EXCHANGE RATE FORECASTS AND FORECASTING

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DECLARATION OF RIGHTS

This thesis is dedicated to those I love most,
Mom, Ryan, Rebecca, and most of all to the memory of my Dad.

I have had the benefit of working with many stimulating colleagues at three institutions during the completion of this thesis. It began at the University of Dundee where weekly postgraduate presentations, chaired by Chris Rogers, helped to mould my work. All participants at these meetings deserve my thanks but I would like to acknowledge the special contributions of Angela Black, Peter Macmillan, and Ali Watson. Although he is an accountant, I am not ashamed to say that David Power also helped me enormously.

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ABSTRACT

This thesis is concerned with forecasting key floating exchange rates. The first half is based on the predictions of almost two hundred forecasters, working in banks, industrial companies, chambers of commerce and specialist forecasting agencies. It demonstrates that individual forecasters interpret commonly available information differently, and that these differences of opinion translate into economically meaningful heterogeneity in forecast performance - some forecasters are significantly more accurate than others. It also shows that the dispersion of forecasts helps to explain turnover in the foreign exchange futures market.

The notion that the best predictive model of the exchange rate is a random walk has stood the test of time. In chapter three we evaluate the forecasts of our panellists based on a variety of metrics, using the random walk as a benchmark. Over short horizons (three months) the random walk remains preeminent, but over a one year horizon several forecasters demonstrate an ability to outperform. In an attempt to overturn the short horizon results we combine forecasts using several techniques in chapter four, but to no avail. It would appear that we are unable to find any information that is not discounted into the current spot rate but which is relevant over short forecast intervals.

The second half of the thesis builds three exchange rate models based on an augmented theory of purchasing power parity, with which we forecast key rates. The five variable, simultaneous equation models each incorporate long-run equilibria characterised by economically meaningful restrictions, and complex short term dynamics. The thesis demonstrates that these models are capable of generating fully dynamic forecasts which rank very favourably when compared to our panellists. More tellingly, it also shows that the forecasts are significantly better than a random walk over all but the shortest of horizons.

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CHAPTER 1

INTRODUCTION TO THE FOREIGN EXCHANGE MARKET

1.1 INTRODUCTION

Though most dealers prefer champagne to Carlsberg it is still fair to say that the foreign exchange market is 'probably the largest market in the world.' It is not surprising then that the foreign exchange market has been so heavily researched by economists. This thesis will add to that research, hopefully in a meaningful way. It will concentrate on analysing the forecastability of the three most important exchange rates, based on a novel data base of predictions gleaned from leading forecasters and from the application of the most up-to-date econometric techniques to one of the simplest models of the exchange rate.

The rest of this introductory chapter will describe the various perceptions of how the foreign exchange market operates, introduce terms and concepts which will be used later on in the thesis, and describe the data that we shall use in analysing the market. It closes with a brief summary of the findings of the research presented in the following chapters.

1.2 THE FOREIGN EXCHANGE MARKET

The Bank for International Settlements estimates the average net daily turnover in the largest 26 centres in April 1992 to have exceeded US$870 billion, of which almost one third involved the London market.[1] Although only one survey with this extensive coverage has been performed to date, economists at the Bank of England, who have carried out three surveys of the London institutions, have reported a "substantial increase in the global volume of foreign exchange activity over the last

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1 Bank for International Settlements (1993)

three years [to April 1992]."[2] They further estimate that an even larger rise occurred between 1986 and 1989, and that over both three year periods the rise in turnover exceeded the increase in the value of world trade. They attribute part of these increases to the deregulation of financial markets and the resultant rise in cross-border capital flows. This explanation is borne out by statistics that confirm the rising importance of cross currency trades (i.e. those not involving the US dollar), particularly against the Deutsche mark. It is still true to say, however, that the dollar dominates the market with over fifty percent of the London total being transactions involving the dollar against the 'big three' (pound sterling, Deutsche mark or Japanese yen). In the following subsections we shall examine trading in the foreign exchange market in more detail, and introduce some terms to be used through the rest of the thesis. We shall concentrate on the London market as it is (a) the largest, (b) the most diversified and (c) has been surveyed the most. Where possible comparisons will be made with other centres. Unless otherwise noted, the following data are taken from the Bank of England Quarterly Bulletins referenced in footnote 2.

The most popular type of transaction is for spot value. That is a contract to sell one currency for another with settlement no more than two days after the deal is made. In London in April 1992, such deals constituted fifty percent of all transactions, though this was down on both of the previous survey levels. A similar drop in spot business as a proportion of total turnover has also been recorded in the US markets. The beneficiary of this decline has been the forward contract in its many different forms. The general definition of a forward contract is that it is a transaction for settlement in more than two business days time. This is obviously a rather broad category and further divisions are often made. An outright forward is a single sale or purchase of currency for future settlement. A swap is a spot sale (purchase) against a matching forward purchase (sale), and a forward/forward is a swap transaction between two forward dates. Swaps (both spot/forward and forward/forward) dominate the forward market, as can be seen from Table 1.

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[2] Bank of England (1992). Details of earlier Bank surveys are contained in Bank of England (1986, 1989).

Futures contracts are standardised contracts committing the parties to buy or sell a specified amount of currency on specified future dates. They can be viewed as outright forwards, but due to the standardising of terms (currencies, amounts and dates) they are more liquid and so can be traded in secondary markets more easily than a forward contract. An option gives the holder the right, but not the obligation, to buy or sell a specified amount of currency at an agreed rate at a specified future date or dates. These too can be standardised exchange traded contracts or may be more tailored over-the-counter deals. Unlike other contracts mentioned, where no exchange of money occurs until settlement, an option is purchased for an up-front premium. Futures and options, collectively known as derivative instruments, are growing in use quickly but still make up only a small part of the foreign exchange market in London (see Table 1). They are more prevalent in the US and Japan, with most of the growth in this sector coming from over-the-counter option trades. The Bank of England did note, however, that the big users of derivatives were not captured by their survey, which focused on banks, brokers and investment houses that made markets in foreign exchange (see later for further discussion of exchange participants). Two major users of options in particular are companies facing uncertain foreign currency flows who want to hedge exposure but who need the flexibility of options, and portfolio managers who wish to minimise the downside of currency exposure whilst maximising potential upside profits, neither of whom were covered by the questionnaires.[3]

[3] See Cavalla (1989) for some of the investment strategies available to options users.

Table 1
Breakdowns Of Gross Foreign Exchange Dealings In London 1992

		Shares of total turnover by currency		
		Spot	Forward	Total
Deutsche mark		13.7	8.5	22.2
Pound sterling		7.3	11.2	18.5
Japanese yen		5.1	6.9	12.0
Other		23.7	20.7	44.4
of which cross rates		13.8	2.7	16.5
Total		49.8	47.3	97.1
		Shares of total turnover by instrument and maturity		
Spot			50	
Forward	Outright		6	
	Swaps		41	
	Total forward		47	
of which	Up to 7 days		33	
	7 days - 6 months		11	
	6 months +		3	
Derivatives			3	

NOTES: *Source - Bank of England (1992), Tables A and C.*

Despite the growth of forward business, over 80% of all deals are for settlement within seven days (this is also true for the US). This does not necessarily imply that the majority of investments are for equally short periods of time since the proceeds of a short dated deal can be invested in long dated assets. In fact, the relative illiquidity of the longer dated forward and swap markets means that long term foreign currency investments often involve a spot purchase.

The breakdown of currencies traded depends very much upon the financial centre in question. Dollar-yen trades dominate the Tokyo market, for instance, (72% of trade in April 1989), whilst in London the yen is placed third after sterling- and

Deutsche mark-dollar deals. Though the breakdown is not available for other centres, the Deutsche mark is gaining importance in London in terms of trading business against non-dollar currencies. Sterling-Deutsche mark turnover doubled in the three years to April 1992 and other Exchange Rate Mechanism (ERM) related cross trades are thought to be increasing in demand. Nevertheless, the dollar is still dominant with at least 50% (and as much as 85%) of the total business in each of the largest four foreign exchange centres[4] being pound-, mark- or yen-dollar transactions. This does not necessarily mean that the US economy is either the source or destination of the funds due to the dollar's role as a vehicle currency. Spreads between the bid and ask rates in the market are in general much lower for currencies quoted against the dollar rather than non-dollar currencies due to the greater liquidity.[5] Hence, the dollar is frequently used as a vehicle currency, being bought in one deal and sold in another to give the net result of a cross-currency trade. Of course such trades only serve to re-enforce the liquidity effect.

Who, in economic terms, uses the foreign exchange market? An obvious source of a trade is the commercial sector where currency is needed to pay for imports (or equivalently, currency resulting from exports is sold). In London, roughly one-quarter of total net turnover is with non-banks, of which 9% is with non-financial customers. Though a small percentage, such business has a multiplier effect as banks lay off the exposure caused by such a deal with other traders, and so the proportion of non-bank customer to total business is misleading. To some extent, however, such a distinction is becoming increasingly blurred as commercial houses set up their own dealing rooms, that not only service the transactions demand of the company for foreign exchange, but also manage cash flows and generally 'play the markets' to boost corporate profits.

The non-trade related deals in the market will in the main reflect capital flows. These may be short term flows across the exchanges or longer term portfolio adjustments by investment houses. So-called speculation in foreign exchange has

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[4] London, New York, Tokyo and Singapore.

[5] See Commission of the European Communities (1990) Annex A for a further discussion.

been the subject of much discussion lately and we cannot do the subject justice in this introduction. We shall, however, return to it in later chapters.

The final source of trading volume is business related to central bank dealings, consisting of both market intervention and reserve management activities. The actions of central banks are discussed in greater detail in later sections.

1.3 THE ASSET APPROACH TO THE EXCHANGE RATE AND THE ROLE OF EXPECTATIONS

1.3.1 FUNDAMENTAL VARIABLES AND THE EXCHANGE RATE

The pervasive view among economists is that the exchange rate is determined in an asset market, and this thesis will sit firmly within this broad framework. This approach has been developed by Mussa (1976), Frenkel (1976), Dornbusch (1976) and Branson (1977), who see the foreign exchange market as an organised forward looking market that adjusts to expected future developments rather than just clearing short term flows. This is the fundamental difference between flow-determined (standard Marshallian) markets and stock-determined asset markets. Whilst in a goods market demand is a function of, *inter alia*, tastes, wealth and prices, and supply is determined by the costs of production and technology, suppliers and demanders in an asset market are motivated by the same variables. Hence, the price of an asset will adjust to whatever the market as a whole decrees to be the appropriate price.

A simple model will give the essence of the asset market approach and allow us to examine some implications. The spot exchange rate at time t, S_t, is a function of the basic conditions of supply and demand that prevail in the market at time t (often termed the fundamental or driving variables, and which we shall represent by X_t) and the expected change in the exchange rate, conditional on information available at time t

$$S_t = X_t + \alpha E_t(S_{t+1} - S_t) \tag{1}$$

It is the inclusion of the expected rate change in the model makes this an asset pricing equation. The price of foreign exchange today is determined not only by supply and demand conditions today, but also by expectations of the future price. Since α is presumed positive, an expected future fall in the exchange rate will result in an immediate depreciation of the currency, and the degree of unanimity of expectations will determine the flow of trades through the market needed to produce this fall. Universal agreement over the expected drop in the exchange rate will result in the marking down of the spot rate without any trades actually taking place. Disagreement will result in many deals as the exchange traders try to 'find the level' at which stocks are in equilibrium.

Clearly, the formulation of unobserved expectations is central to this approach to determining the exchange rate. The standard theoretical approach to closing this model is to assume rationality on the part of market participants. Repeated forward iteration of equation (1) then reveals that the spot rate depends on a weighted sum of expected future fundamentals.

$$S_t = \frac{1}{1+\alpha} \sum_{i=0}^{\infty} \left(\frac{\alpha}{1+\alpha} \right)^i E_t(X_{t+i}) \tag{2}$$

While there is little debate about the general validity of equations (1) and (2), there is considerable disagreement on which fundamental variables drive the exchange rate. The monetary approach to the exchange rate views the exchange rate as the relative price of two monies, and hence the fundamental variables are simply those which enter the domestic and foreign money demand functions. That is, the domestic monetary equilibrium can be written as

$$m_t = p_t + \phi y_t + \alpha r_t \tag{3}$$

where m denotes the (log of the) money supply, p the (log of the) price level, y the (log of) income, and r represents the interest rate. A similar equation can be written for the foreign money demand function. The exchange rate is introduced via equilibrium in the traded goods market. It is assumed that purchasing power parity holds continuously such that there are no arbitrage opportunities in the goods market

$$s_t = p_t - p_t^* \tag{4}$$

where s represents the (log of the) spot exchange rate and an asterisk denotes a foreign variable. Substituting the domestic and foreign versions of equation (3) into (4) gives

$$s_t = (m - m^*)_t - \phi(y - y^*)_t + \alpha(r - r^*)_t \tag{5}$$

where, for convenience, the parameters in the domestic and foreign money demand functions are assumed identical. A final assumption which allows us to express (5) in the same form as (2) is uncovered interest parity

$$E_t(s_{t+1} - s_t) = (r - r^*)_t \tag{6}$$

which implies that the expected change in the exchange rate is given by the interest differential. Finally, substituting (6) into (5) and solving forward gives

$$s_t = \frac{1}{1 + \alpha}\sum_{i=0}^{\infty}\left(\frac{\alpha}{1 + \alpha}\right)^i E_t\left[(m - m^*)_{t+i} + \phi(y - y^*)_{t+i}\right] \tag{7}$$

Thus the basic monetary approach to the exchange rate holds that the exchange rate depends on the discounted expected future values of relative money supplies and incomes.

A different set of models argue that the exchange rate is determined by the allocation of wealth between a range of international assets - the portfolio balance approach to the exchange rate (see, for example, Branson (1977) and Isard (1978)). The fundamentals driving the exchange rate in the portfolio balance models are the stocks of all possible alternative assets, although in practice the asset classes are typically limited to monies and bonds issued by domestic and foreign governments. Since the balance on the capital account of a country can be defined as either the change in net foreign assets or as the inverse of the current account, the current account can also be introduced as a driving variable behind the exchange rate. A further distinction is that in the monetary models, monies issued by different countries are assumed to be perfect substitutes, whereas in the portfolio balance models they are imperfect substitutes. The degree of substitutability is hypothesised to depend, amongst other things, on the perceived riskiness of alternative assets. Changes in risk perceptions will have an impact on asset allocations and therefore on the value of the exchange rate. We can then add variables which affect risk perceptions to our list of fundamental variables.[6]

The monetary and portfolio balance approaches to the exchange rate are the most important in the academic exchange rate literature and arguably provide a relatively short list of fundamental variables. However, market participants might include additional variables in their decision making processes. In particular, the factors influencing the risk of an asset are not well defined by theory and could in practice include such ephemeral factors as market confidence or political stability. Several other important economic variables, including the fiscal stance of the government, employment levels, and the state of central bank reserves, are often not explicitly included in models of the exchange rate (though they can undoubtedly be shoe-horned into existing models) but may be regarded as important by market participants.

This discussion of omitted variables leads naturally into the issue of bubbles. Suppose initially that the monetary approach is the correct fundamental model of the exchange rate. We can denote by S_t^f the fundamental exchange rate determined by equation (7), which of course satisfies (2). A speculative bubble represents a deviation of the market price from fundamentals such that

$$S_t = S_t^f + B_t \tag{8}$$

[6] We have treated the monetary and portfolio balance views as independent but Mussa (1984) and Frenkel and Mussa (1988) provide syntheses of the two approaches.

An equation in the form of (8) will also satisfy equation (2) so long as the current value of the bubble term is the expected discounted value of the bubble in the subsequent period. That is

$$B_{t+1}^{e} = \frac{1+\alpha}{\alpha} B_t \tag{9}$$

This is most easily pictured by considering an extrapolative expectations mechanism. A rise in the exchange rate results in an expected future rise (the extrapolation of the past) that is fulfilled through equation (2) and the expectations of further rises continue. This will have the effect of driving the spot rate ever further away from its fundamental value, and so may sound irrational. However, though there will be some probability of collapse back to this fundamental price, a rational speculator holding this asset over a given period may see the expected appreciation as sufficient compensation for the risk. Thus, though expectations are not rational in the sense of being model consistent, the agent is still acting rationally.

The rise and fall of the US dollar in the 1980's is the most quoted potential foreign exchange bubble. We say 'potential' since empirical tests for the presence of bubbles have had mixed success. Even when research has indicated the presence of an anomaly, concrete conclusions have proved elusive. Flood and Hodrick (1990) re-interpret bubbles tests as "interesting specification tests" since Flood and Garber (1980) note that omitted variables can bias bubble tests towards rejection of the no-bubbles hypothesis. Suppose now that the monetary model augmented by relative trade balances is the true determinant of the exchange rate, and consider a researcher who does not include these balances as a fundamental variable in his model. Since the 'true' model should contain the external balance, unexpected developments in the trade balance can cause bubble-type dynamics. A pro-bubbles economist may interpret such dynamics as yet more evidence in his favour, whilst an anti-bubbles scholar would extend his model's information set. Since the potential information set is practically limitless unequivocal conclusions are impossible.

The debate over the driving forces behind exchange rates could possibly be settled if models could be shown to explain the bulk of movements observed in the markets. Unfortunately, with the exception of the early tests conducted in the seventies on a small data sample, all models appear to suffer from severe problems. Dornbusch and Frankel (1988) head a ten point list addressing the question of how the flexible exchange rate system has worked in practice with the rather damning phrase "Exchange rates move inexplicably". Their conclusion is based on the fact that in-sample diagnostics from all models result in insignificant or even incorrectly signed coefficients and very poor fit. Economists' failure to explain currency movements is highlighted by Mussa's (1979) set of standards for judging the success, or otherwise, of a model - one capable of explaining ten percent of quarter-on-quarter changes in exchange rates should be deemed successful, one capable of explaining 25 percent is extraordinarily successful, while one able to explain more than fifty percent should either be rejected as too good to be true or reported to the Vatican as a miracle. If in-sample problems are large, out-of-sample problems are enormous. Two papers by Meese and Rogoff (1983*a*, *b*) devastatingly show that the commonly used models cannot predict movements in the exchange rate better than the most naive of all possible alternatives, a forecast of "no change" or the random walk model. This paper is the starting point for much of the rest of this thesis. It is now a stylised fact that economic models cannot predict changes in the exchange rate over horizons shorter than one year. Chapter 5 contains a survey of those attempts to overturn this result which have met with any success. For reasons which are explained more fully in that chapter, even these supposedly successful attempts have not shown any real ability to forecast exchange rates *ex ante*. Rather, by giving the models certain advantages (e.g. the actual values of the exogenous explanatory variables) these papers have demonstrated the validity of the theory. Once these advantages are removed, all ability to predict truly out-of-sample disappears.

1.3.2 THE EFFICIENT MARKETS HYPOTHESIS

While a lack of predictive power may be seen as an indictment of economic models of the exchange rate, it is also fully consistent with another theory regarding the operation of large asset markets. The efficient markets hypothesis (EMH) can be traced back at least to Fama (1965) who describes an efficient market as consisting of a "large number of rational, profit maximisers actively competing with each other to predict future market values of individual securities and where important current information is almost freely available to all participants." With the possible exception of the assumption of rationality, this description fits the foreign exchange market well.

