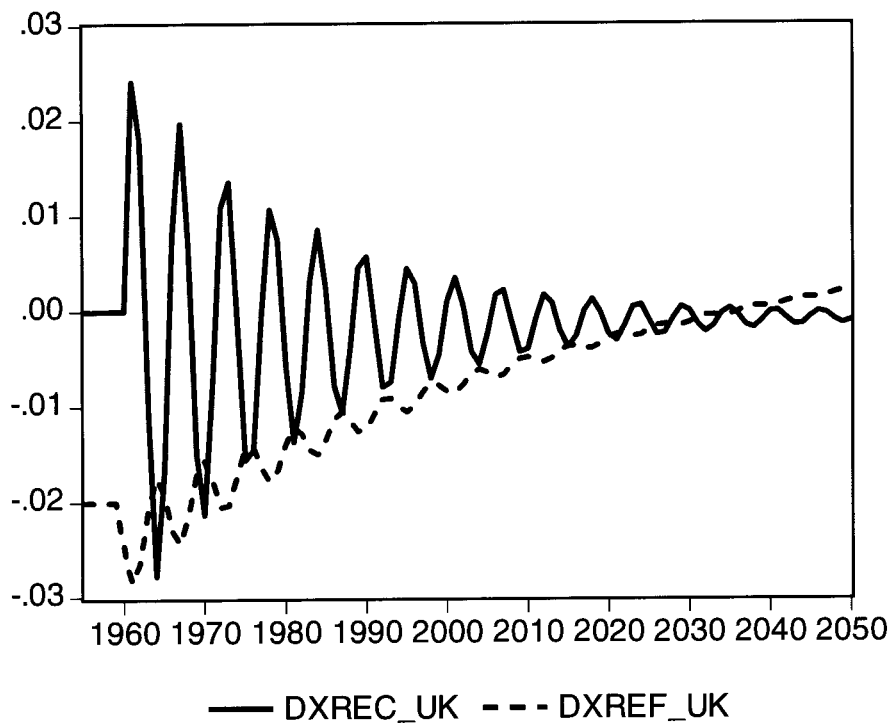
Figure 8: U.K. exchange rate expectations and U.S. wealth (right axis)
(Experiment 1)



Though it is not perfectly clear from Figure 8, the changes in the exchange rate expectations are leading the changes in wealth. We can therefore conclude that the exchange rate expectations are the source of the oscillating pattern. The dynamics are as follows. After the U.K. interest rate increases, the U.K. bill demand rises, and therefore the exchange rate appreciates. This causes dxr_e^f to be positive in the next periods, which puts more upward pressure on U.K. bill demand and thus, on the exchange rate. However, since the λ_{s_2} parameter is very small compared to the λ_{s_1} parameter, the impact of dxr_e^f and of the higher U.K. interest rate are quickly overshadowed by the home country bias since the U.S. interest rate is multiplied by a much larger lambda. This puts downward pressure on the U.S. demand for U.K. bills and on the exchange rate. The exchange rate then depreciates until the higher interest rate in the U.K. forces it up again. This process continues along a downward trend until a new steady state is reached.

Another thing to note in Figure 6 is that exchange rate expectations always seem to be lower than the actual exchange rate. This can easily be explained by remembering that we set the fundamental exchange rate variable to .9. Therefore, whenever the exchange rate is increasing, the chartists expect it to increase while the fundamentalists expect it to decrease. On the other hand, whenever the exchange rate is decreasing, both chartist and fundamentalists expect it to decrease. This is illustrated in Figure 9.

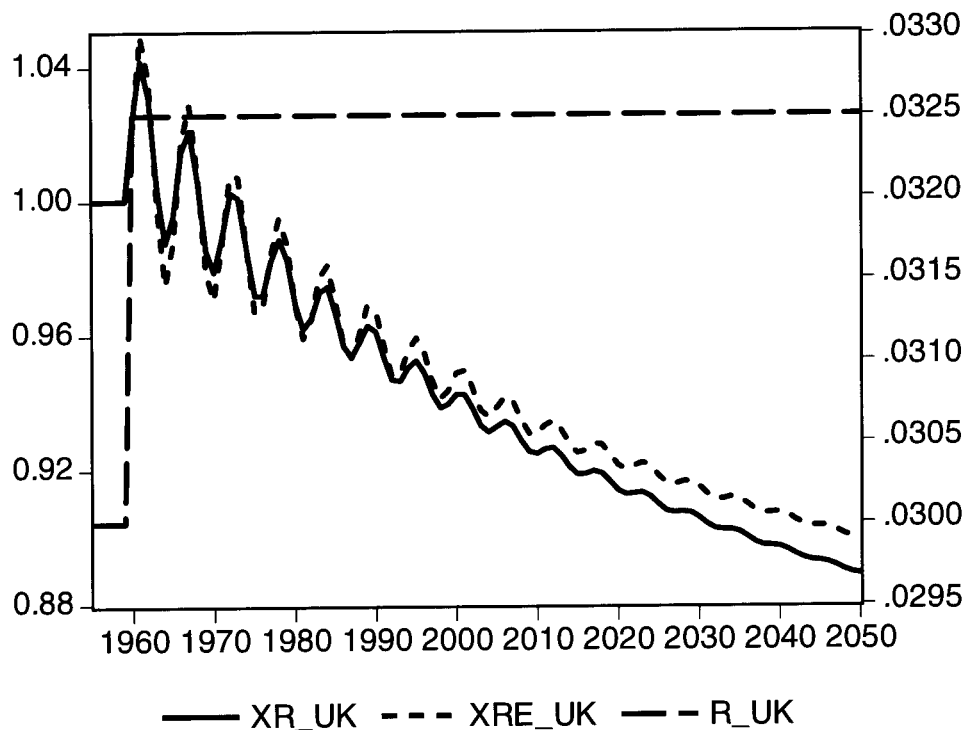
Figure 9: Chartist and fundamentalist expectations of future exchange rate movements (Experiment 1)