If a financial market is efficient "it utilizes all of the available information in setting the prices of assets" (Ross (1989)). As Ross also states, this definition is purposefully vague and is designed more to be intuitive than to be a formal mathematical statement. We shall see, however, that this does not stop the EMH being interpreted very mathematically.

The EMH is often broken down into three categories, depending on the definition of 'available information'. Weak form market efficiency occurs when the current exchange rate incorporates all the information contained in past exchange rates. An exchange rate determined in a semi-strong form efficient market would incorporate all publicly known information, including past rates. Finally, strong form efficiency implies that all possible information, public and private, is incorporated into the current rate (see Baillie and McMahon (1989) or MacDonald (1988)). A different set of divisions of the EMH is set out in Fama (1991), although the exercise was more for expositional purposes than a totally new approach to the subject.

If the capital market is efficient, standard neoclassical theory shows that the return from investing in an asset will equal the opportunity cost of using the funds. This opportunity cost might also include a risk premium over and above the return on a risk-free investment to induce risk-averse investors to buy (or sell) the asset. Representing the opportunity cost by R, the EMH can be represented mathematically as

$$E(p_{t+1}|I_t) = (1 + E(R_{t+1}|I_t))p_t \qquad \textbf{(10)}$$

That is, the price expected to hold next period conditional on information available in this period (where this information set is defined according to the form of market efficiency) is the price that holds in this period, plus the expected return (the opportunity cost). Equivalently, the discounted price must follow the martingale process

$$\frac{1}{(1 + E(R_{t+1}|I_t))}E(p_{t+1}|I_t) = p_t \tag{11}$$

The fundamental problems in testing the EMH are clear from this last equation. First, the information set must be specified. Weak form efficiency presents no problem since only lagged (own) prices enter. The particular difficulty here is in determining what is publicly available information and what is private (see Ross (1989) for a few examples). Second, expectations must be generated. Finally, and most problematically, the opportunity cost must be determined.

In the foreign exchange market, the capital invested in purchasing currency earns a return equal to that currency's interest rate. Similarly, earnings are foregone in the form of the return from the domestic interest rate. Risk neutral investors will be indifferent between the two alternative strategies if

$$E[(I + r_t)|I_t] = E[(1 + r_t^*)(S_{t+1}/S_t)|I_t] \tag{12}$$

where r denotes a domestic interest rate, r^* a foreign interest rate, and the price of foreign exchange, that is the exchange rate, is given by S. By rearranging equation (12), the opportunity cost, or expected return, is given as

$$E(R_{t+1}|I_t) = \frac{r_t - r_t^*}{1 + r_t^*} \tag{13}$$

and similarly

$$E(S_{t+1}|I_t) = \frac{1 + r_t}{1 + r_t^*}S_t = F_t \tag{14}$$

That is, the expected future spot rate equals the current spot rate multiplied by the ratio of (one plus) the interest rates, which assuming covered interest parity, in turn equals the forward rate, F. With risk neutrality, the forward rate ought then be the best predictor of the future spot exchange rate.

If investors demand a premium for taking risky positions in the foreign exchange market, this must be added to the opportunity cost and means that the forward rate is not necessarily the best prediction of the future spot rate. Many researchers take this as the reason for the poor performance of the forward rate as a predictor of the future spot. Not surprisingly, since the forward discount usually forecasts a movement in the exchange rate in the opposite direction to what actually occurs, the Meese and Rogoff (1983*a*) results show that the forward rate is almost uniformly less accurate than the current spot rate as a predictor. Indeed, the failure of the forward rate as a predictor of future spot rates is so well documented that we will not even consider it as an alternative forecasting model in this thesis (see Hodrick (1987) and Goodhart, McMahon and Ngama (1992) for discussions of the poor performance of the forward rate).[7]

The random walk model, which Meese and Rogoff (1983*a*) show to be such a powerful predictor of exchange rates, imposes a strong condition on equation (14): the exchange rate expected to hold in the next period is the exchange rate that holds in the current period.

$$E(S_{t+1}|I_t) = S_t \tag{15}$$

This will only be true if the expected return is zero and if no premium is demanded as compensation for establishing risky investments.

At this point we should distinguish between a true random walk and a martingale process. If the exchange rate evolves according to a random walk, then

$$S_{t+1} = S_t + \epsilon_{t+1} \tag{16}$$

where ε_{t+1} is a sequence of independently, identically distributed random variables with zero mean and a constant variance. A martingale process requires only that the

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[7] Earlier work based on the databases used in this thesis indicate that the random walk is still more accurate than the forward rate for all currencies considered (see MacDonald and Marsh (1994)).

error terms be uncorrelated rather than independent. Since we shall not examine the error processes of the exchange rate in this thesis we shall use the term random walk to simply imply that the forecast of the next period's exchange rate is the current rate.

While it is clear that if markets are efficient the random walk model does not necessarily have to hold (because of the additional assumptions this implies), a random walk process is fully compatible with EMH. Following Meese and Rogoff, and several authors who have confirmed their results, the more stringent condition of a random walk process will be taken as our baseline assumption of how the market for foreign exchange behaves.

Based on the assumptions of zero mean expected returns and risk neutrality, attempting to predict exchange rates using academic asset approach models is doomed to failure if the market is semi-strong form efficient or better, since the information included in these models will be in the public domain and therefore incorporated in the current exchange rate. Furthermore, if any relevant variable is omitted from the model yet discounted in the current rate, the current rate will be a better predictor of the future than the model.

Nevertheless, analysis of the performance of foreign exchange traders suggest that the majority make profits, not only from exploiting the bid-ask spread but also from position taking (see Goodhart (1988)). Schulmeister (1987) surveys twelve large US banks and finds that every bank reported profits from foreign exchange operations in every year considered.

There would appear to be a contradiction here. On one hand we have traders that perform their job very well and make tremendous profits for their institutions. But on the other, we have academics who argue that we have no useful model of the foreign exchange market, and that any movements in the rate are in any case essentially unpredictable since the spot foreign exchange market is efficient.

Three answers suggest themselves. First, the profits may be being made from positions held for much shorter periods than are typically examined. Traders may be able to regularly exploit very short-lived profit opportunities which occur between information becoming available and it being discounted in the spot rate. The second rationalisation of immense profits being generated in a supposedly efficient market is that, as the Cambist view of the forward market suggests, the problem may lie with forward market, where the speculative positions are established (see Hallwood and MacDonald (1994)). This approach argues that the forward premium is essentially determined by two separate domestic money markets and that it therefore contains no information about the future movements of the exchange rate. If the best predictor of the future exchange rate is today's rate (i.e. the random walk model holds) a forward market premium in favour of one currency can provide profitable opportunities. It may be this inefficiency that traders are exploiting. Third, traders may simply have private information which is not discounted in the current exchange rate and which allows them to make trading profits.

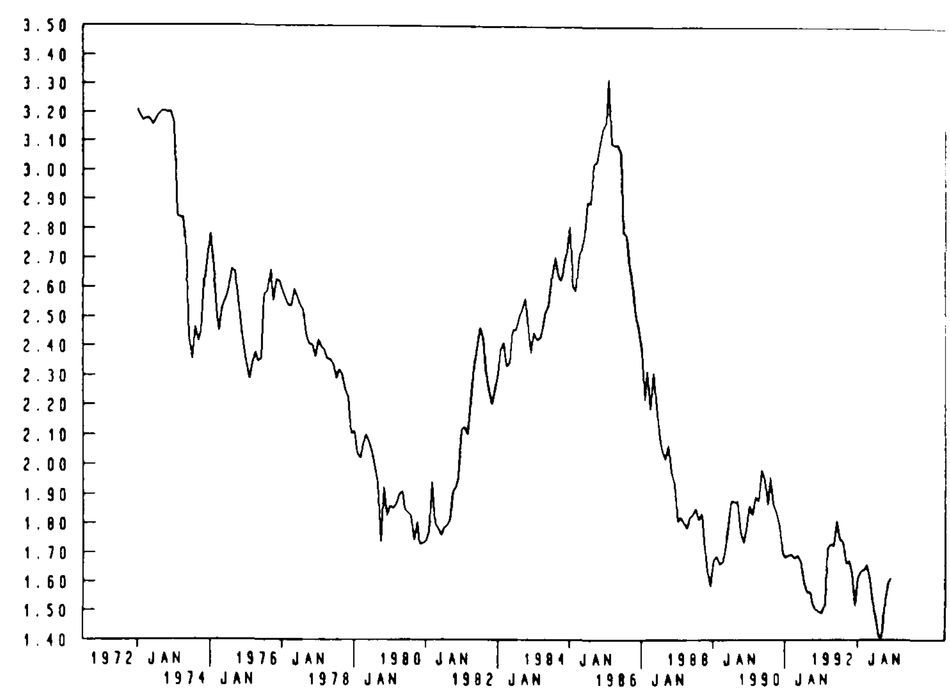
1.3.3 THE FOCUS OF THIS THESIS

In this thesis we shall concentrate on the key aspect of the forecastability of foreign exchange rates. Using a unique set of predictions gleaned from an international panel of forecasters close to the foreign exchange market, we shall examine whether their use of a potentially much wider information set than typically considered by academics allows them to forecast future exchange rates, or whether the spot rate truly does discount all available information. A variety of metrics will be used which will, in particular, allow us to change our assumptions about the expected return and risk attributes of market participants.

We shall also attempt to improve on previous academic attempts to predict the exchange rate using comparatively simple models combined with advanced econometric techniques. It could be that the models are correct in theory but badly estimated in practice, leading to poor performance.

In addition to this concentration on forecastability, we shall also examine the degree of heterogeneity of market participants' forecasts, the implications these differences of opinion have for the market and the reasons behind them. The next section describes the history of the recent float, and section 1.5 details our data sets. In section 1.6 we summarise the forthcoming chapters in more detail.

Figure 1 Deutsche marks per US dollar



Figures 1 through 3 show the course of the three main exchange rates since the end of the Bretton Woods System in the early 1970s. Large swings in the value of the US dollar are evident against both European currencies, and to a lesser extent against the yen. The latter currency has appreciated strongly and the cycles in the value of the yen are dominated by the strong upward trend. The experience contrasts markedly with the expectations of many at the start of the float (see Dornbusch and Frankel (1987)). The volatility of exchange rates in particular is much greater than predicted. The consequences of this increased uncertainty about the future value of currency are difficult to prove (for want of a counter-factual history) but frequently seen as dramatic. Trade between nations has risen since the last war but it is argued that volatile exchange rates have restricted the potential expansion as producers have concentrated on supplying a domestic market, whose prices they can rely on. Cross border investment (both real and financial) has also risen, but here the argument is that the opportunities for profit have released a monster that is out of control.

Figure 2 US dollars per pound sterling

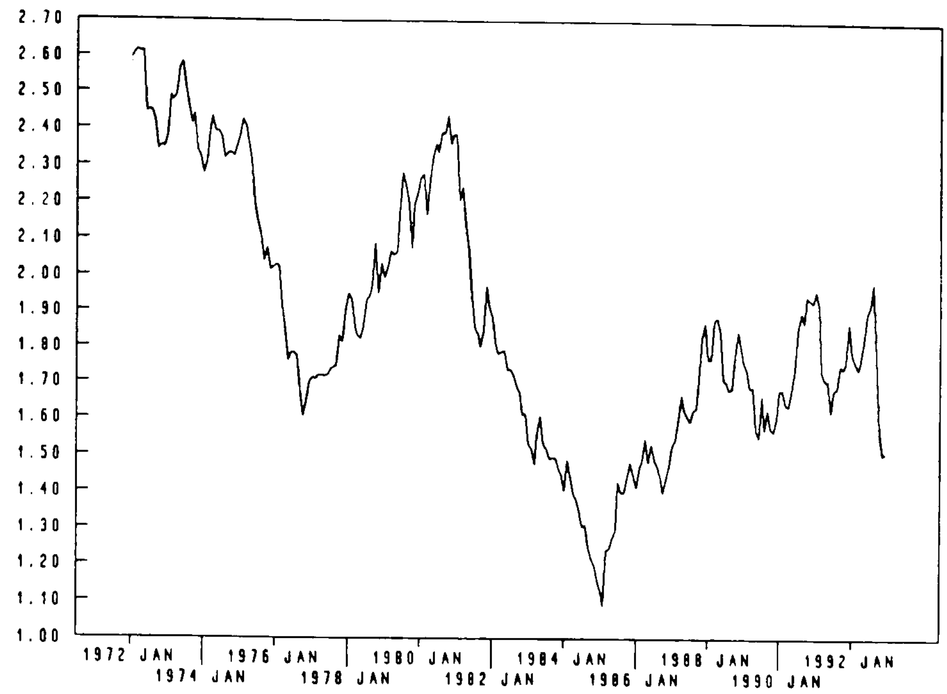
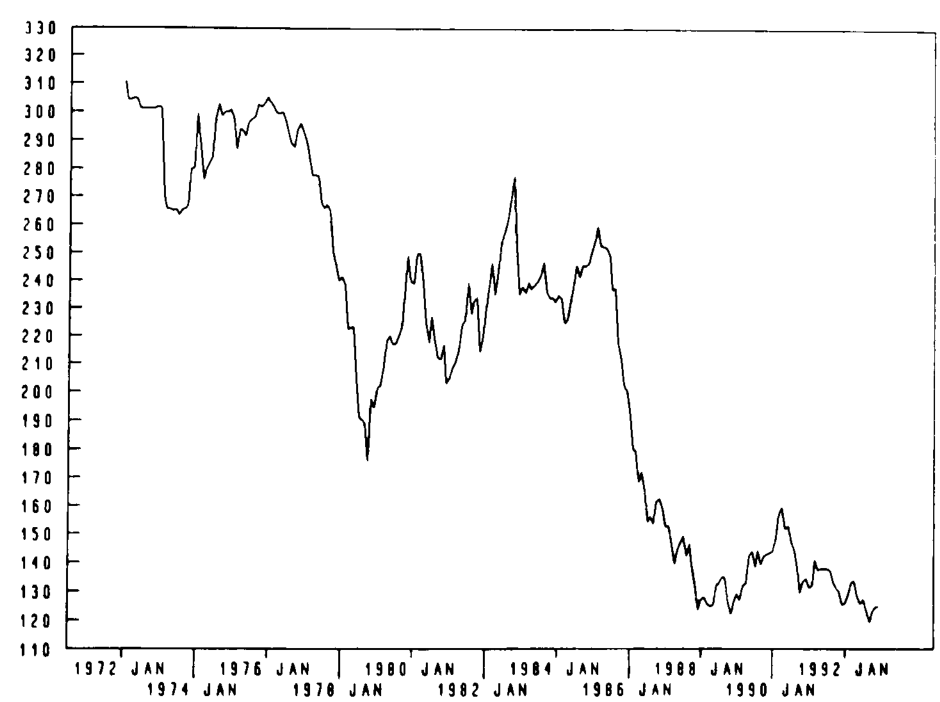


Figure 3 Japanese yen per US dollar



Logically, speculative flows ought to be stabilising, since a profitable trader will buy when a currency is undervalued and sell when it is overvalued. In other words, speculators will push the exchange rate back towards supposedly fundamental levels. Unfortunately, with hindsight speculation is no longer thought to be so obviously stabilising. One school of thought has it that if traders have little idea about the factors which determine the exchange rate and their best guess of the future spot rate is today's rate, then their expectations will not be based on some fundamental equilibrium but rather on the current level of the exchange rate. Dornbusch and Frankel (1988) argue that if the expected change in the exchange rate is near zero then speculation cannot then be stabilising. In view of the amount of money at their disposal the results of their trades on the value of currencies can be dramatic and yet be also unrelated to fundamentals.

Possibly most importantly, there is growing evidence that traders pay little attention to fundamentals anyway. Instead they rely on chartist or technical analysts' advice. These analysts forecast the exchange rate on the basis of patterns in the exchange rate. This is not as simple as it seems, however. Each technical analyst sees a different pattern in the charts, or uses data of different frequency or over different time periods. Some use highly complex mathematical formulae to compute their indicators, others combine information from an array of simple statistics. Some trade on their own account, but more often than not, chartist advice is taken as one element in the decision making process of market participants. Such advice is ignored by very few, but equally is used to the exclusion of everything else by very few. Its importance as far as we are concerned is that chartist elements are not included in academic economic models of the exchange rate, probably because chartism is more of an art than a science and so practically impossible to model in all its complexity.

Given these problems, governments have repeatedly tried to manage exchange rates. An excellent historical account of these attempts is contained in Dominguez and Frankel (1993), and in this section we are concerned only to give a flavour of the effects that intervention by the authorities can have on exchange rates.

There are many different methods of management. The first resort is to 'talk the market up or down'; an official with influence makes on or off the record comments about the value of a currency. Recently, the intergovernmental organisations have taken to making group statements about the appropriateness or otherwise of prevailing exchange rates. In times of speculative uncertainty such comments can stabilise a currency, but as often as not lead to examination of the precise wording used, disagreement between analysts and yet more uncertainty. The next step is often unsterilised intervention in the markets. Again this may be off the record (an intermediary is used who does not disclose that he is trading on behalf of the government or central bank) or on (full disclosure of parties involved). Debate rages over whether sterilised intervention can affect the exchange rate (see Dominguez and Frankel (1993)) but whatever academics may decide, the authorities regularly use sterilised intervention in attempts to push the exchange rate in the direction they wish. If sterilised intervention fails the authorities' final resort is to alter their (monetary) policy stance. This may be through unsterilised intervention, by altering the money supply through open market operations, or by adjusting administered interest rates.

We have stressed the actions of governments and central banks in the market since their reason for trading is usually very different to other participants. Unlike almost every other trader they are not usually trying to make a profit. They are rather trying to manipulate the market is accordance with their monetary policy. If they do have a impact on the exchange rate, models which fail to include some policy reaction function will accordingly fail to capture an important element in the determination of exchange rates.

This thesis will incorporate both chartism and the impact of central bank actions through its use of a novel database of predictions from a panel of professional forecasters. Since there is no restriction on the fundamental determinants used in making their forecasts, at least some of the participants can be expected to incorporate chartist advice and the expected actions of central banks. The next section describes the data used in the thesis, and expands on some of its advantages and disadvantages.

1.5 THE DATA - SOURCES, DESCRIPTIONS AND PROBLEMS

The data series used in this thesis come from several sources. Chapters 2 through 4 are based on the forecasts of a panel of exchange rate experts, who are surveyed monthly by a London-based financial consultancy. These forecasts are matched with actual market data gathered from Barclays Bank International via Datastream. In chapters 6 through 8, we produce forecasts from several econometric models estimated using International Monetary Fund (IMF) and Organisation for Economic Cooperation and Development (OECD) databases.

On the first Monday of each month economists, foreign exchange dealers and executives in over 150 companies and institutions in the Group of Seven nations (G7) complete a fax from Consensus Economics of London asking for point forecasts of, *inter alia*, the spot exchange rate of the Deutsche mark, pound sterling, Japanese yen, French franc and Italian lira against the US dollar three and twelve calendar months ahead (termed the forecast days). Consensus, as their name suggests, construct a consensus (simple mean) forecast from all respondents which is distributed the following Thursday to their subscribers.

The companies surveyed include commercial and investment banks, industrial corporations, chambers of commerce and forecasting agencies (in both the private and public sectors). For reasons of confidentiality we cannot reveal the identity of forecasters and instead we denote each respondent by a mnemonic. The mnemonic comprises a letter giving the nationality of the forecasting company (C - Canada, F - France, I - Italy, J - Japan, B - Britain, U - USA and G - Germany) and a number to distinguish between respondents.

The number of companies surveyed varies from country to country and the panel has expanded with time. The first survey took place in September 1989 when 105 companies were approached and 97 responded. Our data ends in November 1992, at which time 161 companies received the survey form and 124 replied. A total of 177 different companies have been approached over the three years of the survey. Of these, 39 were British-based companies, 24 German and 38 from the United States. A smaller number of companies are approached in Canada, France, Italy and Japan. Companies do not always respond in every month and some only give forecasts for certain currency/forecast horizon combinations. The use of this panel differs in each chapter since different response rates are necessary to examine alternative aspects of the market. The exact use is clarified in each chapter.

We matched this survey database with actual market rates taken from the Barclays Bank International pages on Datastream. These are the middle market (mean of bid and ask) rates prevailing in the foreign exchange market at a time between 3:30 and 4:00 pm in London. Spot, three and twelve month forward rates were collected for the five dollar bilateral rates forecast by our panel. The forward and spot rates are contemporaneous across all currencies, allowing us to calculate cross exchange rates.

Despite the rapid gathering technique of Consensus Economics there are certain imprecisions that we cannot avoid in studying their forecast data set. First, given the global nature of the panel, deducing the exact timing of the forecasts is impractical and hence precise specification of the spot rate prevailing when each individual forecast was made is impossible.[8] We tried to avoid this problem by collecting the Monday rates together with the previous Friday's rates. The true rate should lie somewhere between the two in a trending market. In practice, we find very little qualitative difference between the two and in the rest of the thesis only results pertaining to Monday close rates are reported. Second, the panel are asked to forecast 'the' exchange rate prevailing on some specified date, rather than, say, the New York closing rate. We have chosen the mid-afternoon London rate as the most appropriate due to the London market's dominance of foreign exchange trading and its central position in the daily trading pattern. Occasionally, the forecast day fell on a weekend or holiday, when we took the nearest business day instead. Again, alternative approaches had no significant impact on our results. One final limitation is that the forecasts are collected from companies rather than individuals. If, for example, the chief economist changes job (or has a summer vacation during which

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8 Consensus have informed us that 80% of their forecasts arrive some time on the Monday or on the Tuesday morning. The balance are received before the weekend since the request fax is sent out on the Tuesday preceding the forecast date.

his assistants make the forecasts) the nature of the forecasts might change. We have made no attempt to correct for this due to the obvious difficulties of keeping track of around two hundred people.

Based on our earlier comments, the advantages of the survey database should be clear. The forecasting mechanisms used are not restricted in any way. The panellists can use any or no economic model in making their predictions, and can augment their forecasts with chartist advice, expectations regarding central bank intervention, customer orders, or any other variable which may influence the course of the exchange rate. It is unfortunate that we have no record of the mechanisms used by each forecaster, but anonymity constraints prevented such an investigation. We have, nevertheless, been assured by Consensus Economics that the forecasters polled are key participants in the market, working for leading companies and agencies. If the use of wider information sets can result in improved predictive performance, we would expect our panellists to reveal it.

Chapter 5 uses data on exchange rates, consumer price indices and long-term government bond yields taken from IMF data bases to construct models of the exchange rate. Further details of the exact series used are given in the text of the chapter.

We have examined the broad movements of exchange rates since 1973 in section 1.4. We shall now focus on the period September 1989 to December 1992 - the months during which our forecast panel provided their predictions and the out-of-sample period used in testing the models derived in chapter 5.

The spot exchange rates of our three major currencies against the US dollar over this period are shown in Figures 4 through 6. There are three notable features. First, the large swings in the European exchange rates, with the Deutsche mark for example peaking in February 1991 at around DM1.46 before falling to DM1.82 in the following July - a 24% depreciation in five months. This depreciation reversed over the subsequent year, only to be followed by a period of more dollar strength. Second, we note the relative stability of the yen against the dollar. Over the same five month period to July 1991 the yen fell by only 5.4%. The third major feature is the sharp depreciation of the pound following Black Wednesday in September

Figure 4 Deutsche marks per US dollar

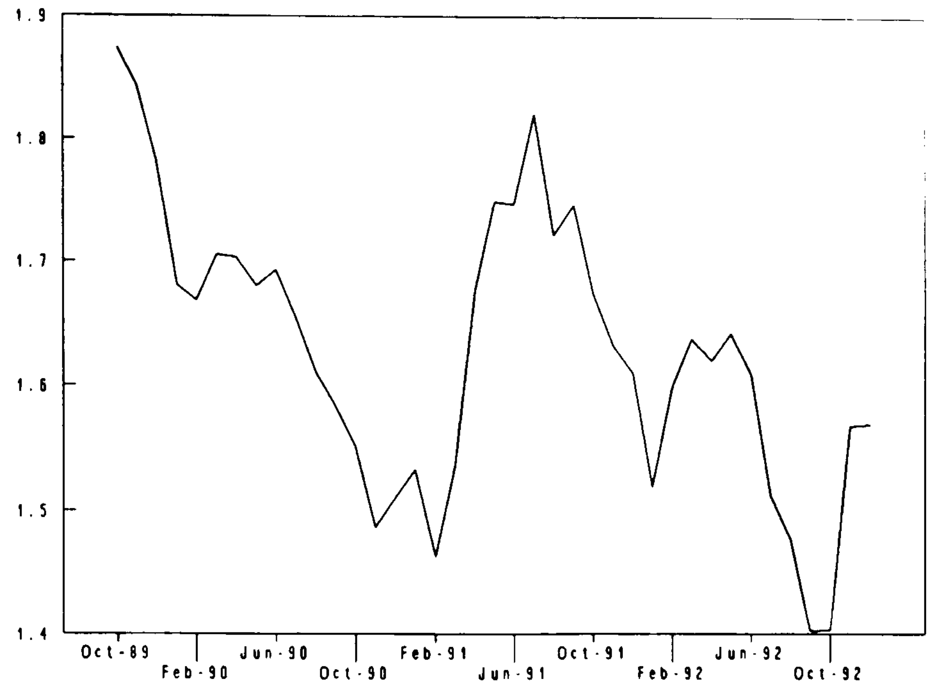
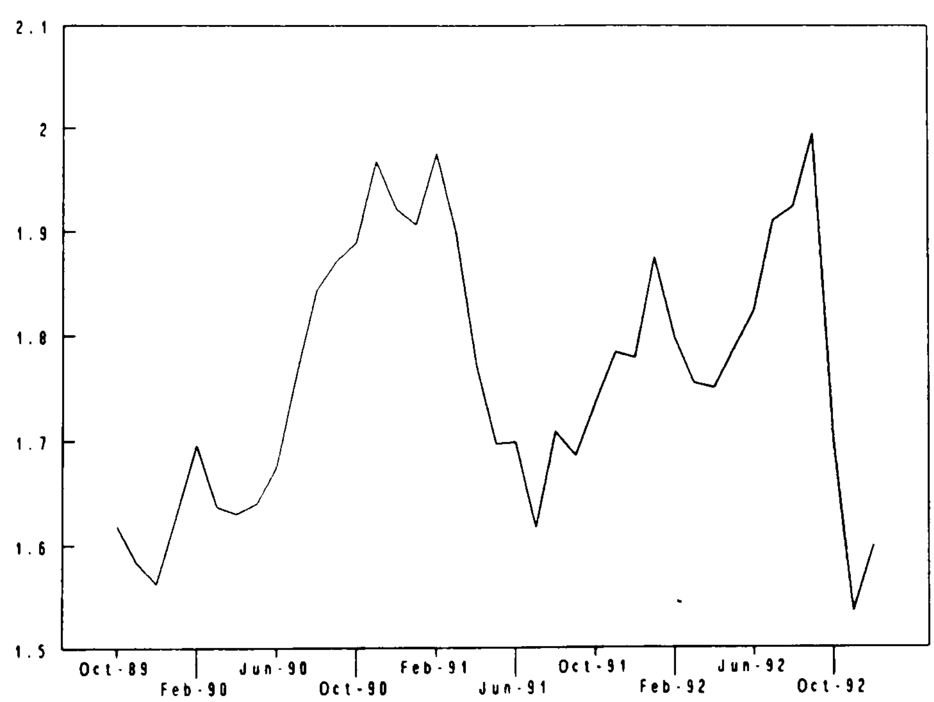


Figure 5 US dollars per pound sterling



1992.

Figure 6 Japanese yen per US dollar

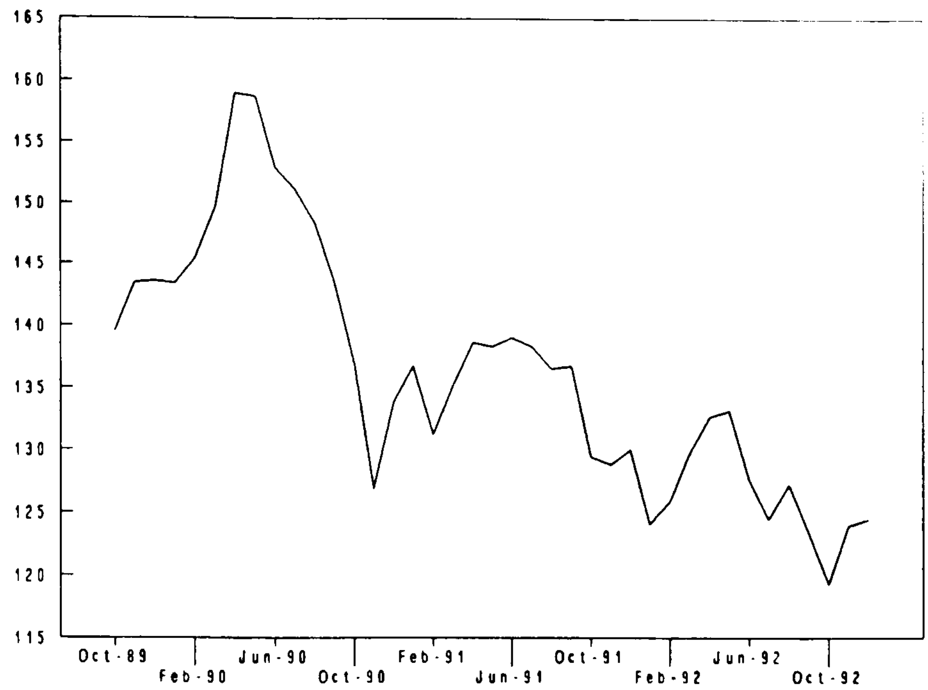
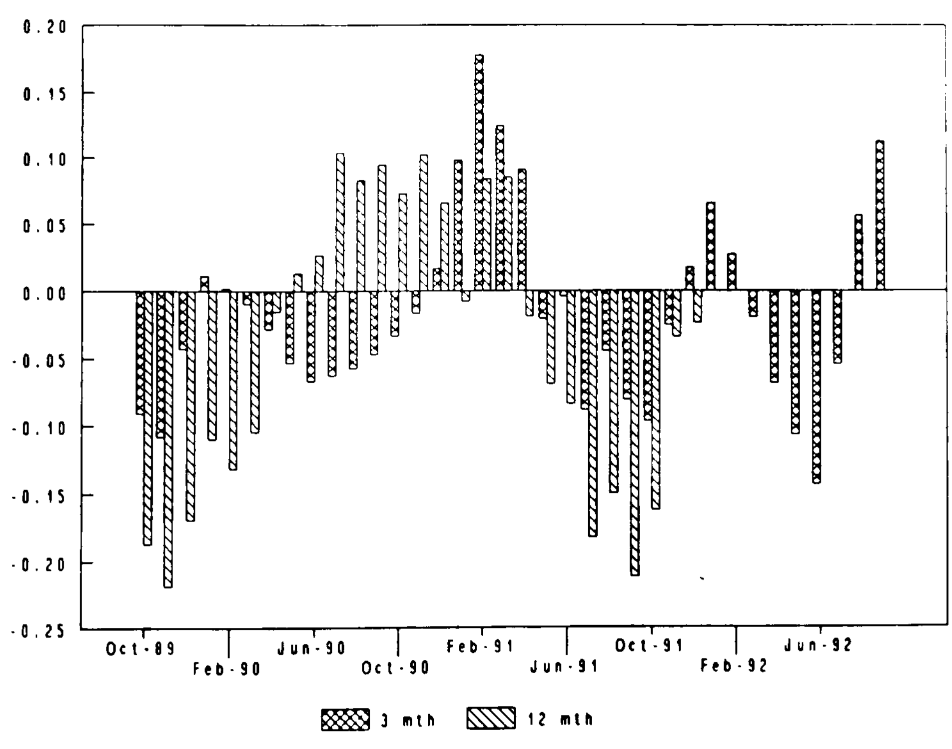


Figure 7 Changes in Deutsche mark exchange rate



The three and twelve month changes in the Deutsche mark, pound and yen

Figure 8 Changes in pound sterling exchange rate

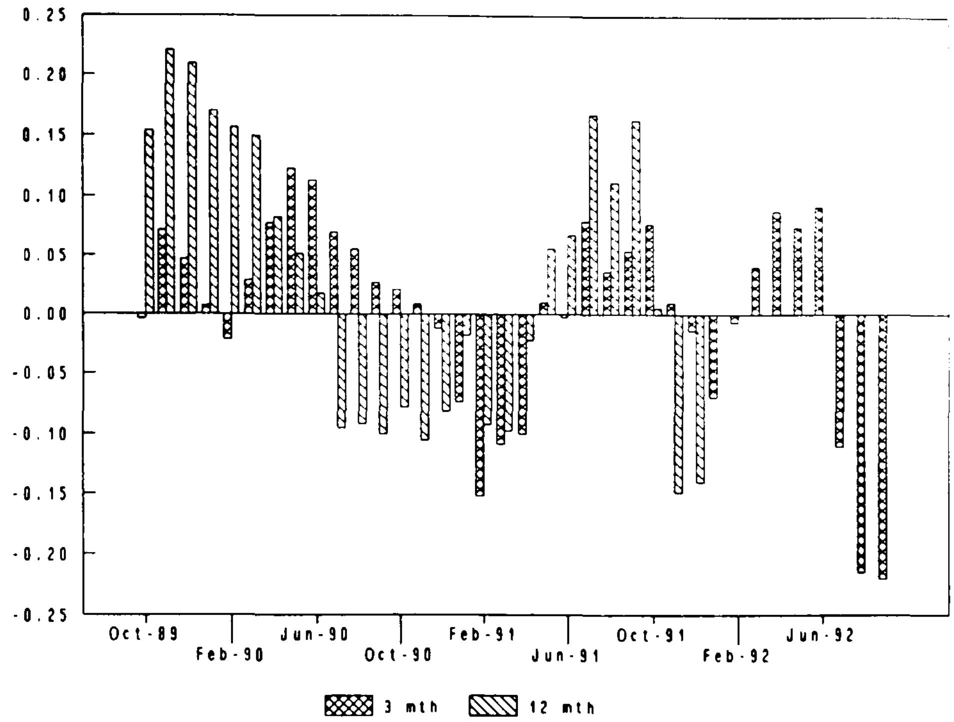
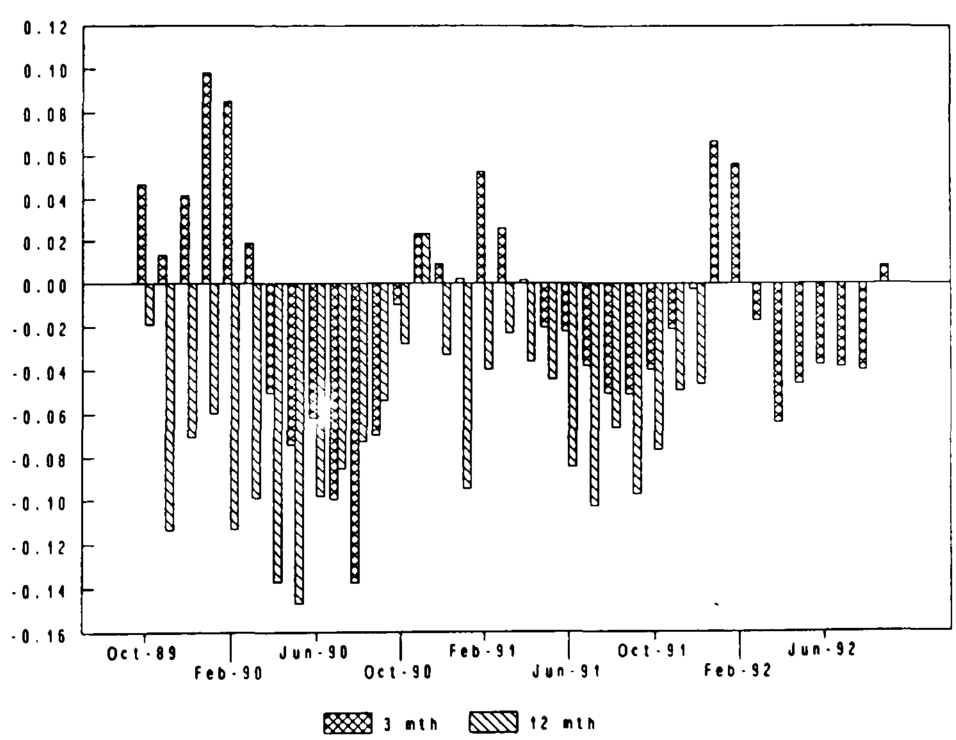
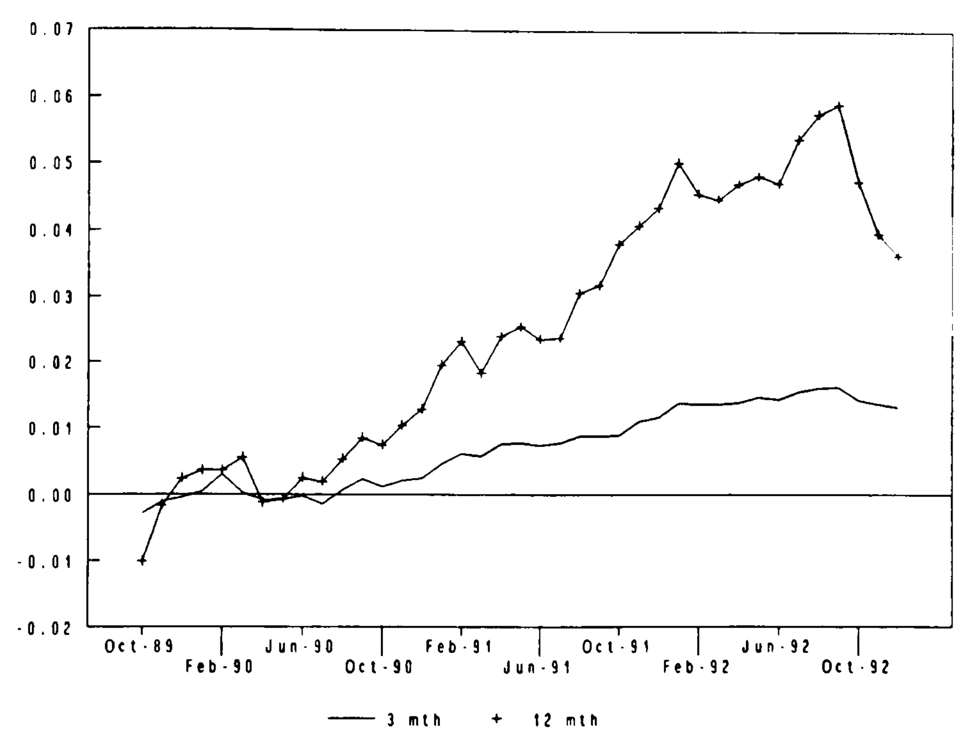


Figure 9 Changes in Japanese yen exchange rate



spot rates that our panellists are trying to forecast are plotted in Figures 7 to 9. These graphs serve to emphasise some of the points mentioned earlier about this period of exchange rate movements, together with some new characteristics. First, we note that three month and twelve month changes are frequently in different directions. Related to this point is the fact that the twelve month changes are not four times the magnitude of the three month ones. Finally, we again note the pronounced tendency for the Japanese yen to appreciate. Of the twenty-seven twelve month changes in the yen-dollar exchange rate only one was positive. The other two currencies have a much more even distribution of appreciations and depreciations.