7B. Experiment 2

We will now conduct the same experiment where we increase the U.K. interest rate from 3% to 3.25%, this time setting the xr^e * variable to 1. We call this Experiment 2. The rationale for this experiment is that the fundamentalists could anticipate the inflation caused by the higher interest rate and expect the monetary authority to bring interest rates back to 3% in the near future⁴.

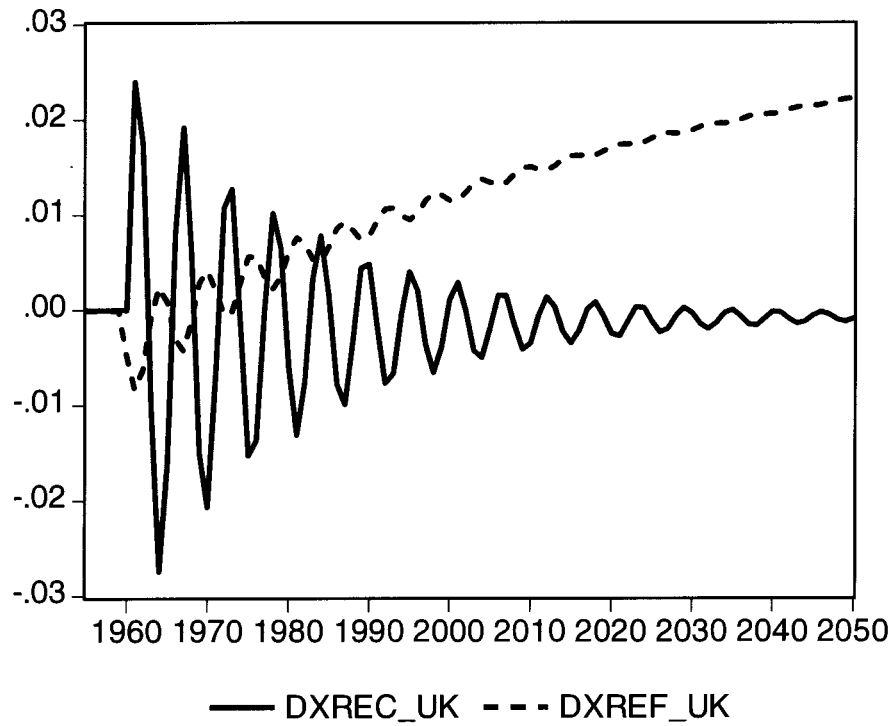
Figure 10: An increase in the U.K. interest rate (right axis), U.K. exchange rate and expectations about the U.K. exchange rate (Experiment 2)



⁴ Remember that in this simplified world with no banking sector and no credit, the effect of an increase in interest rates is an expansion of economic output and an increase in prices. In this world, expansionary monetary policy therefore corresponds to an increase in the interest rate and a restrictive monetary policy corresponds to a decrease in the interest rate.

As one would expect, once the exchange rate dips below 1, the exchange rate expectation is more and more consistently above the actual exchange rate. This is because whenever the exchange rate is decreasing, the chartists expect it to decrease while the fundamentalists expect it to increase. On the other hand, whenever the exchange rate is increasing, both chartist and fundamentalists expect it to increase. This is illustrated in Figure 11.

Figure 11: Chartist and fundamentalist expectations of future exchange rate movements (Experiment 2)

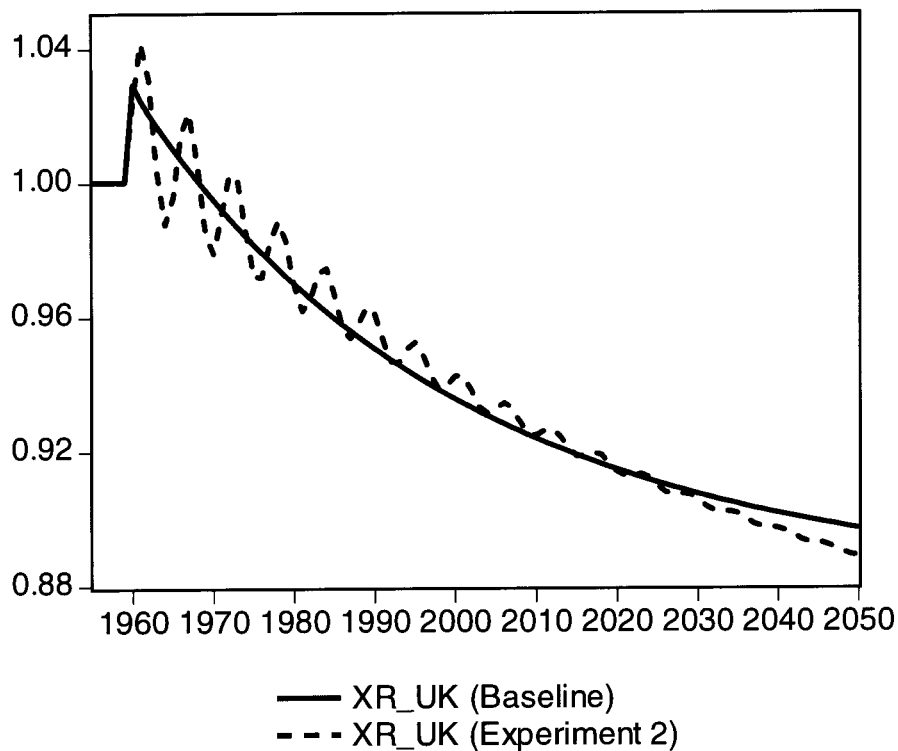


8. Path dependence

An important component of Post-Keynesian theories is the concept of hysteresis, or path dependence. This is the notion that transitional dynamics are important to the long-run equilibrium of an economic system. We will now investigate to see whether or not speculator expectations about exchange rates can have an impact on the long-run exchange rate and on real variables.

Our first step will be to compare the exchange rate in the baseline case to the one in Experiment 2⁵ in Figure 12.

Figure 12: U.K. exchange rate (Baseline and Experiment 2)

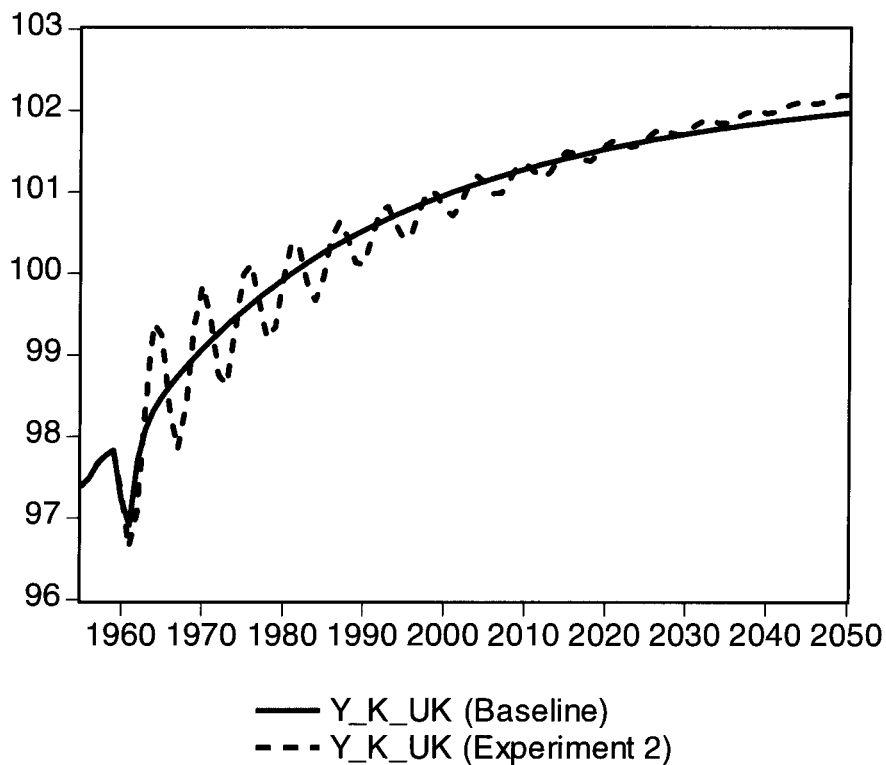


⁵ The choice to compare to Experiment 2 is arbitrary. The same comparison with Experiment 1 would yield similar results.

We see that the exchange rate ends up slightly lower when exchange rate expectations are modeled. The difference, however, is negligible. Analysis of the last data point of the simulation shows that the difference between the two is less than 1%.

Next, we look at real output in the U.K. for both the baseline simulation and the Experiment 2 simulation in Figure 13.

Figure 13: Real output in the U.K. (Baseline and Experiment 2)



Again, when looking at real variables, the difference is negligible. The difference between the long-run steady state of real output of the two simulations is less than 1%.

The next step is to see whether or not the monetary authority's decision to raise the U.K. interest rate by 25 basis points has long-term effects in the Baseline simulation and in the Experiment 2 simulation. To do this, we double the simulation period and roll back the interest rate increase midway through the simulation. In other words, the monetary authority increases the interest rate from 3% to 3.25% at the beginning of the simulation and then brings it back down from 3.25% to 3% midway through the simulation. Figure 14 shows the evolution of the dollar per pound exchange rate for the baseline case, where expected exchange rate movements are constant at 0.

Figure 14: An increase in the U.K. interest rate, followed by a decrease in the U.K. interest rate by (right axis) and U.K. exchange rate (Baseline)