Figure 10 Forward premia on Deutsche marks



The next three charts show how the three and twelve month forward premia have behaved over the three year period. This time trends are rather more apparent, although the currency volatility in September 1992 resulted in some abrupt shifts in European interest differentials as governments moved to protect their currencies. The simple trends result from the series of cuts in US interest rates as the authorities tried to pull the economy out of recession, combined with high European rates as the Bundesbank fought to keep German inflation down in the face of reunification. Britain and Japan stand apart somewhat since over the final two years at least, the three month forward differentials have remained essentially unchanged. Both of these

Figure 11 Forward premia on pounds sterling

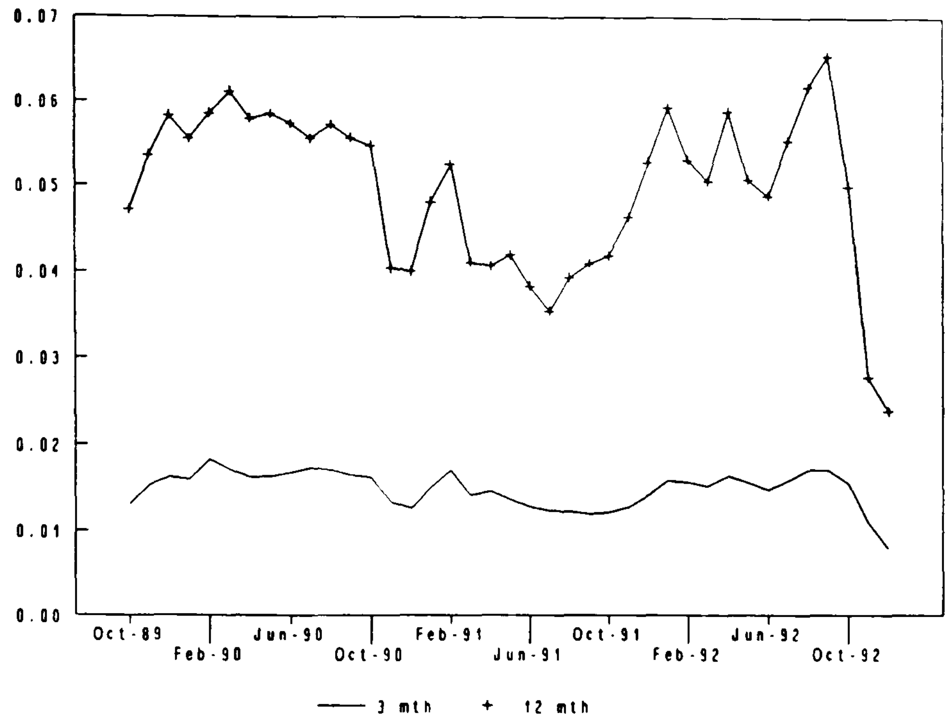
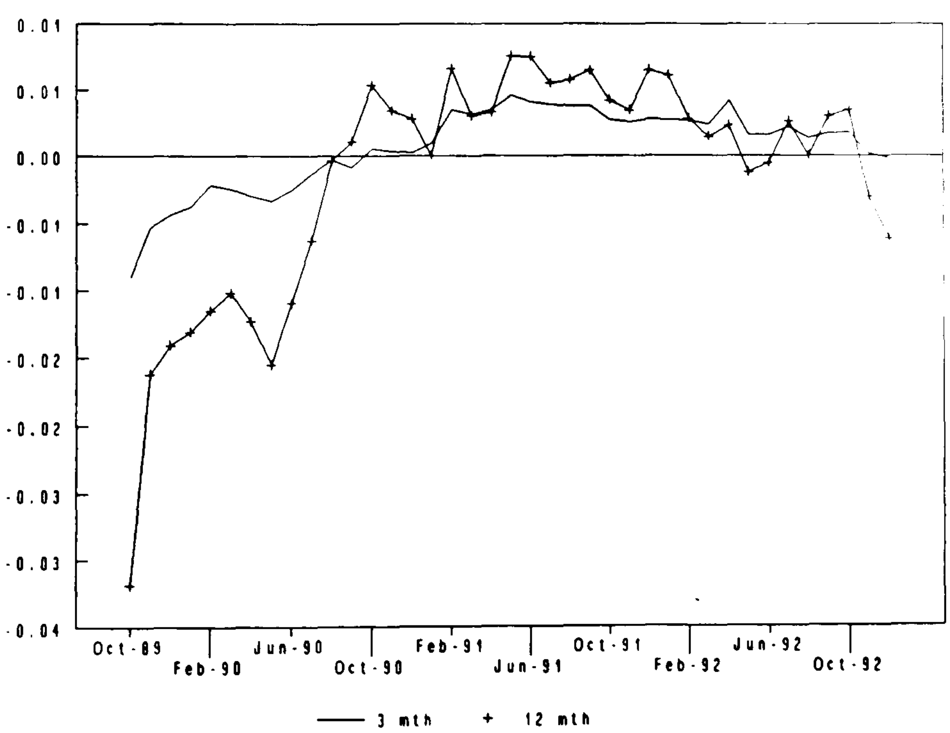


Figure 12 Forward premia on Japanese yen



countries have faced similar problems to the US in terms of a slowing economy and have tried to cut interest rates whenever the opportunity arose. Britain's ERM constraint gave it less room for manoeuvre leading to more volatile three month premia, but after its two year flirtation with the Mechanism was abruptly ended, so was the British policy of high interest rates.

1.6 AN OUTLINE OF THE FOLLOWING CHAPTERS

As we shall document, there have been many papers that have used survey data, a substantial proportion of which concentrates on financial markets. This study is differentiated by its use of the results of a fully disaggregated survey. This database is almost unique in the analysis of the foreign exchange market (a companion set of interest rate forecasts collected by the same company has been considered). However, if a disaggregated data set is to be more insightful than the use of consensus (mean or median) forecasts we must expect there to be some degree of heterogeneity between forecasters. The second chapter is therefore concerned to establish the heterogeneity between our panellists. We show that individual forecasters interpret commonly available data differently and investigate whether these differences of opinion translate into significantly different forecast performance. Using two tests, one parametric one non-parametric, that account for the incomplete response rates of our panel members, we demonstrate that some forecasters are significantly more accurate than others. This holds true when we examine the panel in full, or when we concentrate on forecasters from one country. The heterogeneity is also present across all three major currencies and both time horizons, although to slightly different extents. In the final section of the chapter we show that heterogeneity of beliefs helps to explain the volume of trading in the foreign exchange futures market.

Having demonstrated that forecasters are different we examine how good they are. The conventional wisdom is that it is impossible for econometric models to produce more accurate predictions than a forecast of 'no change' in the foreign exchange market, at least over relatively short horizons (see Meese and Rogoff (1983*a*, *b*). Can our panel of forecasters who are close to the market, who may have private information, or who may have a wider information set than an econometrician overturn this result? The answer is no. Using the simple accuracy measures that are standard in the literature we find that over the three month horizon very few forecasters outperform the alternative and that none are significantly better. Over the longer forecast interval good performance is more commonplace, in line with prior expectations. Arguing that accuracy may not be the best way to judge asset price forecasts we also examine the profits accruing from a simple trading strategy based on our panellists' forecasts. We find that many forecasters are more profitable than the benchmark, even over the short horizon, although due to the nature of the trading strategy it is difficult to establish the significance of these results. Nevertheless, we are able to highlight the inconsistencies between the two measures of performance and conclude that both are needed if a full evaluation is to be made. Concentrating on a subset of our panellists who have a high response rate across three currencies, we extend the analysis of profit performance to first, take advantage of the correlation between contemporaneous forecasts of different exchange rates made by the same forecaster, and second, to explicitly include risk in the evaluation. From a group of twenty-two forecasters we isolate just one, forecaster G9, who is able to return consistently significant profits from a portfolio of three month investments.

In an appendix to chapter 3 we demonstrate that whilst the three month forecasts are not particularly accurate, when taken as a whole they can provide useful information about the value of a currency. In contrast with the rest of the thesis we focus on the European cross exchange rates with the Deutsche mark (i.e. the sterling-, French franc-, and Italian lira-mark rates) over the months in the run-up to the September 1992 breakdown of the Exchange Rate Mechanism. An analysis of the expectations of our panellists shows that an increasing proportion correctly predicted spot exchange rates would lie outside the band (i.e. predicted a realignment) in the days preceding the breakdown for the pound and lira, but, again correctly, not for the franc which maintained its link, at least for a few more months.

Chapter 4 is concerned with ways of combining the information contained in the individual forecasts to provide an optimal 'consensus' forecast. Several methods of combination are examined but with little success. Taking the simple mean proves to be a competitive method as does the slightly more sophisticated Granger and

Newbold approach. Nonetheless, we are still unable to find a method capable of consistently out performing the naive alternative of a no change prediction in terms of accuracy.

Having established that professional forecasters are not noticeably better than the econometric models used by academic economists, we investigate whether the forecasts from such models can be improved by the application of advanced econometric techniques. Based on one of the oldest foreign exchange theories, purchasing power parity, we construct models that incorporate long-run equilibrium relationships and complex short-run dynamics, and that are capable of producing fully dynamic exchange rate predictions. The history of academic exchange rate forecasting, the motivation for our model, and the econometric techniques used are given in chapter 5.

In chapters 6, 7 and 8 we estimate models for the three main exchange rates, while in chapter 9 we apply the evaluation techniques of chapter 3 to the forecasts they produce. We find that they are better than the naive alternative, even over relatively short horizons. They are more accurate and more profitable, even when risk is included in the analysis. We conclude that the use of state-of-the-art econometric techniques can lead to forecasts of exchange rates that are better than a prediction of 'no change', even when all the benefits typically given to the econometric model are removed.

The thesis closes with a short summary of conclusions, a re-interpretation of some of the results and suggestions for further research.

CHAPTER 2

FORECASTER HETEROGENEITY - CONFIRMATION, CAUSES AND CONSEQUENCES

2.1 THE USE OF SURVEY DATA

Economic research based on survey data is not a new phenomenon. The long established Livingston survey has been widely used in studies of inflation expectations, from as early as Turnovsky's (1970) examination of price forecasts. However, it has only recently become fashionable to use survey-based data on agents' expectations to examine the workings of financial markets. Cavaglia *et al.* (1993*a*, 1993*b*), Dominguez (1988), Frankel and Froot (1987, 1990), MacDonald and Torrance (1988, 1990) and Taylor (1989) use a variety of survey databases of exchange rate forecasts to gain insight into the formation of expectations. Froot (1989), Batchelor (1990) and Batchelor and Dua (1991) use survey data on market expectations of interest rates to gain a perspective on the existence of term premia in bond markets. Examples of the literature on stock market surveys include Taylor (1988*a*), who uses a UK data base, and Fraser and MacDonald (1992), who work with survey data on the French CAC 40 stock market index - both studies using qualitative survey responses. Brown and Maital (1981), Dokko and Edelstein (1989), Lakonishok (1980) and MacDonald and Marsh (1993*a*), all use quantitative US data.

The connection between the above papers is that they all use aggregate survey data. Very little work has been done with fully disaggregated forecasts. Exceptions to this generalisation include Ito (1990) who uses Japanese exchange rate forecasts, Pearce (1984) who analyses the disaggregated Livingston stock price forecasts and MacDonald and Macmillan (1992) who examine interest rate expectations. MacDonald (1992) uses the first two years of forecasts from our Consensus Economics database, and the later part of this chapter can be seen as an extension of some of his work.

There are several reasons why one might want to use data with a greater level of disaggregation. Information is lost when just the median or mean forecast is used if forecasts differ. Since speculative foreign exchange trades are most likely to occur if different valuation expectations are held, the immense turnover in this market suggests *a priori* that we should expect a degree of heterogeneity among individual forecasters.[9] Furthermore, aggregated forecasts have at best a very weak link with the marginal individuals who trade in the market and thereby determine the price of foreign exchange (see Tagaki (1992)). However, the future spot price of currency is clearly related to individual forecasts weighted by the volume of trades that are made as a result of each forecast. The use of disaggregated data provides access to one-half of this equation.

There are also problems with using forecasters surveyed from only one country, or worse, from only one financial centre, due to the global nature of the foreign exchange market. For there to be a reliable relationship between the individual forecasts and the (marginal) price, any survey should cover as large a section of the market participants as possible. Our database is both wide ranging and disaggregated. By including corporate forecasters, professional forecasting agencies (whose predictions are used by other market participants) and financial institutions from the G7 countries, as wide a coverage of market practitioners as possible is achieved. As the panel provide predictions on up to five exchange rates over two forecast horizons we can also examine any differences in an individual's forecasts across currencies or prediction period.[10]

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9 The most likely reason for trading when investors agree on valuation is for diversification purposes. However, as Lyons (1991) points out, the proportion of total trading that can be explained by shifts in wealth, taxes and return higher moments is very small in typical portfolio choice models. He concludes that "the burden of explanation, then, appears almost certain to fall on differences in beliefs regarding valuation."

10 In the main part of this thesis we shall only consider the Deutsche mark, pound sterling and yen forecasts due to the low number of Canadian, Japanese and US forecasters' predictions of the franc and lira. In the appendix to chapter 3, these European rates are examined in more detail.

2.2 WHY MIGHT FORECASTERS DIFFER?

If the study of disaggregated forecasts is to be any more insightful than analysis based on a consensus measure some degree of heterogeneity across our panel members should be observable. Ito (1990) provides a simple and robust test for detecting differences among forecasts that he applies to a database of Japanese forecasters' predictions of the yen-dollar rate. Ito finds considerable heterogeneity in the form of what he terms "individual effects." Significantly, these individual effects are in the form of a constant bias and not due to different modelling techniques. We proceed with a summary of Ito's approach and the results of applying his methods to our international panel.

Suppose an individual i makes a forecast of the (log) exchange rate at time t that consists of two parts, X_t, based on public information I_t common to all forecasters, and an individual (constant) bias, g_i. This individual's forecast is then the sum of these two parts plus an individual random disturbance term u_{it} that could occur because of rounding or measurement errors

$$s^e_{it} = X_t + g_i + u_{it} \tag{17}$$

The average forecast at time t is then

$$s^e_{AVG} = X_t + g_{AVG} + u_{AVG\,t} \tag{18}$$

Normalising such that g_{AVG} equals zero and subtracting (18) from (17) we obtain

$$s^e_{it} - s^e_{AVG\,t} = g_i + [u_{it} - u_{AVG\,t}] \tag{19}$$

Ito then estimates the individual effects g_i from a regression of the difference between an individual and the average forecast on a constant term. A non-zero g_i shows that an individual's forecasts are biased compared to those of the representative, average forecaster. Note that it tells us nothing about the forecasting ability of the individual.

There is no need to specify the common forecast element X_t, or the information set I_t on which it is based, so long as it can be assumed common to all individuals. However, it is possible to test for idiosyncratic coefficient terms on information in I_t. Suppose that besides individual biases g_i each forecaster places different weights on, say, the forward premium that holds at time t, fp_t. Then

$$s^e_{it} = X'_t + g'_i + \beta_i fp_t + u_{it} \qquad (20)$$

where X'_t is the common forecast term based on I_t less the forward premium, and g'_i is the new individual bias. Specifying the equivalent equation for the average forecast and subtracting as above implies that

$$s^e_{it} - s^e_{AVG\,t} = g'_i + [\beta_i - \beta_{AVG}]\, fp_t + [u_{it} - u_{AVG\,t}] \qquad (21)$$

This somewhat richer formulation allows us to test for both individual biases ($g'_i \neq 0$) and idiosyncratic effects ($\beta_i - \beta_{AVG} \neq 0$). Due to the international nature of our database we not only calculate these effects with respect to the overall average but also with respect to the relevant country average. This allows us to examine, among other aspects, whether our individuals are more inclined towards, say, a dollar depreciation than the overall average or than their fellow countrymen. This distinction may be important if we cannot be sure that the information set is common to all forecasters, due, for example, to language differences. Averaging within a country is less likely to suffer from such informational asymmetries. Possibly more importantly, this constitutes a check on the importance of the timing of the forecasts. Suppose, for example, Japanese forecasters respond to the Consensus fax early in the global trading day while Americans reply some twelve hours later when their trading day begins. Large swings in the exchange rate between those times may mean that we measure the expected change in the exchange rate with a measurement error.[11] If so, we would expect to see differences between the results using the global consensus and those using the country consensus; specifically, those that pertain to

[11] If forecasters are in fact predicting a level of the exchange rate due to some concept of a target range based on PPP we would not have so severe a measurement problem.

the country consensus should not indicate heterogeneity, while those that relate to the global consensus should.

In order to cover as many of our panel as possible, and due to the simplicity of the regressions, we include all forecasters who replied in at least 20 months of the total survey for any currency. The averages with which they are compared are calculated from all responses in each month, regardless of whether the individual is contained in our reduced panel. This criterion has no substantive effect on our conclusions. Membership of this smaller group is shown in the appendix. The results of estimating equations (19) and (21) are summarised in Tables 2 and 3. In examining idiosyncratic effects we include two information terms, the forward premium relevant for the forecast horizon and the lagged one month change in the spot rate.

We find considerable evidence of heterogeneous expectations for both the three and twelve month forecast horizons. This is apparent when either the overall average or the country average is used as a benchmark. As discussed above, this similarity shows that measurement errors are not a problem in our data set. In the rest of this thesis we assume that any measurement errors that do exist are orthogonal to the explanatory variables, as in Froot and Frankel (1989) and practically all other papers that use survey data.