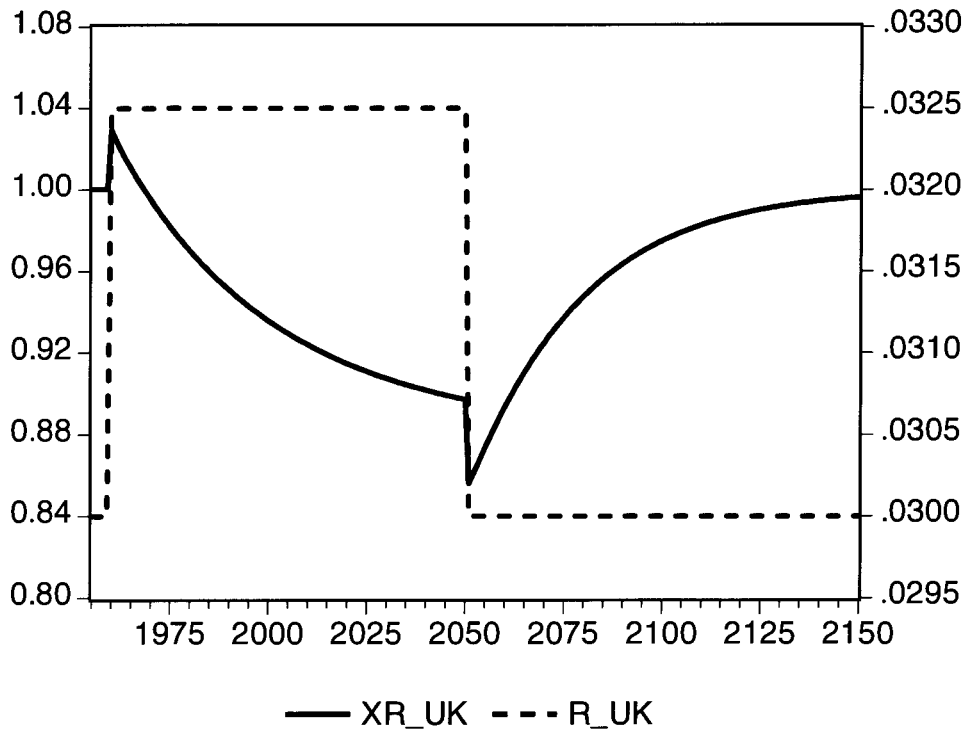
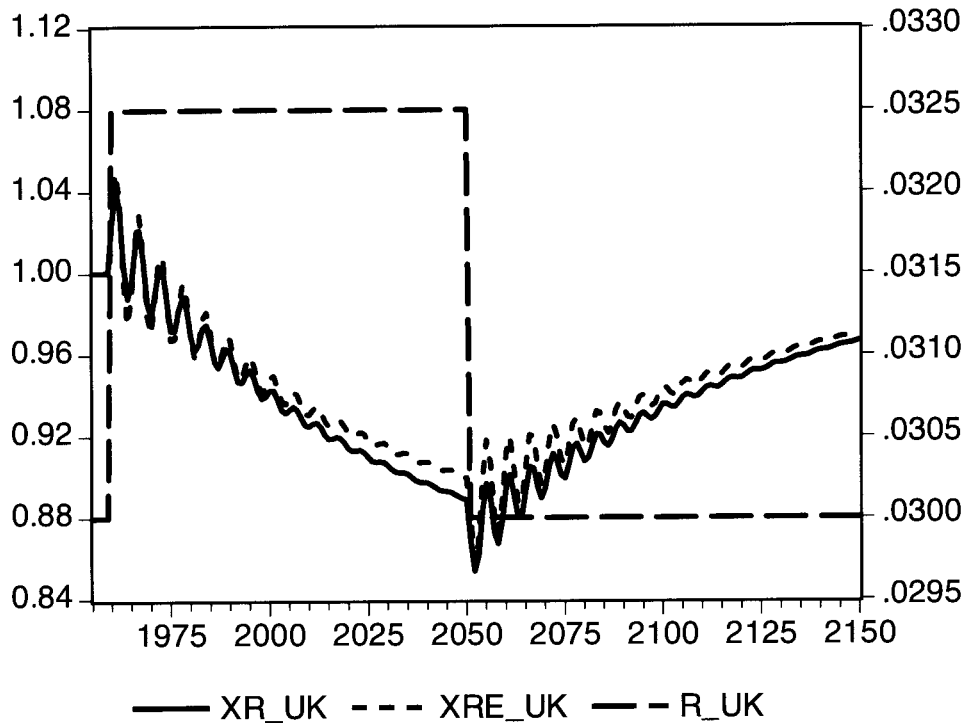


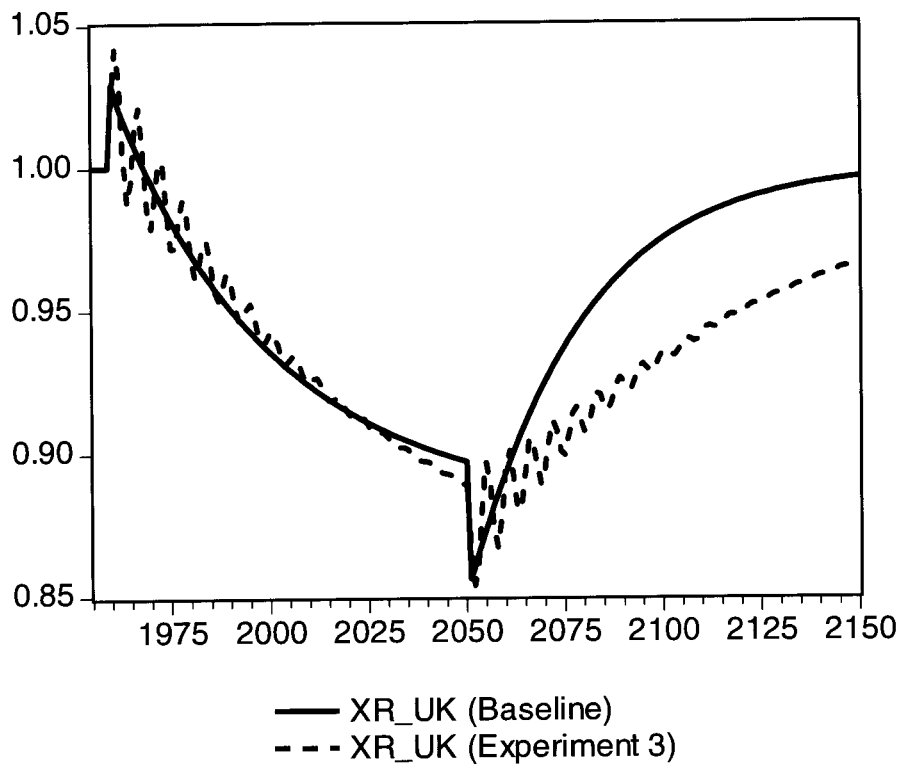
Figure 14 clearly shows that after the interest rate decreases back to 3%, the exchange rate goes right back to 1. Figure 15 shows the results of the same experiment when exchange rate expectations are modeled using the same parameter specifications as those used in experiment 2.

Figure 15: An increase in the U.K. interest rate, followed a decrease in the U.K. interest rate by (right axis), U.K. exchange rate and expectations about the U.K. exchange rate (Experiment 3)



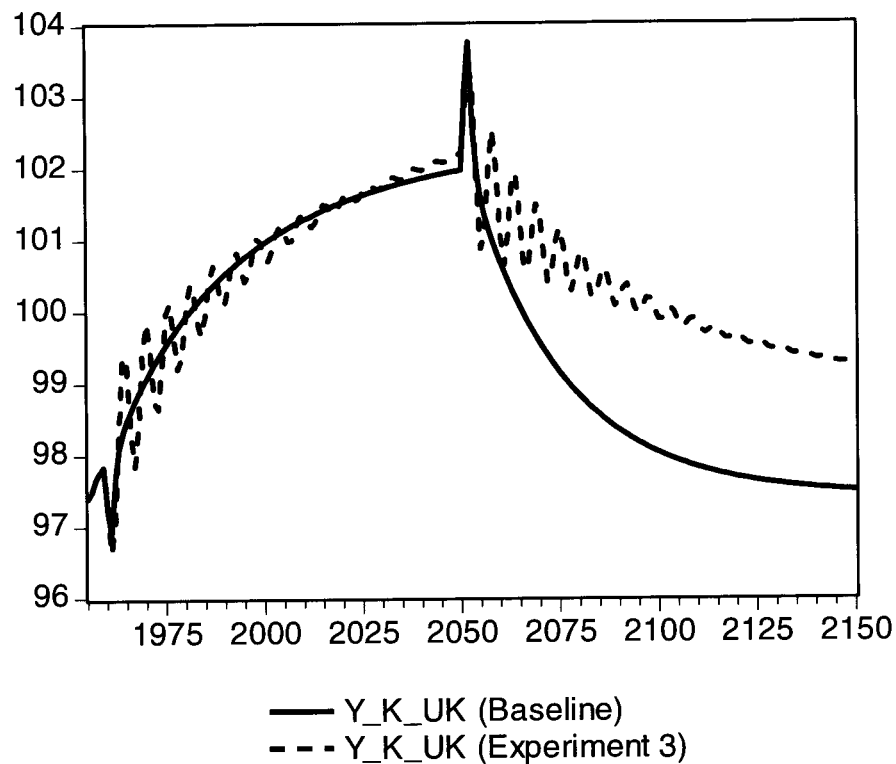
It is obvious from Figure 15 that the exchange rate converges to a level below 1. This can better be seen by comparing the exchange rates in Figure 14 and 15 side by side. They are presented in Figure 16.

Figure 16: U.K. exchange rate (Baseline and Experiment 3)



The second interest rate change seems to amplify the small difference between the baseline simulation and the Experiment 3 simulation. In fact, we find a 3% difference between the steady state exchange rate of the Baseline simulation and that of the Experiment 3 simulation. To see if this translates into differences in real variables, we plot real output for the two simulations in Figure 17.

Figure 17: Real output in the U.K. (Baseline and Experiment 3)



There is a 2% difference between the steady state level of real output in the U.K. in the baseline case and the one in Experiment 3.

These results suggest that speculator expectations about future exchange rate movements can be a cause of path dependence. The increased volatility created by speculators in foreign exchange markets creates small effects on real macroeconomic fundamentals. These small deviations are amplified every time the economic system is shocked by changes to key variables such as the interest rate.

9. Further experiments, when propensities to import change

In order to check the robustness of our results and conclusions, we now run a second set of experiments where instead of changing the interest rate in the U.K., we modify the propensity to import in the U.S.

The two key equations involved will thus be those governing trade flows in the Godley-Lavoie stock-flow consistent model:

$$\log(x^{\pounds}) = \varepsilon_0 - \varepsilon_1 \cdot \log(p_{m-1}^{\$} - p_{y-1}^{\$}) + \varepsilon_2 \cdot \log(y^{\$})$$

and

$$\log(im^{\pounds}) = \mu_0 - \mu_1 \cdot \log(p_{m-1}^{\pounds} - p_{y-1}^{\pounds}) + \mu_2 \cdot \log(y^{\pounds})$$

where x^{\pounds} are U.K. exports, im^{\pounds} are U.K. imports, $p_m^{\$}$ are U.S. import prices, p_m^{\pounds} are U.K. import prices, $p_y^{\$}$ are U.S. domestic prices, p_y^{\pounds} are U.K. domestic prices and $y^{\$}$ & y^{\pounds} are U.S. and U.K. output, respectively.