Table 2
Expectations Heterogeneity With Respect To Overall Consensus

	Indiv.	Idiosyn.	Both	Neither	Other	Total
DEM 3mth						
Eqn (19)	53	-	-	54	-	107
Fwd Prem.	16	29	12	40	10	107
Lag Change	50	7	3	47	0	107
STG 3mth						
Eqn (19)	47	-	-	46	-	93
Fwd Prem.	5	1	11	44	32	93
Lag Change	43	3	5	42	0	93
JPY 3mth						
Eqn (19)	43	-	-	64	-	107
Fwd Prem.	27	14	20	46	0	107
Lag Change	33	5	10	58	1	107
DEM 12mth						
Eqn (19)	60	-	-	29	-	89
Fwd Prem.	24	21	26	15	3	89
Lag Change	52	1	8	27	1	89
STG 12mth						
Eqn (19)	51	-	-	30	-	81
Fwd Prem.	6	6	23	19	27	81
Lag Change	45	0	7	29	0	81
JPY 12mth						
Eqn (19)	50	-	-	41	-	91
Fwd Prem.	28	22	24	16	1	91
Lag Change	48	3	4	35	1	91

NOTES: *The figures in each column give the number of forecasters in each category. INDIV indicates significant individual biases, IDIOSYN denotes idiosyncratic coefficients on the specified information term, BOTH denotes that both individual and idiosyncratic effects were present, NEITHER that an F-test of no individual or idiosyncratic effects cannot be rejected, and OTHER denotes that while the t-tests each rejected individual and idiosyncratic effects, the F-test rejected joint zero terms. Where Equation (21) is being estimated, the figures in the NEITHER column denote no findings of individual effects.*

Table 3

Expectations Heterogeneity With Respect To Country Consensus

	Indiv.	Idiosyn.	Both	Neither	Other	Total
DEM 3mth						
Eqn (19)	49	-	-	58	-	107
Fwd Prem.	17	27	14	33	16	107
Lag Change	50	6	5	46	0	107
STG 3mth						
Eqn (19)	47	-	-	44	-	93
Fwd Prem.	3	1	14	38	37	93
Lag Change	45	5	5	38	0	93
JPY 3mth						
Eqn (19)	43	-	-	64	-	107
Fwd Prem.	20	11	24	51	1	107
Lag Change	34	4	10	58	1	107
DEM 12mth						
Eqn (19)	63	-	-	26	-	89
Fwd Prem.	19	17	26	13	14	89
Lag Change	55	1	6	25	2	89
STG 12mth						
Eqn (19)	54	-	-	27	-	81
Fwd Prem.	8	4	19	18	32	81
Lag Change	46	1	10	23	1	81
JPY 12mth						
Eqn (19)	52	-	-	39	-	91
Fwd Prem.	33	20	22	15	1	91
Lag Change	48	2	5	35	1	91

NOTES: *See notes to Table 2.*

In contrast to Ito, we find evidence of idiosyncratic coefficients as well as individual effects. Since the standard variables used (lagged spot rate changes and the forward premium) are available at very little cost to all market participants regardless of location, we would argue that these differing coefficients are not due to asymmetric information, but rather to the use of different forecasting models. The exclusion of these variables from equation (19) could bias the estimation of g_i, and the effect of this is significant when we examine the interpretation of the forward premium. In almost all cases, including the relevant forward premium in equation (21) results in a fall in the number of significant individual effects, and a rise in the number of idiosyncratic findings (or occurrences of both effects). There is little evidence of idiosyncratic interpretation of lagged spot rate changes, which is in line with the findings of Ito. Another notable feature of the results concerning the forward premium is the high count of "Other" cases, particularly for the pound. Such an occurrence arises when t-tests of significant intercept and slope are rejected but a joint F-test is not. This could be because the relative stability of sterling's forward premium for most of the sample period leads to near collinearity with the constant term, and hence large standard errors.

The results provide clear evidence of heterogeneity among a panel of international foreign exchange market participants and advisers that confirm and extend the Japanese-specific results of Ito. Forecasters appear to maintain individual biases relative to their peers, and to interpret the importance of key variables in different ways. We now examine the question of whether these differences of opinion translate into differences in forecast performance.

2.3 ARE SOME FORECASTERS SYSTEMATICALLY BETTER THAN OTHERS?

We have shown that our forecasters hold biases relative to each other and that they appear to use different forecast methods. To paraphrase a comment received on these results, which was itself a paraphrase of a famous line from *Casablanca*, a reader might be justified in saying "I am shocked. I am shocked to learn that different forecasters are heterogeneous in the foreign exchange market." The issue is not that forecasters are different, it is that this heterogeneity matters in some economically meaningful sense. At a horse-race meeting, each gambler will have a different system for picking winners. Some will win money and some will lose money. What would be interesting would be to find out whether those that win do so systematically over time. Various methods of determining the 'winners' and 'losers' in our panel are discussed in the next chapter, and in this section we shall concentrate on the absolute accuracy of our forecasters. We are interested in the hypothesis that certain forecasters, possibly but not necessarily because of their interpretation of commonly held information, are systematically more accurate than other forecasters. The alternative, clearly, is that whatever the method used, different forecasters are equally inaccurate.

The analysis of predictive performance is complicated by the differing response rates of the panellists in this study. Our problem is that of an unbalanced data set. It is not immediately apparent how to compare the performance of a forecaster who gives returns for, say, the first two years of the three-year sample with another who only forecasts over the final two years. Assuming that rates are equally easy to forecast each month is, we feel, too heroic, and although using the twelve common forecasts is one alternative, generalising the example to a large group of forecasters makes this impractical. MacDonald and Marsh (1993*b*) avoid the problem by restricting their sample to only those with a perfect response record over 27 months, but for our longer data set this proves to be an exceptionally severe selection criterion. Instead we use a fixed-effects regression model and a non-parametric test, both of which control for imperfect response rates and therefore allow us to include a larger proportion of our total database.

2.3.1 FIXED-EFFECTS MODEL OF AVERAGE FORECAST ACCURACY

The fixed effects model computed is given in equations (22) and (23)

$$|e_{it}| = \mu_i + \delta_t + \varepsilon_{it} \tag{22}$$

where

$$e_{it} = S^e_{it} - S_t \tag{23}$$

and where μ_i and δ_t are termed forecaster and month effects respectively. The dependent variable is a column of (unlogged) absolute errors stacked by forecaster. The forecaster effects dummies take the form of i column vectors, one for each forecaster. Forecaster j's dummy vector contains a one if the element of the dependent variable is an absolute error of forecaster j and a zero otherwise. The month effect dummy for period k contains a one if the element of the dependent variable is an error relating to a forecast made in period k and a zero otherwise. Note that this is not a seasonal dummy in the usual sense since a forecast made in January 1990 needs a different dummy to one made in January 1991.

The estimates of μ_i can be interpreted as the average accuracy of forecaster i, conditional on the months in his sample of predictions. The inclusion of month effects controls against attributing superior forecasting ability to a panel member who, by chance or design, only provides forecasts for relatively easy months. As noted in the introduction, our forecast period includes major events such as national elections, currencies' entry to and exit from the Exchange Rate Mechanism, and German reunification. Forecasters who chose not to provide predictions for a currency during these turbulent event periods derive no advantage over the average of those that did.

The fixed-effects model is estimated for the three month Deutsche mark-, pound- and yen-dollar exchange rate forecasts for the period October 1989 to September 1992 inclusive, and over the interval October 1989 to December 1991 for the twelve month predictions.

Since the dependent variable is a series of (absolute) forecast errors sampled at a higher frequency than the forecast period, the estimated variance-covariance matrix is inefficient. We therefore use Hansen's (1982) generalised method of moments (GMM) to correct the coefficient covariance matrix. Furthermore, since many researchers have shown that the variance of forecast errors in the foreign exchange market is heteroscedastic (see, for example, Cumby and Obstfeld (1984)) we allow for this by using a heteroscedastic-consistent covariance matrix that does not require knowledge of the form of the heteroscedasticity. Specifically, we estimate the equations, written here in general form, by OLS

$$y_{t+k} = X_t\beta + v_{t+k} \tag{24}$$

where **y** is the dependent variable, **X** is the matrix of explanatory variables and the variance-covariance matrix of the coefficient estimates, β, is

$$\hat{\Lambda} = (X'X)^{-1}X'\hat{\Omega}X(X'X)^{-1} \tag{25}$$

Here, Ω is the variance-covariance matrix of the residuals, and the *ij*'th element of Ω is given by

$$\begin{aligned} \hat{\lambda}(i,j) &= \hat{v}_i\hat{v}_j \qquad && for|i-j|\leq k \\ &= 0 && otherwise \end{aligned} \tag{26}$$

where $\hat{\lambda}$ is the estimated autocovariance. To ensure that the variance covariance matrix is positive definite in finite samples, the off-diagonal elements are down-weighted as suggested by Newey and West (1987). Estimating this model entails running a regression containing $(t\times i)\times(i+t)$ elements. Due to computing constraints therefore it is necessary to restrict the data set.[12] In order to keep the panel down to

[12] In practice, since we also carry out a Generalised Method of Moments correction blank entries are needed at the end of each forecaster's series of errors. This effectively increases *i* by 2 (11) for the 3 (12) month horizon. The simple fixed-effects model is easily estimated with much less restrictive data constraints, but the need for the GMM correction forced us to follow conventional OLS estimation procedures.

a manageable size, and to ensure reliable estimation for each forecaster, only those who have responded to a minimum of 29 months for the Deutsche mark, sterling and yen three month forecasts are included. This lower limit is reduced to 23 for the twelve month forecasts. In the three month Deutsche mark model, this cuts our panel down to 65 forecasters who provide 2,200 forecasts. These make up 38% of the total panel membership but their better response rate is such that they account for almost 60% of total forecasts made. Mnemonics of forecasters retained are again given in the appendix.

We estimate the fixed effects model for all of our (reduced) panel of forecasters, and for individual country groupings over both forecast horizons. Homogeneity of predictive performance is rejected if the hypothesis that all μ_i's are equal in equation (22) is rejected. The results of these tests are given in Table 4. Due to the overlapping nature of the forecasts the results are computed using GMM standard errors as chi-square tests with degrees of freedom equal to i-1.

There is strong evidence of differences in forecast accuracy within countries and between our panel members as a whole. All tests conducted over the full group of forecasters reject the null of homogeneity. At the three month forecast horizon the hypothesis of equal accuracy of group members is rejected for eight out of twenty-one country groups at the five percent significance level (and two more fail at the six percent level). This inequality is present in all three currencies, although it is stronger for the yen than the pound. Differential performance is noticeably centred in Germany, the USA, Britain and, to a lesser extent, Italy. Different levels of predictive accuracy are even more prevalent over the longer forecast horizon. Sixteen out of twenty-one groupings reject homogeneity of accuracy. At least one rejection is found for each country bloc, and, again, the inequality is most prevalent for the yen. It would appear that the different biases and information interpretations found in the previous section translate into different forecast performance.

Table 4
Fixed Effects Regression Tests Of Predictive Homogeneity

		Three Month Forecast Horizon					
		Deutsche mark		Pound sterling		Japanese yen	
All	(64)	126.06	(0.00)	120.58	(0.00)	116.84	(0.00)
Canadian	(8)	9.87	(0.28)	3.83	(0.87)	0.99	(0.99)
French	(4)	5.32	(0.26)	5.15	(0.27)	4.20	(0.38)
Italian	(4)	1.32	(0.86)	9.43	(0.05)	19.30	(0.00)
Japanese	(4)	4.26	(0.37)	3.64	(0.46)	7.74	(0.10)
British	(17)	32.15	(0.01)	23.65	(0.13)	36.43	(0.00)
American	(7)	25.80	(0.00)	13.98	(0.05)	17.92	(0.01)
German	(14)	31.61	(0.01)	40.14	(0.00)	28.60	(0.01)
		Twelve Month Forecast Horizon					
		Deutsche mark		Pound sterling		Japanese yen	
All	(65)	171.77	(0.00)	240.78	(0.00)	752.03	(0.00)
Canadian	(9)	14.62	(0.10)	17.87	(0.04)	77.60	(0.00)
French	(4)	26.34	(0.00)	35.14	(0.00)	83.36	(0.00)
Italian	(5)	4.12	(0.53)	20.38	(0.00)	38.66	(0.00)
Japanese	(3)	2.61	(0.46)	5.46	(0.14)	25.61	(0.00)
British	(17)	102.05	(0.00)	75.85	(0.00)	111.14	(0.00)
American	(7)	20.16	(0.01)	45.61	(0.00)	428.83	(0.00)
German	(14)	22.83	(0.06)	54.50	(0.00)	70.77	(0.00)

NOTES: Figures in each column give the value of the test statistic. The figures in parentheses after the grouping give the degrees of freedom associated with each test, and the figures in parentheses after the test statistics are the marginal significance levels.

However, despite the significance of many of our test statistics, caution should be expressed when interpreting our conclusions because of the nature of the residuals from the fixed effects regressions. Tests indicate that the residuals series often exhibit positive kurtosis which would lead to too frequent rejection of the null of homogeneity. In some cases there is also evidence of skewness, but the implications in terms of the hypothesis tests are unclear. In an attempt to overcome this problem, we have also estimated the models with the log of the absolute forecast error and the square root of the absolute forecast error as dependent variable. These transformations, designed to preserve the ordering of the prediction errors, have no effect on the results of the heterogeneity tests. Unfortunately, they also result in little improvement in terms of residual normality. As an alternative strategy, we use a non-parametric test of equal forecast performance that requires less stringent assumptions about the distribution of residuals.

2.3.2 A ROBUST NON-PARAMETRIC TEST OF HETEROGENEOUS PERFORMANCE

Friedman (1937) proposed a distribution-free test applicable to equation (22) based on within-month rankings, that alleviates the problem of non-comparability across months. This statistic has been used in the forecasting literature before (Batchelor (1988) and MacDonald and Marsh (1993*b*)[13]) but is confined to use with completely balanced panels i.e. perfect response rates. Recently, statisticians have introduced a variety of adjustments to the basic Friedman statistic that deal with unbalanced data. Foremost amongst these are Prentice (1979), Klotz (1980), Skillings and Mack (1981) and Wittkowski (1988). Investigation of the corrections suggested generally reveals a positive correlation between applicability and computational complexity. The exception is the relatively simple method proposed by Prentice, that Wittkowski (1988) shows to be suitable for unbalanced data.[14]

Concentrating initially on the basic Friedman test to introduce notation, suppose that we have m months of forecasts ($1 \leq i \leq m$) from p forecasters ($1 \leq j \leq p$) which result in $m \times p$ absolute forecast errors, X_{ij}. These errors are then ranked within each month, whereby $X_{i1}, X_{i2}, \ldots, X_{ip}$ are compared and rank 1 assigned to the largest

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[13] Reid (1990) also uses a variety of tests including Friedman and our chosen method, Prentice, in an analysis of small firm financing.

[14] Wittkowski's own method contains that of Prentice as a special case but is very complex to calculate for large data sets. We believe that the high significance levels associated with our results are strong enough to overcome any induced errors.

absolute error, rank 2 to the next largest, etc. Suppose that r_{ij} is the rank of forecast error X_{ij}. Tied values are given their average rank. The null hypothesis that we are interested in is that the ranking of the errors within months are equally likely, against an alternative that at least one forecaster tends to yield higher ranks than at least one other forecaster. One representation of Friedman's test statistic is then

$$A = \frac{12}{mp(p+1)} \sum_{j=1}^{p} (R_j - \tfrac{1}{2}m(p+1))^2 \tag{27}$$

where $R_j = r_{1j} + \ldots + r_{mj}$. For m, p not too small, the Friedman statistic A has approximately a chi-squared distribution with degrees of freedom equal to $(p - 1)$.[15]

Durbin (1951) derives a version of (27) applicable to balanced incomplete panels. In our situation, its use would implies that each panel member should produce an equal number of forecasts, and that each panellist should appear with every other panellist an equal number of times. Upon generalisation by Benard and Van Elteren (1953) to account for unbalanced data such as we face, the form of this statistic becomes

$$B = u'V^{-1}u \tag{28}$$

where u is a $(p - 1)$ vector whose j'th element is

$$u_j = \sum_{i \in S_j} (r_{ij} - \tfrac{1}{2}(k_i + 1)) \tag{29}$$

S_j is the set of months for which forecaster j supplied a forecast, k_i is the number of forecasts ranked in month i and one of the p possible sums is omitted from u to avoid singularity. V is the $(p - 1)\times(p - 1)$ covariance matrix of the $(p - 1)$ remaining u_j's, where

15 Iman and Davenport (1980) suggest an alternative small sample approximation that has an F-distribution under the null.

$$v_{jj} = \frac{\sum_{i \in S_j} (k_i^2 - 1)}{12}, \qquad v_{jj'} = \frac{-\sum_{(i \in S_j \cap S_{j'})} (k_i + 1)}{12} \qquad (j \neq j') \tag{30}$$

This statistic controls for the problem that in an unbalanced panel a forecaster can raise his rank sum by forecasting regularly. By centring each individual rank (subtracting the mean of the ranks in each month) this effect is mitigated. The asymptotic distribution of B is again chi-squared with $(p - 1)$ degrees of freedom.

Prentice's (1979) modification standardises the so-called 'reduced rank', $r_{ij} - \frac{1}{2}(k_i+1)$, to take into account the fact that with unbalanced data k_i can vary greatly across time. To quote, "it does not seem reasonable that an object ranked first out of four objects should have the same reduced rank as an object ranked 49th out of 100", as it would when computing B. To compensate for this inequity he weights the reduced rank by $1/(k_i + 1)$. Prentice's test statistic is then

$$C = y'W^{-1}y \tag{31}$$

where

$$y_j = \sum_{i \in S_j} (r_{ij}(k_i + 1)^{-1} - \tfrac{1}{2})$$

$$w_{jj} = \frac{\sum_{i \in S_j} ((k_i - 1)(k_i + 1)^{-1})}{12}, \qquad w_{jj'} = \frac{-\sum_{i \in S_j \cap S_{j'}} (k_i + 1)^{-1}}{12} \qquad (j \neq j') \tag{32}$$

As before, just one of the p possible elements of y is omitted from both y and the covariance matrix W. The asymptotic distribution of C under the null of no performance difference is again chi-squared with $(p - 1)$ degrees of freedom. The weighting factor applied by Prentice is, he admits, arbitrary and is chosen for computational ease. Skillings and Mack (1981) choose a different weight designed to simplify the covariance structure but Wittkowski (1988) shows that this and most other weights are not suitable for unbalanced data. The Prentice weighting, however, is found to be acceptable, since it places neither too much nor too little weight on missing values.[16]

Table 5

Prentice's Non-Parametric Test Of Forecaster Homogeneity

		Three Month Forecast Horizon					
		Deutsche mark		Pound sterling		Japanese yen	
All	(64)	126.99	(0.00)	115.19	(0.00)	145.32	(0.00)
Canadian	(8)	10.12	(0.26)	2.89	(0.94)	1.44	(0.99)
French	(4)	5.86	(0.21)	8.01	(0.09)	5.61	(0.23)
Italian	(4)	2.54	(0.64)	9.82	(0.04)	11.38	(0.02)
Japanese	(4)	3.98	(0.41)	1.74	(0.78)	5.55	(0.24)
British	(17)	36.67	(0.00)	31.50	(0.02)	44.69	(0.00)
American	(7)	25.58	(0.00)	11.30	(0.13)	21.09	(0.00)
German	(14)	31.29	(0.01)	34.87	(0.00)	35.36	(0.00)
		Twelve Month Forecast Horizon					
		Deutsche mark		Pound sterling		Japanese yen	
All	(65)	162.26	(0.00)	179.69	(0.00)	376.58	(0.00)
Canadian	(9)	26.21	(0.00)	10.99	(0.28)	52.06	(0.00)
French	(4)	16.94	(0.00)	17.09	(0.00)	22.21	(0.00)
Italian	(5)	6.41	(0.27)	13.01	(0.02)	17.58	(0.00)
Japanese	(3)	5.70	(0.13)	6.84	(0.08)	23.96	(0.00)
British	(17)	50.16	(0.00)	55.25	(0.00)	98.72	(0.00)
American	(7)	17.45	(0.01)	27.88	(0.00)	85.04	(0.00)
German	(14)	22.21	(0.07)	32.94	(0.00)	37.39	(0.00)

NOTES: The figures in each column give the value of the test statistic. The figures in parentheses after the grouping give the degrees of freedom associated with each test, and the figures in parentheses after the test statistics are the marginal significance levels.