Of course, since the model contains only two economies, U.K. exports equal U.S. imports, and vice versa:

$$x^{\pounds} = im^{\$}$$

and

$$x^{\$} = im^{\pounds}$$

Therefore, the import prices in the U.S. are the export prices in the U.K., and vice versa:

$$p_m^{\$} = p_x^{\pounds} \cdot xr^{\pounds}$$

and

$$p_m^{\pounds} = \frac{p_x^{\$}}{xr^{\pounds}}$$

These last two equations clearly show the link between trade flows and the exchange rate.

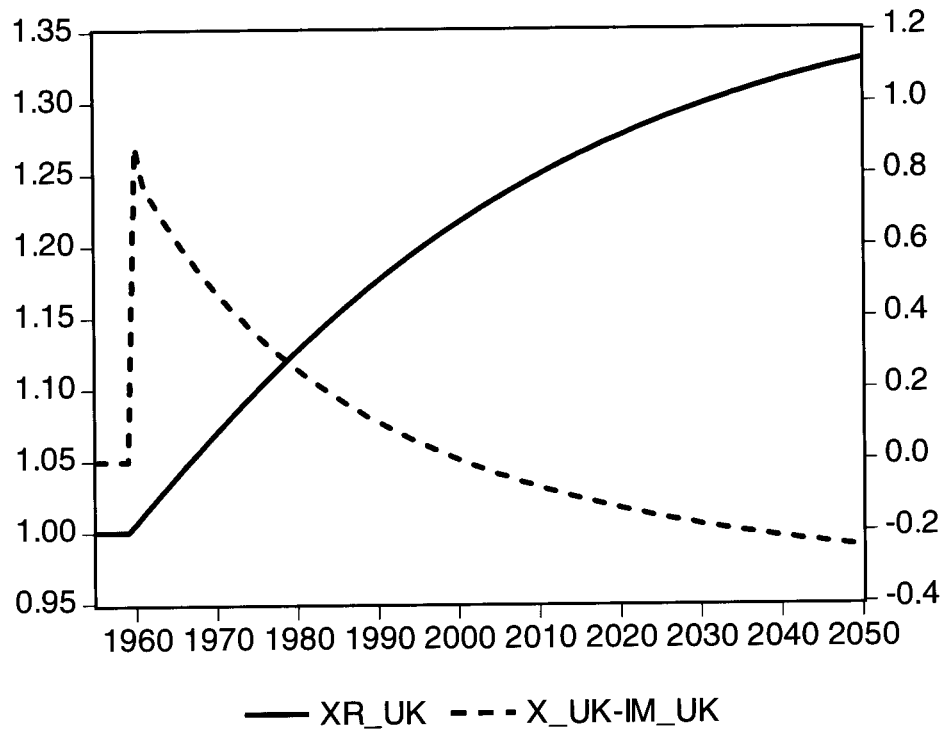
9A. Baseline experiment

As was the case in earlier experiments, where the interest rate was our shock variable, we begin with a baseline experiment where exchange rate change expectations are set to 0.

In order to increase the propensity to import in the U.S. we will increase the ε_0 parameter in the equation governing U.K. exports from -2.1 to -2⁶. The results of this baseline experiment are presented in Figure 18.

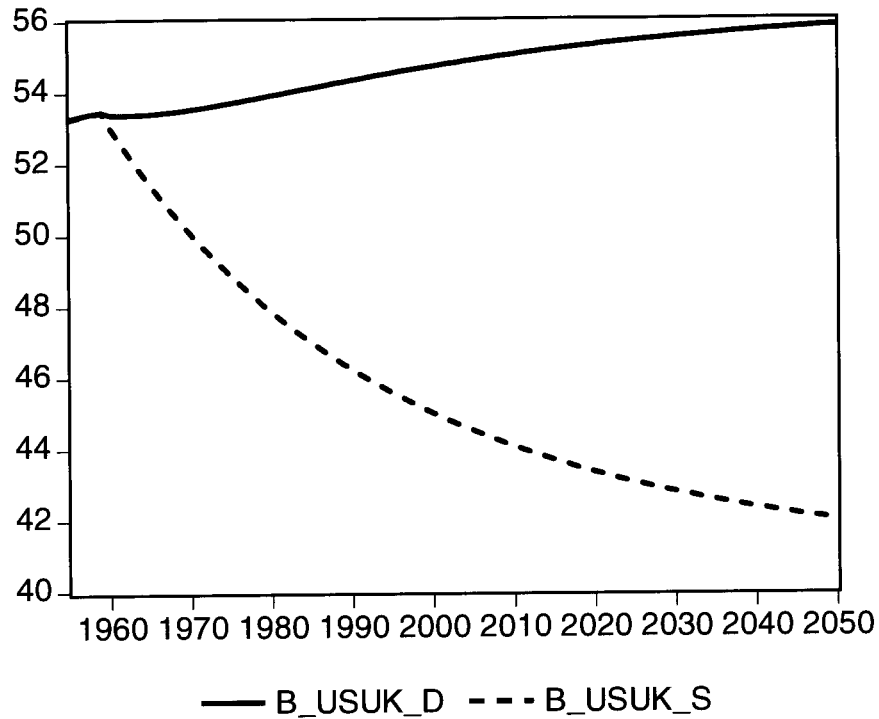
⁶ Remember that since there are only two economies in this model, a parameter change that increases U.K. exports is equivalent to increasing the propensity to import in the U.S.