[16] Reid (1990) questions this conclusion from an economic rather than statistical viewpoint, and for his data set concludes that the Prentice method gives undue weight to options that should be lower ranked. This is a conclusion specific to his data, however, and we feel that the Prentice correction is more applicable to our panel than his preferred alternatives.

We compute values for Prentice's C for all of the groupings tested parametrically in the previous section. Results are given in Table 5. The non-parametric results correspond almost exactly with those obtained using the fixed effects regression model. Over the three month horizon, ten out of 21 country groupings indicate significantly different forecast performance. This rises to sixteen for the long-horizon forecasts.

One notable feature of the results is that the test statistics for the twelve month forecast horizon are generally lower, and hence marginal significance levels higher, under the non-parametric test than under the regression-based analysis. This could be due to the very high degrees of kurtosis and skewness found in the fixed-effects residuals. As noted above, positive kurtosis induces too frequent rejection of forecast homogeneity, however the significance levels of our results are such that even when a more appropriate testing method is applied our conclusions remain unaltered.

We have established that our forecasters are different. They place different weights on commonly available variables when forecasting and exhibit individual biases. Furthermore, these differences translate into a distribution of forecasting performance - some forecasters are significantly more accurate than others. We now examine one possible implication of this heterogeneity, namely the relationship between trading volume and forecaster disagreement.

2.4 DIFFERENCES OF OPINION AND TRADING VOLUME

In the introduction to this chapter we boldly stated that trades in the foreign exchange market are most likely the result of participants holding different opinions as to the value of currency in the future. In this section we empirically address the issue of forecaster heterogeneity and trading volume.

The implications for turnover resulting from differences of opinion have been theoretically derived by Varian (1987). More recently, empirical work has established a positive association between the dispersion of stock analysts' forecasts of company earnings and share trading in the United States.[17] Frankel and Froot (1990) show that the standard deviation of exchange rate predictions, price volatility and futures trading volume exhibit complex Granger causality relationships over very short forecast horizons (one week). In this chapter, we show that the degree of heterogeneity of our panellists' forecasts is positively related to turnover in the Chicago currency futures pits, even after controlling for other potential determinants of trading volume.

There are several alternative models of heterogeneity and trading volume. Kim and Verrecchia (1991*a*, *b*, 1994), for example, detail a model in which information asymmetries between market participants explain trading volume. Given that we have demonstrated differences in opinion based on common variables, however, calling on private information seems inappropriate. Alternatively, Varian (1987) provides a model much closer in spirit to the results reported earlier in this chapter, and which we outline below. We note that the final equation tested is almost identical to that estimated by Atiase and Bamber (1994), who base their approach on the Kim and Verrecchia model. Our results (and those of Atiase and Bamber) should not therefore be interpreted as favouring one particular theoretical model, but rather demonstrate that differences of opinion, caused by whatever means, matters.

Varian's model is based on earlier work by Grossman (1976, 1978). Assume there are two assets, one with a certain payoff (domestic currency) and one risky (foreign currency). The price in the next period of this risky asset is P_1. For simplicity the return on the domestic currency is assumed to be zero. There are n individual investors, and each investor i has a subjective prior distribution for the next period price of foreign exchange that is assumed to be Normal with mean P_{1i} and variance $1/\alpha$. Varian terms α the 'precision' of the prior belief. Assuming that investors all have constant absolute risk-tolerance utility functions, with Arrow-Pratt measures of absolute risk aversion equal to $1/\tau$, it is shown that each agent's demand function for foreign currency will be of the form

[17] See Comiskey *et al* (1987), Ziebart (1990) and Ajinkya *et al* (1991).

$$D_i = \frac{\tau[E_i(P_1) - P_0]}{var_i(P_i)} = \tau\alpha(P_{1i} - P_0) \tag{33}$$

where P_t is the period t price. Supposing that each investor has a supply Z_i of currency and that the price adjusts to equate aggregate supply and demand, the current period equilibrium price will be

$$P_0^* = \overline{P_1} - \frac{\overline{Z}}{\tau\alpha} \tag{34}$$

where a bar denotes a mean value of the variable across investors. Solving for the demand of each investor yields

$$D_i = \tau\alpha(P_{1i} - \overline{P_1}) + \overline{Z} \tag{35}$$

That is, each investor's demand is a function of the difference between his individual and the average opinion of the future price of currency. Given each investor's initial endowment of the asset, the net trade of individual i is

$$T_i = \tau\alpha(P_{1i} - \overline{P_1}) - (Z_i - \overline{Z}) \tag{36}$$

Aggregating over the n investors in the market then gives the total volume of trade. At this stage, turnover results purely from differences in prior beliefs.

The asset market approach to exchange rates has as a central tenet the belief that the release of new information, 'news', will be reflected in changes in the spot rate. How will the arrival of such new information affect trading volume in this model? Suppose that each individual observes a signal Ω_i where

$$\Omega_i = P_1 + \varepsilon_i \tag{37}$$

ε_i is assumed IID Normal with mean zero and variance $1/\omega$; that is each investor will have different information about the next period price of foreign exchange, but they will know it with equal precision. What Varian terms 'an omniscient observer' could then calculate the mean value of the individual signals, $\bar{P}_I$, which would be distributed N(P_I, $1/n\omega$). He then demonstrates that as long as agents are able to observe the change in the price of foreign exchange, and know the values of α and ω (the precision of their prior beliefs and news signals), they can estimate the mean of the individual signals. Although too convoluted to reproduce here, his proof has a simple interpretation that fits well with the asset approach - the price adjusts to reveal all information in the economy. In Grossman's (1976) words, the price system acts as an aggregator of information, and in this model the price reveals information to each investor which is of a higher quality than his own private information. Thus the arrival of news results in price changes that reveal the aggregate information flow. What happens to trading volume? The answer, it turns out, is nothing. Since each investor can work out the aggregate information from the price change, his individual information is redundant and his demand for foreign exchange remains as given in equation (35). This outcome epitomises the very nature of a fully revealing equilibrium. Since price changes reveal all information there is nothing left to be revealed by trading volume, and turnover cannot be independently related to the information received by investors. This may seem a little unrealistic, especially since a fully revealing price mechanism also eliminates the incentive for individuals to collect information, but there are many examples of price gaps - price zones in which no trades occur. One such price jump is described by Bruce Kovner, a fund manager described as the world's largest trader in the interbank currency and futures markets (Schwager, 1990, p78):

> "...the sterling/mark cross rate was in a yearlong congestion [a bounded price range] between approximately 2.96 and 3.00....The Bank of England kept on defending it. Finally the Bank of England gave in. As soon as the cross rate pierced the 3.01 level, there were no trades. In fact, there were no trades until it hit 3.0350. So it moved virtually a full 1 percent without trading."

Remembering the results of section 2.2 we note that individuals interpret information differently. We may then wish to ask whether the arrival of new information in this situation will affect volume? Varian addresses this point as follows. Let Y_i denote the 'magnitude' of a piece of information observed by agent i. Investor i's idiosyncratic interpretation of the impact of this information on the price of foreign exchange, P_{1i}, equals $\delta_i Y_i$. Assuming that both the information Y_i and the idiosyncratic interpretations δ_i are independently distributed across agents, such that $\bar{P}_1$ equals $\bar{\delta}\bar{Y}$, and that the value of $\bar{\delta}$ is known by all investors, Varian shows that as before each agent will be able to infer $\bar{Y}$ from the change in the equilibrium price. Thus the individual agent i will revise his estimate of the expected price of the foreign currency to be $\delta_i \bar{Y}$ and hence his individual equilibrium net trade can be shown to equal

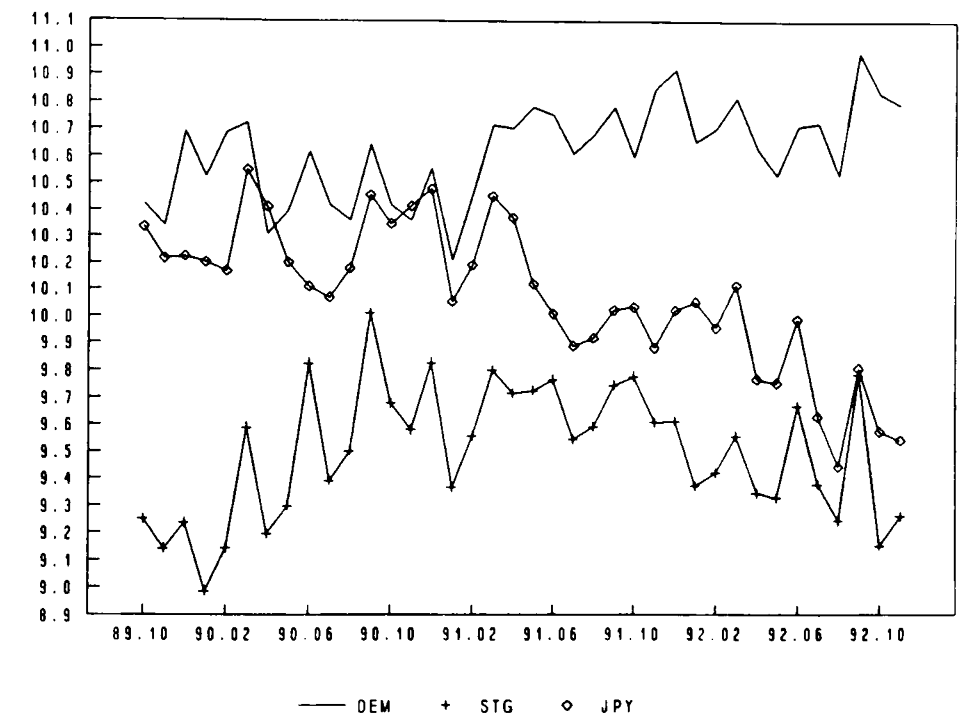
$$T_i = \tau[\alpha(P_{1i} - \bar{P}_1) + \beta(\delta_1 - \bar{\delta})\bar{Y}] + (Z_i - \bar{Z}) \qquad (38)$$

The net trade of an individual investor is then a function of the difference from the average value of (i) his prior opinion about the future price of the currency, (ii) his interpretation of the impact of new information (not his own private information, but the aggregate information flow revealed by changes in the market price) and (iii) his initial endowment of the asset. Thus in this version of the model, trading volume is correlated with the change in the exchange rate since the interpretation placed on the information flow revealed by the price change will differ. The implication of this more complex model is that in assessing of the effect on turnover of differences in forecaster opinion we have to control for the impact of heterogeneous interpretation of new information. In an empirical test of this model a proxy for the flow of information is needed. The most obvious proxy to use is the change in the price level, since this is used by individuals to infer the aggregate information flow. The operational equation we estimate is:

$$T_t = a + b\ std.dev(s_{it}^e) + c\ std.dev(s_t) + T_{t-1} + \text{seasonals} \qquad (39)$$

Turnover, T, is calculated as the daily average dollar value of trade in the relevant IMM futures pit on the Chicago Mercantile Exchange measured over a period that covers the two weeks prior to the day on which expectations are surveyed together with the two subsequent weeks. Volumes for all contract maturities are combined, though the total is always dominated by the nearest dated. Lagged turnover is included for two reasons. First, previous studies have indicated that volume is Granger causal to both forecast dispersion and price volatility and we wish to control for these effects. Second, the mean-variance model implies that differences in initial currency holdings will also induce trading volume. In a world of costly adjustment to equilibrium holdings, lagged turnover can act as a proxy for asymmetric currency holdings.

Figure 13 Log of average daily futures turnover



Seasonal and trend terms are included where necessary due to the nature of trading on the futures markets. Figure 13 shows the pattern of turnover in the three currency futures pits over our period of estimation. A strong downward trend in yen turnover is evident, while, to a lesser extent, there appear to be changes in the behaviour of turnover for both the pound and the Deutsche mark around the end of 1990. The break for sterling appears around September 1990 suggesting an ERM effect, given that Britain joined the Mechanism on October 8th of that year. This is discussed further below. For the mark, weak evidence exists of a jump in the mean of daily turnover in the early months of 1991. We can find no strong rationale for this and so again make no modelling provisions. We note in passing that with the pound joining the ERM a part of sterling's turnover could have been transferred to the more liquid Deutsche mark market which would account for both of the above changes in behaviour.

The results of estimating equation (39) using the three month forecasts are given in Table 6.[18] For the pound and yen two estimated equations are presented; for both currencies version I is closest to the theoretical model, but II is empirically more valid. Further lags of independent variables for all three currencies are found to be statistically insignificant and are not reported. For the yen and mark, the dispersion of expectations [std.dev(s^e_{it})] is positive and significant at the five percent level. The current period price change [std.dev(s_t)] is also significant, though at differing levels. For the yen, lagged turnover is dominated by a time trend but its inclusion has little impact on the coefficients of interest.

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[18] The dispersion of twelve month forecasts produces weaker results, probably because the futures market is not ideal for opening such long-term positions.

Table 6
Trading Volume, Forecast Dispersion And Volatility

	Deutsche mark	Pound sterling		Japanese yen	
	I	I	II	I	II
Standard deviation (s^e_{it})	11.098	2.978	10.238	13.871	17.976
	(3.34)	(0.51)	(1.64)	(2.09)	(3.32)
Standard deviation (s_t)	4.949	0.179	-1.527	0.948	1.051
	(1.82)	(0.05)	(2.28)	(2.21)	(2.56)
Standard deviation (s_{t-1})			-8.459		
			(2.28)		
T_{t-1}	0.376	0.659	0.582	0.211	
	(2.74)	(4.03)	(3.78)	(1.09)	
Time				-0.011	-0.014
				(3.35)	(7.31)
R^2	0.83	0.73	0.78	0.90	0.89
SEE	0.095	0.164	0.150	0.115	0.113

NOTES: *t-statistics given in parentheses.*

Sterling is somewhat different. Lagged turnover is found to be very important in explaining current volumes, and while the current period price change is not significant, lagged values are strongly so. Incorporating this lagged term drives up the coefficient on expectations dispersion such that it becomes significant at the 11.5% level. Nevertheless, the fit of the models for sterling is poor in comparison with the others, a fact we ascribe to distortions caused by the pound's entry to and exit from the ERM. In particular, there is a marked change in the seasonality of turnover after sterling's entry accompanied by a reversal of trend. This may have been caused by futures traders switching into the more liquid Deutsche mark contract once the sterling/mark cross rate was quasi-fixed. Incorporating three dummies to remove the excess seasonal turnover peaks in 1990 and one to account for the jump in turnover in September '92 results in a rise of coefficient on forecast dispersion with little change to the value of other significant terms in Model II:

$$T_t = \underset{(2.37)}{13.305}\ std.dev(s^e_{it}) - \underset{(1.08)}{4.282}\ std.dev(s_t) - \underset{(2.94)}{9.724}\ std.dev(s_{t-1}) + \underset{(4.91)}{0.687}\ T_{t-1}$$

+ constant, seasonal and deterministic dummies

Our results provide strong support for the mean-variance model of Varian (and of other models of heterogeneity and trading volume). For the yen and Deutsche mark the variables are correctly signed and typically significant. For all three currencies the trading volume of the currency futures pits in Chicago is positively related to the dispersion of our panellists' forecasts, even when other determinants of turnover are accounted for.

2.5 SUMMARY AND CONCLUSIONS

In this chapter we have been concerned to establish the existence and importance of heterogeneity in the foreign exchange market using a high quality disaggregated survey database. Using parametric and non-parametric methods, we have shown that the accuracy of forecasters' predictions are not randomly distributed and that some forecasters are significantly better than others. These findings are strong for all three currencies over both forecast horizons.

We have also demonstrated that an explanation for this differential performance can be found in the different interpretations placed on information by forecasters. The information set used in making exchange rate predictions is potentially vast, but using commonly available information such as the forward premium we reveal that not only do individuals hold individual biases, they also interpret the importance of key variables in different ways. There does not appear to be a systematic pattern to these differences - in particular, forecasters from one country do not uniformly place any more, or less, importance on a variable than the global average. This fact, together with the similarity between Tables 2 and 3, suggest that the foreign exchange market does have a largely common information set and that informational asymmetries between nations are small. Finally, we examined one implication of forecaster heterogeneity. Using the mean-variance model of Varian which theoretically addresses the linkage between trading volume and market sentiment, we demonstrate that even when other potential determinants are controlled for, the dispersion of forecasts is positively related to turnover.

CHAPTER 3

ARE EXCHANGE RATE FORECASTS WORTH THE PAPER THEY ARE FAXED ON?

3.1 INTRODUCTION

In chapter 2 we saw that our forecast panellists form a heterogeneous mass. Easily available information is interpreted differently, and forecasters hold individual biases. These differences translate into differential forecast performance, measured in terms of absolute accuracy, whilst the dispersion of forecasts helps to explain changes in trading volume in the currency futures markets in Chicago.

In this chapter we examine the performance of our panellists in more detail. Alternative measures of performance are proposed that relate broadly to the different uses to which the forecasts may be put. We start with two groups of descriptive statistics frequently used in the literature to assess the record of forecasters. The first classification is a pair of error measures (root mean square and mean absolute error) that have become the standard test statistics following Meese and Rogoff (1983*a*). These measures are compared with a more market-oriented performance metric based on a simple forecast-dependent trading rule. In both cases, the outcome for each forecaster has to be compared with a benchmark, the most logical of which is a simple random walk, a prediction of 'no change'. Section 3.3 focuses on the rationality of the forecasters, and we perform both the standard tests and alternatives that allow us to concentrate on the directional forecasts embedded in our panellists' returns.

The above evaluation criteria are based upon forecasts of individual currencies. In section 3.4 we examine portfolio performance, taking account of the fact that a panellist's contemporaneous forecasts of several currencies will be related. Two alternative methods of computing optimal portfolio holdings based on these forecasts are compared. The first, based on Bilson's (1981) speculative efficiency hypothesis, tests whether statistically significant average profits can be earned from portfolios constructed from an individual's forecasts. Our second method, used by Bilson and Hsieh (1987), follows a similar procedure but internalises the gearing of the portfolio whereby the size of the positions established depends positively on the size of expected profits.

The various tests all address the same basic question from different perspectives. In the final section we relate the outcomes of each test and conclude as to the usefulness or otherwise of the forecasts of our panel members.