Figure 18: U.K. exchange rate and U.K. trade balance (right axis) after an increase in the propensity to import in the U.S. (Baseline)



When the propensity to import increases in the U.S., U.K. exports increase immediately. As the dollar per pound exchange rate increases, however, the U.K.'s trade balance decreases as U.K. goods and services become more and more expensive relative to U.S. goods and services. In order to understand the U.K. exchange rate's appreciation, let us once again look at the demand and supply of U.K. bills. This is represented in Figure 19.

Figure 19: Demand and supply of U.K. bills in the U.S. (Baseline)

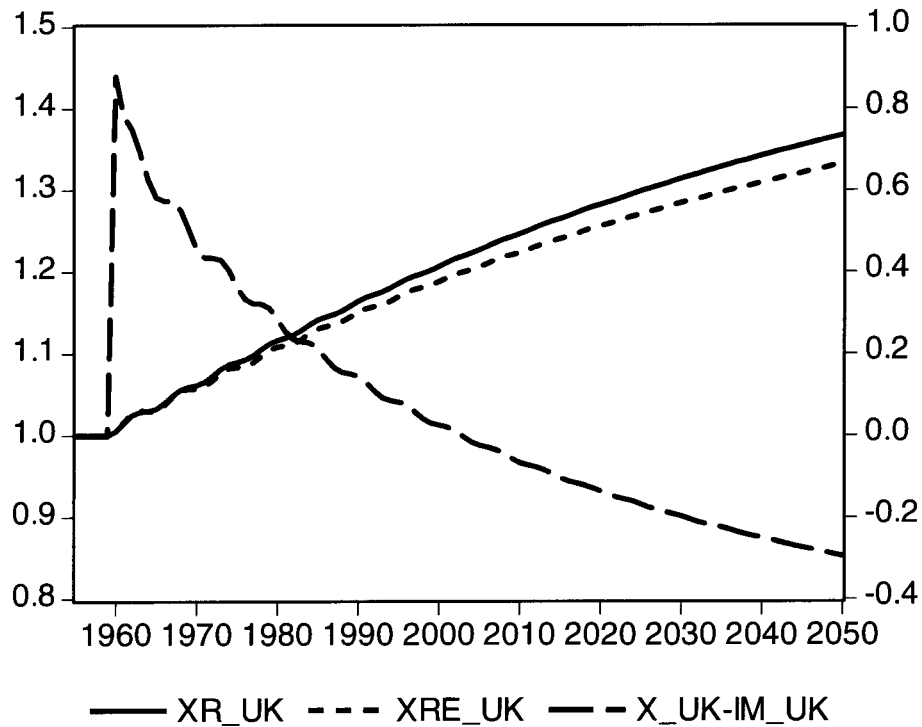


From Figure 19, it is easy to see that the supply of U.K. bills is the main driver in the movement of the exchange rate. We can also conclude that since changes in bills supply are directly related to the government budget, the appreciation in the exchange rate is caused by the sudden increase in U.K. exports which causes an increase in U.K. output. This increase then translates into a government surplus through higher tax revenues and, ultimately, a decrease in the supply of U.K. bills.

9B. Exchange rate expectations

Having analyzed the baseline case, we can now reintroduce exchange rate expectations and see how the model reacts to an increase in the propensity to import in the U.S. To do this, we set up the xr^e variable in the fundamentalists' exchange rate change expectation equation to 1, which is analogous to Experiment 2. Once again, we shock the model by increasing the ε_0 parameter in the equation governing U.K. exports from -2.1 to -2 and call this simulation Experiment 4. The results are presented in Figure 20.

Figure 20: U.K. exchange rate, expectations about the U.K. exchange rate and U.K. trade balance (right axis) after an increase in the propensity to import in the U.S. (Experiment 4)



The first thing to notice is that once again, the general picture is very similar to the baseline case since speculators make up only a portion of the foreign exchange market. The second thing to notice is that since in this experiment, the interest rates are stable and equal in both economies, exchange rate expectations create significantly less volatility than when the U.K. interest rate was the shock variable. This can easily be explained by the fact that the exchange rate is determined by the demand for financial assets. Since the interest rates are stable, the demand for financial assets is much less likely to shift wildly from one country to the other.

9C. Path dependence

To deal with the issue of path dependence, we again double the simulation period and bring the propensity to import in the U.S. back to its initial level halfway through the simulation. The results of the baseline case are presented in Figure 21.

Figure 21: U.K. exchange rate and U.K. trade balance (right axis) after an increase in the propensity to import in the U.S., followed by a decrease in the propensity to import in the U.S. (Baseline)

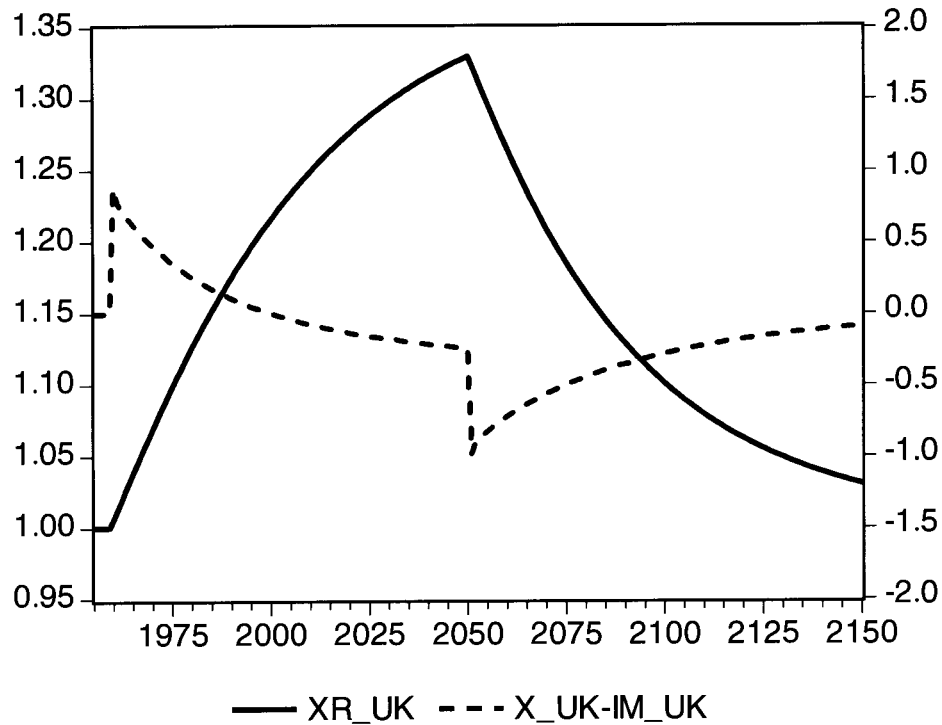
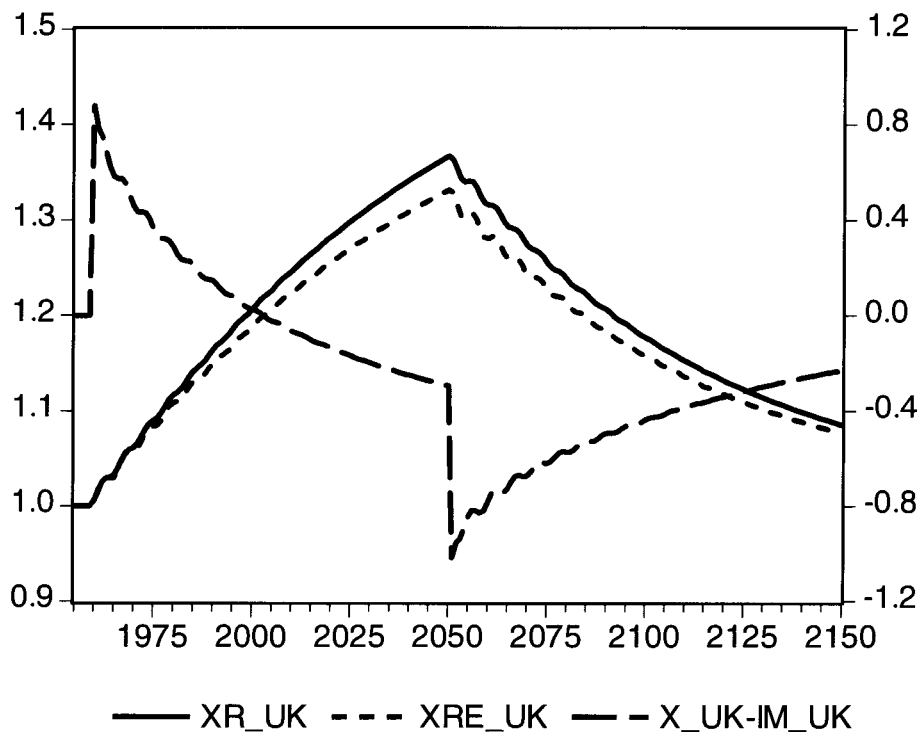


Figure 21 shows that the U.K. trade balance and exchange rate don't quite make it back to their initial levels after we reverse the shock to the propensity to import in the U.S.. The exchange rate is higher than its initial level by approximately 3% and the trade balance is lower than its initial level by approximately 9%. These differences can simply be attributed to slow convergence.

As is shown in Figure 22, however, the discrepancy between the U.K. exchange rate and trade balance at the beginning and at the end of the simulation is much larger when exchange rate expectations are reintroduced into the model.

Figure 22: U.K. exchange rate, expectations about the U.K. exchange rate and U.K. trade balance (right axis) after an increase in the propensity to import in the U.S., followed by a decrease in the propensity to import in the U.S. (Experiment 5)



With exchange rate expectations, the exchange rate is higher than its initial level by approximately 9% and the trade balance is lower than its initial level by approximately 23%. These results are further evidence that the volatility caused by speculation fuelled by exchange rate expectations can be a cause of hysteresis, or path dependence.

Concluding remarks

The theoretical and empirical challenge presented by flexible exchange rate regimes has led economists to explore new ways of modelling agent behaviour. One of these alternatives, behavioural finance, has proven to be very useful in breaking down long-standing assumptions in theoretical models and in getting better out-of-sample fit in empirical studies. However, behavioural finance models can seldom be used independently of other modelling approaches.

In this paper, we have used a stock-flow consistent framework in order to give our results as much realism and coherence as possible. Stock-flow consistent model use a comprehensive accounting framework that doesn't rely on traditional mainstream economics assumptions such as the rational expectations hypothesis. For this reason, the stock-flow consistent framework is ideal for the behavioural finance model presented in this paper.

After running several experiments using numerical simulations, we find that the behavioural finance model of exchange rate expectations can replicate the excessive volatility found in foreign exchange markets. We also found that, within this framework, though exchange rate expectations have a significant effect on exchange rate movements, the long-run effects on real variables is negligible. However, we do find evidence that when successive shocks are imposed on the economic system, the effect of exchange rate expectations on real variables of the model are amplified. We thus find evidence that the volatility caused by exchange rate expectations can be a cause of hysteresis, or path dependence.

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