3.2 STATISTICAL EVALUATION VERSUS MARKET VALUE

One of the most widely read international finance articles of the past three decades is Meese and Rogoff (1983*a*).[19] It also proved to be one of the most destructive pieces of research into asset price forecasting, showing as it did that estimates of the popular asset price exchange rate models of the Seventies were unable to out-perform a prediction of 'no change' in a forecast competition. There have been no new theoretical models of exchange rate determination published since this date, presumably at least in part because any that were developed were also inferior to a random walk.

To remove any dependence of their earlier results on coefficient estimates, Meese and Rogoff (1983*b*) produce forecasts from asset price models whose coefficients are either constrained to values taken from the empirical literature on money demand functions or found from a grid search over a range of plausible alternatives. These forecasts could outperform the no-change prediction, but only over horizons above one year. The results of both studies may be interpreted as supporting the view that the exchange rate is an asset price determined in an efficient market, at least in the short-run.[20]

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[19] All future references to Meese and Rogoff in this chapter relate to this article unless otherwise noted.

[20] Other researchers have managed to produce models capable of matching or beating a prediction of no change, but rarely for a wide range of currencies. See MacDonald and

If this is the true representation of the way the foreign exchange market works, then trading on the basis of forecasts made by models or so-called experts cannot be profitable, as all information about the change in the exchange rate is contained in the current spot and forward rates. Evidence on this point is mixed. Boothe and Glassman (1987) find profitable trading rules based on the real interest differential model for the Canadian dollar and Deutsche mark, although profits for the latter currency are highest from the random walk model. They note, however, that the unexploited profit opportunities could be compensation for risk bearing and hence do not necessarily indicate market failure. Bilson and Hsieh (1987) account for risk and still find evidence of profitable speculation; however, their results are heavily influenced by a few highly profitable opportunities that could be associated with the peso problem.[21]

Although the out-of-sample evidence may be unclear, the in-sample performance of most models is also unsatisfactory in terms of having wrongly signed coefficients, low R^2 values and insignificant magnitudes.[22] This has led some researchers to conclude that the operation of the foreign exchange market is influenced by technical analysts, or chartists, who base their predictions of currency movements on patterns in the history of exchange rate movements. That these analysts play a role in the market is beyond doubt. Taylor and Allen (1992) find from survey results that over a short term (intraday to one week) forecasting horizon over 90% of chief foreign exchange dealers in London, the largest currency market in the world, use some type of chart analysis in formulating their expectations, and that over half of their respondents feel these charts to be at least as important as fundamental determinants of the exchange rate. This is less surprising when one notes that Allen and Taylor (1990) show that some of the chart analysts could

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Taylor (1992) and chapter 5 of this thesis for fuller discussions of the out-of-sample performance of economic models.

[21] The peso problem is usually seen as the non-occurrence of an event within a sample. In this case, however, it is possible that the few large profits made were in-sample occurrences of a small probability event that would be offset by many small loses if the test period were extended.

[22] See Dornbusch and Frankel (1987), MacDonald (1988) and MacDonald and Taylor (1992).

consistently outperform a random walk over a one week and four week forecast horizon. Theoretical models are now being devised that incorporate non-fundamentalist traders.[23]

Work carried out to date on the accuracy of exchange rate forecasts has used the forecasts of either econometric or time series models (economics-based), or chart analysts' predictions. Goodman (1979) uses various measures of predictive power to evaluate the output of ten forecasting services; six of whom use economics-based techniques and four based on chartist methods. His broad conclusions are that the economics-oriented services perform rather poorly and are not notably profitable, while the technical services do much better, producing high returns on speculated capital. Levich (1982, 1983) examines the directional forecast ability of several commercial advisory services. He notes that the proportion of correct directional forecasts recorded by even the best services varied from year to year and was not uniform across currencies or maturities. Only a small proportion of forecaster/currency/maturity combinations display statistically significant abilities.

Instead of producing new fundamental models of the exchange rate, research has shifted to generating non-theoretical models (predominantly VAR's and extrapolative models) and to finding reasons why the asset price theories failed. Two strands are clear in the literature relating to the latter point. First, the modelling of the theories, rather than the theories themselves, are thought to be at fault. Second, irrational agents (either the central banks or, more commonly, chartists) are argued to be interfering in the market, driving the exchange rate away from the models' predictions.[24]

We address the first issue in chapters 5 through 9, where complex dynamic models are created and evaluated. In this chapter, by using survey forecasts we can avoid complications relating to the interference of irrational market participants. In

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[23] See Frankel and Froot (1986, 1990) for a model that helps to explain the behaviour of the US dollar in the mid-1980s and Kirman (1991) for a model in which traders switch between chartist advice and fundamentalist predictions.

[24] A comprehensive survey of these issues can be found in MacDonald and Taylor (1992).

most instances we do not know the techniques used by our forecasters to generate their predictions, but since our panellists are close to the market they can be expected to incorporate the potential activities of other traders (including central bank intervention) and technical influences (chartism).[25] As such then, we are not evaluating academic models of exchange rate determination, but rather practitioners' beliefs about how the market works combined with their 'feel' for the market.

3.2.1 ACCURACY MEASURES OF FORECASTER ABILITY

As a first stage in this mission to evaluate our panellists' forecasts we consider the simple accuracy measures of Meese and Rogoff, namely mean squared errors and mean absolute errors. For these, and later, statistics to be meaningful we are forced to impose the restriction that a panellist have responded to at least twenty questionnaires for a currency (this criterion applies for both the three and twelve month forecast horizons). The error statistics are calculated as follows

Root Mean Squared Error (RMSE):

$$RMSE = \sqrt{\frac{\sum (F_t - A_t)^2}{n}} \tag{40}$$

Mean Absolute Error (MAE):

$$MAE = \frac{\sum |F_t - A_t|}{n} \tag{41}$$

where F_t is the forecast (log) level of the exchange rate, A_t is the actual outcome and n is the number of forecasts made by the panellist. As our respondents rarely provide a full set of forecasts, the random walk alternative (F_t-A_t) is computed for each permutation of response records. Thus, if forecaster C1 replies to all questionnaires

[25] Some of our panel members are professional forecasting companies whose forecasts are based on purely econometric models. They are few in number and, it emerges, quite average in performance.

with the exception of January 1992, the random walk error statistic to which he is compared is also calculated over all months except January '92. To facilitate comparison we calculate the ratio of forecaster error statistic to the appropriate random walk measure. A value less than unity indicates that the forecaster 'beats' a random walk.[26]

Though this ratio alone is often used to compare forecast performance, a simple test of whether the forecaster is significantly better than the benchmark can be found in Williams and Kloot (1953). Let F_M denote the (log) forecast from a panel member, F_{RW} that of the random walk alternative, and A the outcome value of the (log) exchange rate. The Williams-Kloot test is the t-test of the null that the coefficient on $F_{RW} - F_M$ is zero in a regression of $A - (F_M + F_{RW})/2$ on $F_{RW} - F_M$ (see Williams (1959)). This test statistic uses the Newey and West correction for serial correlation and heteroscedasticity. A significantly negative value implies that model forecast is statistically superior to that of the random walk model (and *vice versa*). The results are summarised in Table 7 and given in detail in Table A3 in the appendix. We also present the RMSE results graphically in Figures 14 to 19.

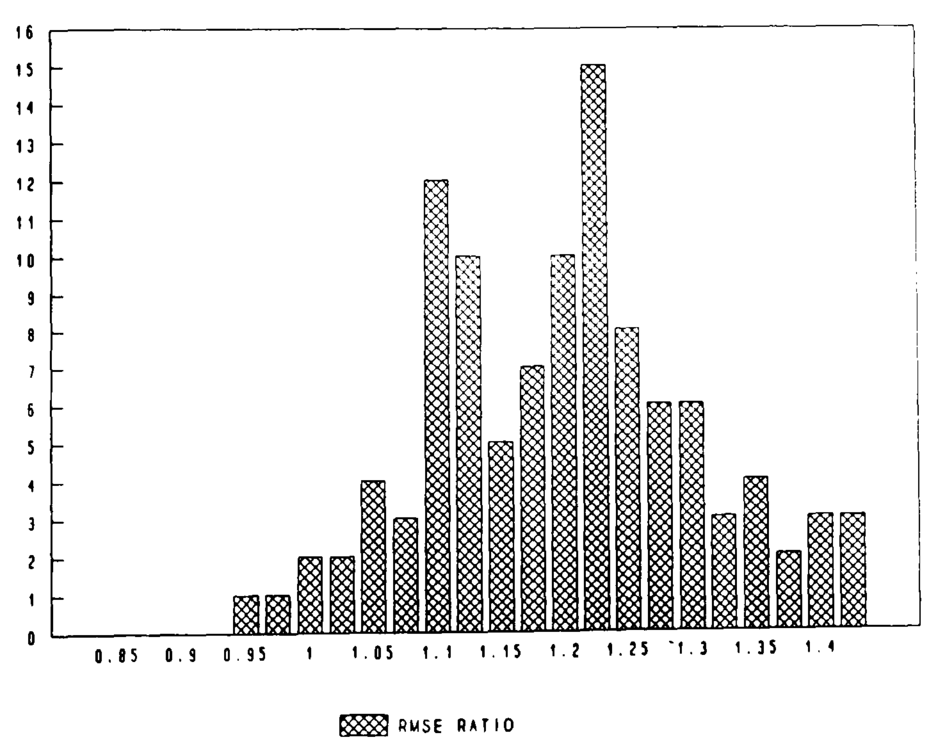
[26] Note that as discussed in chapter 2, the imperfect response rates make comparison between forecasters hazardous unless some correction for what we called month effects is made. In this section we are concerned with the forecasters' performances relative to the benchmark of a random walk model, and the metrics can only be used for comparison of individual forecasters if their response records are identical.

Table 7
Forecasters Versus A Random Walk - Accuracy Statistics

	Number	RMSE	Sig. better	Sig. worse	MAE
DEM 3mth	107	4	0	58	5
STG 3mth	93	5	0	34	2
JPY 3mth	107	2	0	66	2
DEM 12mth	89	26	4	20	23
STG 12mth	81	14	3	19	35
JPY 12mth	91	56	24	14	62

NOTES: The figures in the first column give the number of forecasters who supplied the required number of forecasts for each currency/horizon combination. The second column gives the number of forecasters with RMSE statistics less than that of a random walk. The third and fourth columns give the number who are significantly better and worse than a random walk respectively at the 5% level. The final column gives the number with a MAE ratio of less than unity.

Figure 14 Deutsche mark three month forecasts



At face value, the results are striking, if somewhat expected. Over the three month forecast horizon for all three currencies, very few individual forecasters obtain

Figure 15 Deutsche mark twelve month forecasts

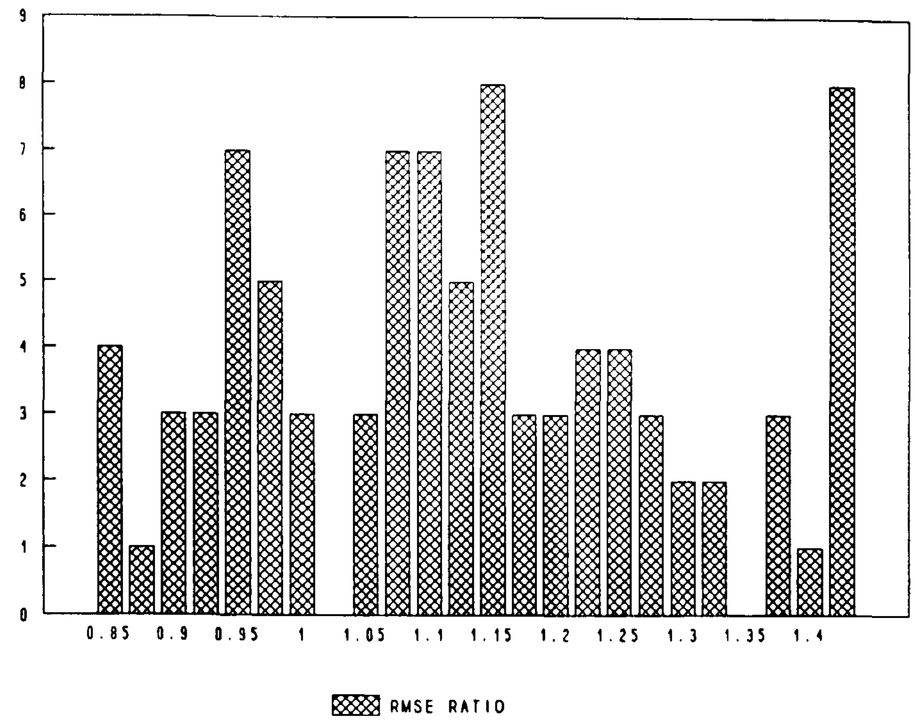
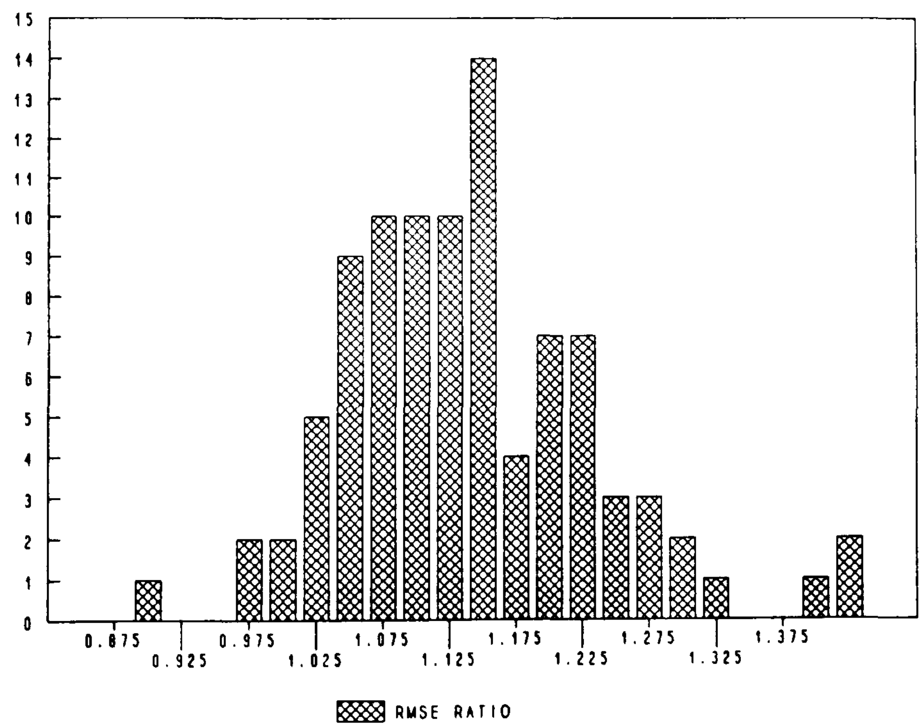


Figure 16 Pound sterling three month forecasts



lower error statistics than the random walk alternative. This is true for both error statistics. Furthermore, no forecasters significantly out-perform a random walk over

Figure 17 Pound sterling twelve month forecasts

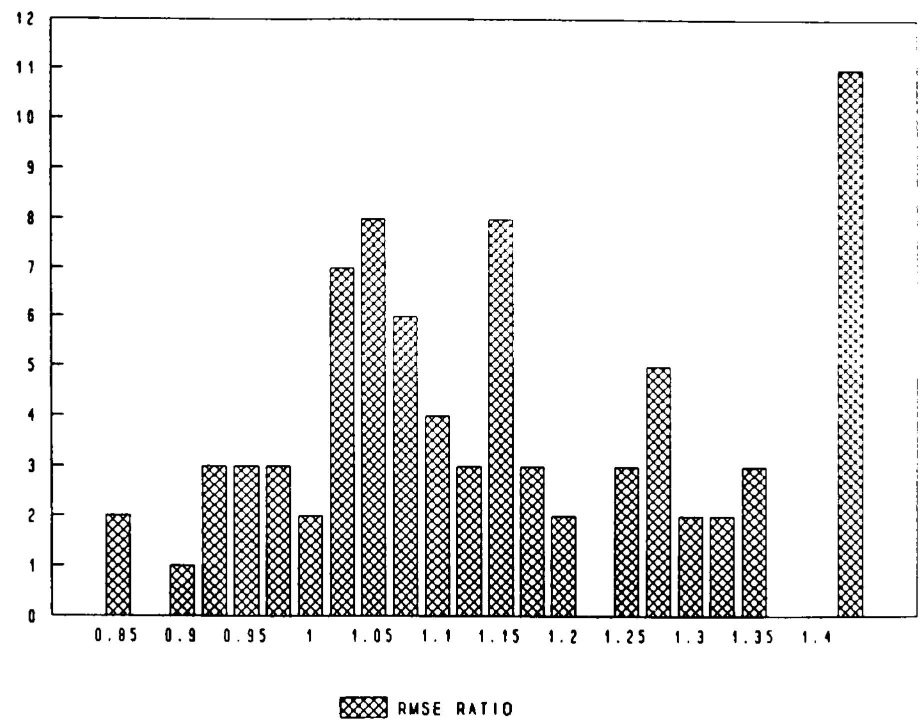
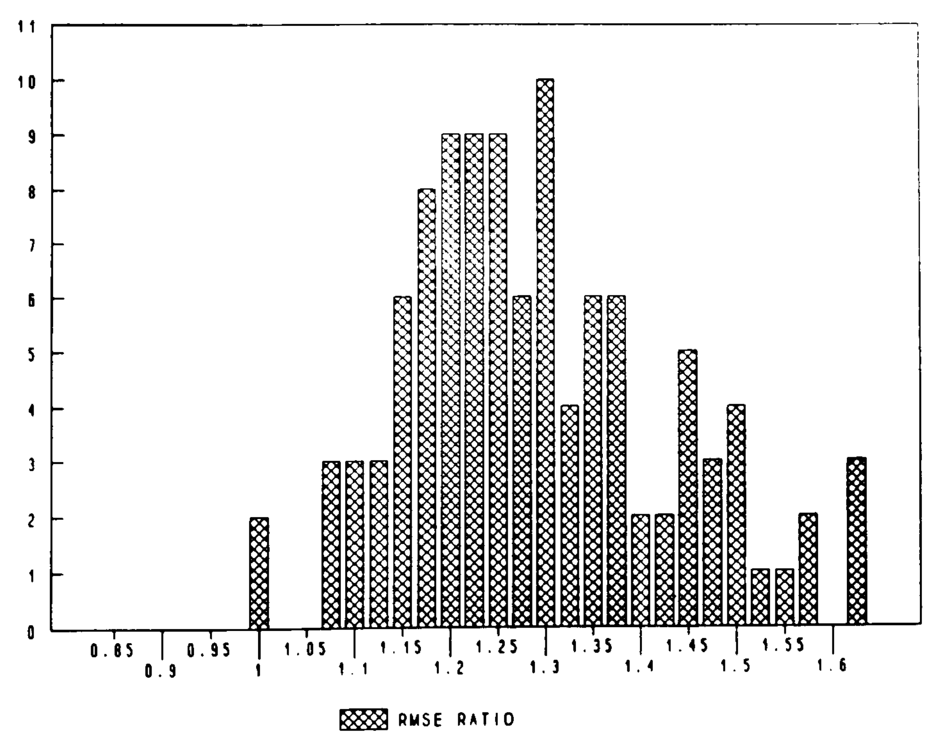
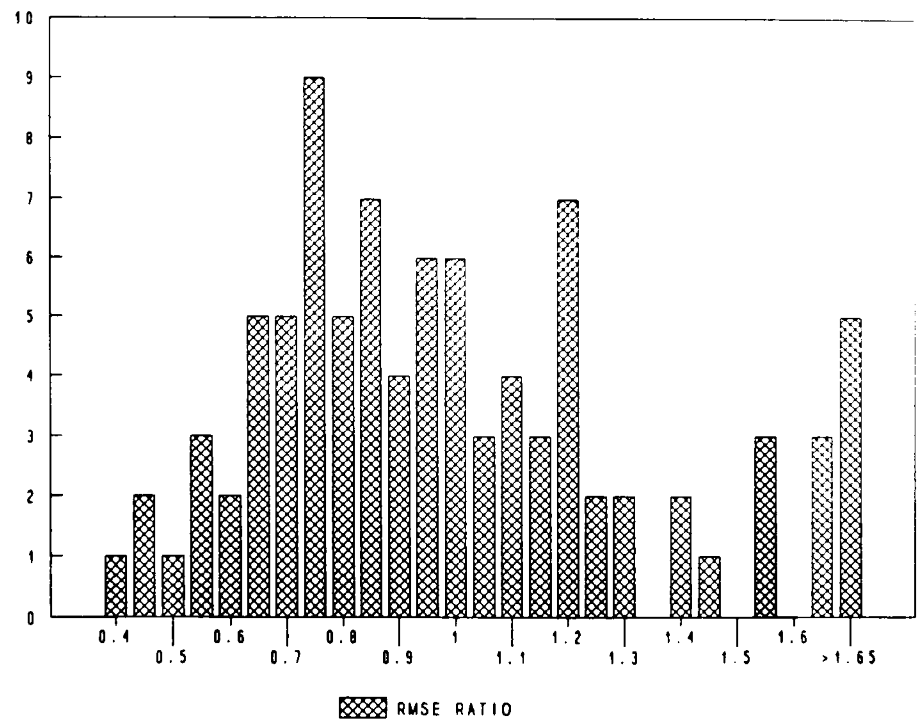


Figure 18 Japanese yen three month forecasts



the three month horizon, whereas the majority are significantly less accurate.

Figure 19 Japanese yen twelve month forecasts



Over the longer forecast horizon, however, a substantial proportion of forecasters appear to out-perform a no change alternative. The improvement in performance is particularly true for those attempting to predict the Japanese yen, where four forecasters have RMSE's less than half as large as a random walk. Approximately half of the forecasters with RMSE ratios less than unity are revealed to be significantly better than a random walk. For all three currencies, the proportion significantly less accurate than the alternative is greatly reduced over the longer horizon.

Overall then, our results are in accordance with those of Meese and Rogoff (1983*a*, 1983*b*) and with the opinion of Salemi (1983, p111) who argues that:

> "in the short run, the spot rate behaves like the price of a speculative asset but that over longer horizons its equilibrium value is systematically related to other economic variables"

In other words, in the short term, the change in the exchange rate is unforecastable but as the forecast horizon extends economic variables (and in the case of our panel, other variables) can provide guidance.

It is difficult to determine whether the incorporation of these other factors, such as chartist influences, results in dramatically improved performance over either horizon. Taylor and Allen (1992) report the results of a survey of the London foreign exchange market. They show that many foreign exchange dealers use chartism over the short term, but that as the horizon extends the relative importance of fundamentals increases.[27] Thus, any improvement from using chartist inputs to the forecasts should be more apparent for the three month horizon. In Table 3.10 of Meese and Rogoff (1983*b*) RMSE figures are given for a random walk and for their "best representative" econometric model. The parameters of this model were determined by a grid search over plausible values, and the best performing model chosen. In line with their previous paper, Meese and Rogoff use realised values of explanatory variables in making multi-period forecasts to focus on the performance of the model. Over a three month horizon, the RMSE ratios are greater than unity for all three currencies. Comparing the ratios with those determined for our panellists we find that their Deutsche mark model would rank within the top quartile with a ratio of 1.096, whilst the sterling and yen models are very poor (both in the last quartile, and absolutely last in the case of the pound). Over the twelve month horizon, the mark model is still a relatively good performer (13th of 90), the pound model is still appalling (80th of 82) and that of the yen fairly average (56th of 92).[28] Given the in-built advantage afforded the Meese and Rogoff models by the use of realised values, we would expect their models to compare favourably with our panellists. That they do not is in some part attributable to the incorporation of chartist and other 'market awareness' factors in the forecasts of practitioners.

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[27] They also note, however, that there is a persistent bloc of traders that relies heavily on technical analysis for all horizons.

[28] Of course, the Meese and Rogoff results are evaluated over a different time period from the one in this study.

3.2.2 PROFITABILITY MEASURES OF FORECAST ABILITY

It could be argued that accuracy in terms of error statistics is probably more relevant to an evaluator of forecasts than to an end-user. In the case of asset price forecasts, a consumer is likely to use a prediction as a guide to speculative opportunities. One could argue that the user is likely to be more concerned with some form of profit measure than the RMSE. As an alternative to the error statistics we therefore calculate a simple measure of profit based on forward market speculation. We use the method of Boothe (1983) and Boothe and Glassman (1987) whereby a foreign currency purchase or sale is made in the forward market dependent on the forecast. If the currency is forecast to be stronger than indicated by the forward rate US$100 equivalent of the currency is bought, and if weaker $100 equivalent is sold. This is clearly only an approximate measure of trading profits as the possibility of an early closing of the contract (cutting of losses) is ignored, but it has the advantage of showing the importance of the qualitative predictions embedded in our forecasts.[29] The profits and losses of these trades are then cumulated to give a final total profit figure. Again, adjustments have to be made for the imperfect response rates. The first method is to express these profits in a 'per trade' format (i.e. divide total profits by the number of forecasts made). Second, in order to allow comparison with the performance of a naive forecast of no change, the difference, or spread, between forecaster profit per trade and random walk profit per trade is computed. Again, for correct comparison the random walk alternative is only calculated for those months in which the forecaster responds. Results are summarised in Table 8 and Figures 20 to 25. Full results are given in Table A4 in the appendix.

[29] An alternative measure would be the profits from a buy-and-hold strategy.

Table 8
Forecasters Versus A Random Walk - Forward Speculation

		Profits		Excess profits	
	Number	Abs.	Sig.	Abs.	Sig.
DEM 3mth	107	27	3	34	2
STG 3mth	93	44	0	6	0
JPY 3mth	107	35	0	25	0
DEM 12mth	89	55	16	27	5
STG 12mth	81	62	36	9	2
JPY 12mth	91	68	41	67	4

NOTES: The figures in the first column give the number of forecasters who supplied the required number of forecasts for each currency/horizon combination. The figures in the second column give the number of forecasters whose profit per trade proved positive in an absolute sense, and the third column gives the number of forecasters whose profit per trade is significantly positive. The fourth column gives the number who were more profitable than the random walk, and the fifth, the number that were significantly so.

Between one-quarter and one-half of three month forecasts prove to be profitable to follow, according to our speculative strategy. The proportions rise to between one-half and three-quarters over the longer forecast horizon. The significance of these profits depends crucially on the forecast horizon. Only three forecasters (all of the Deutsche mark) return significantly positive profits over three months. Conversely, between thirty and sixty percent of the profitable forecasters return significant profits over twelve months. At least over this longer horizon, the efficiency of the market can again be questioned since trading on the basis of professional forecasts can bring positive profits. The crucial question in terms of evaluating the efficiency of the market is whether these profits are merely compensation for the risk taken in holding currency exposure or whether they are supernumerary. If we are willing to accept the simplest model of risk neutrality with a mean expected return of zero, our long-term results strongly violate the efficient markets hypothesis.

When we compare our forecasters' performances to a random walk alternative the picture changes slightly. Typically, over our sample period, a no change

Figure 20 Deutsche mark three month forecasts

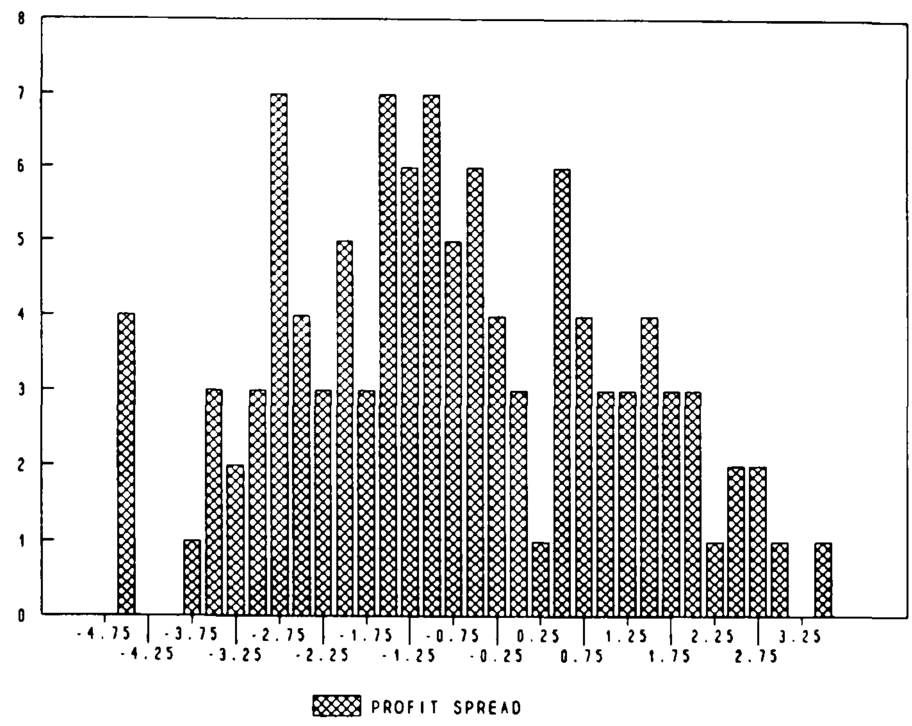
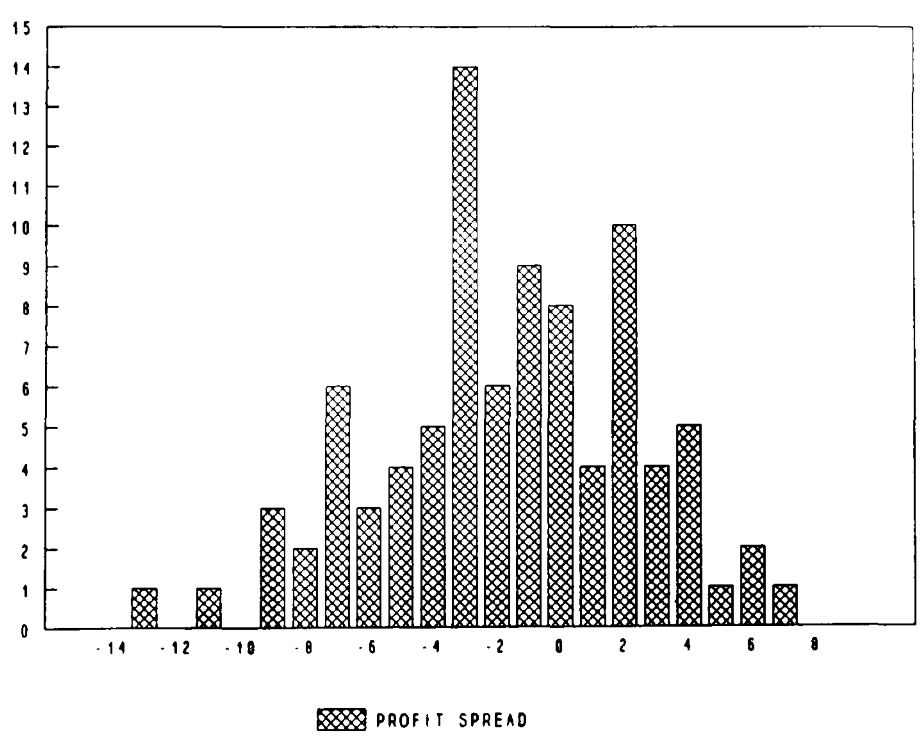


Figure 21 Deutsche mark twelve month forecasts



prediction proves costly to follow for the Deutsche mark over three months and hence while 27 forecasters give positive returns, 34 give returns in excess of a random walk.

Figure 22 Pound sterling three month forecasts

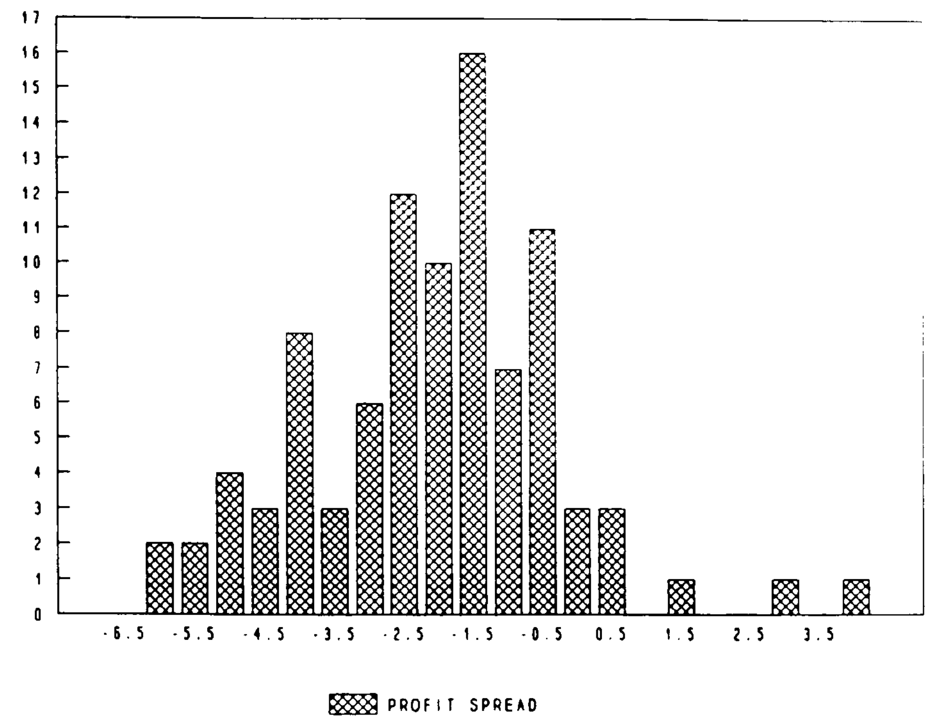
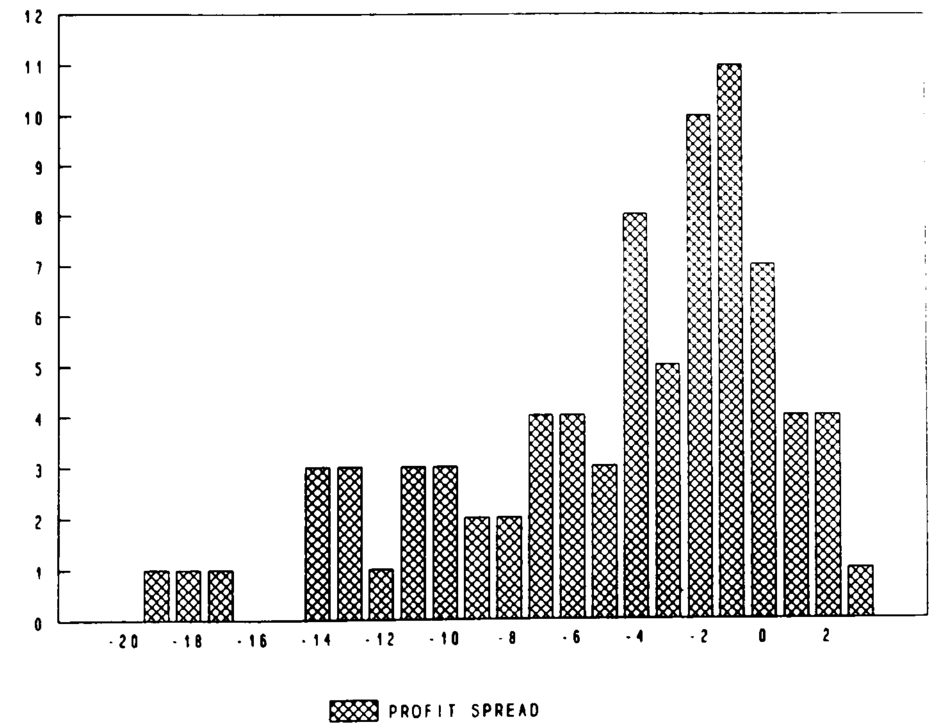


Figure 23 Pound sterling twelve month forecasts



This is reversed over the twelve month horizon, where roughly half of the profitable forecasters beat the no change alternative. For the yen over both horizons a random

Figure 24 Japanese yen three month forecasts

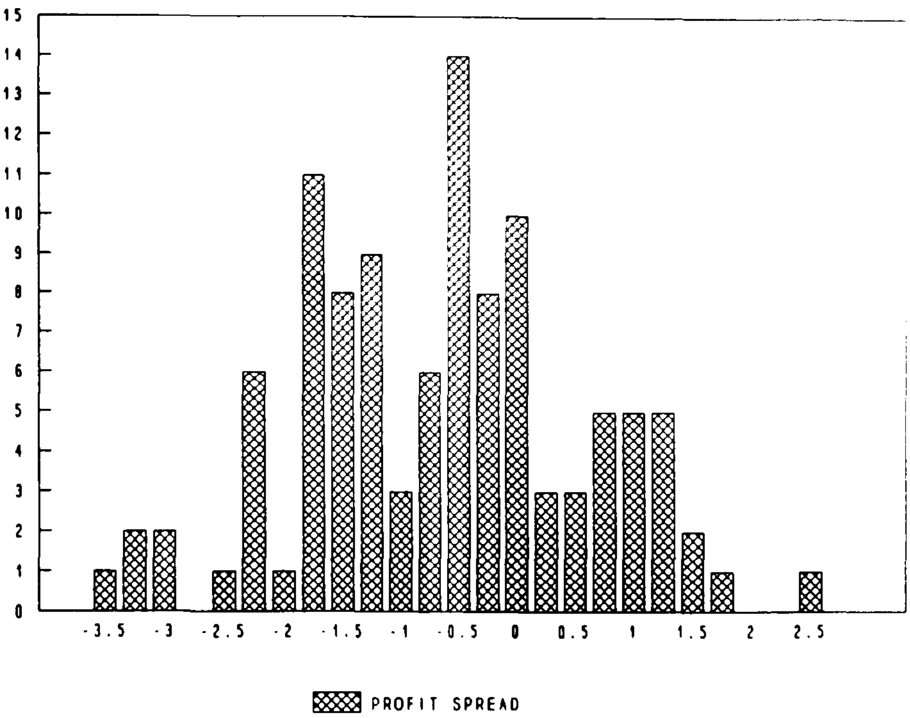
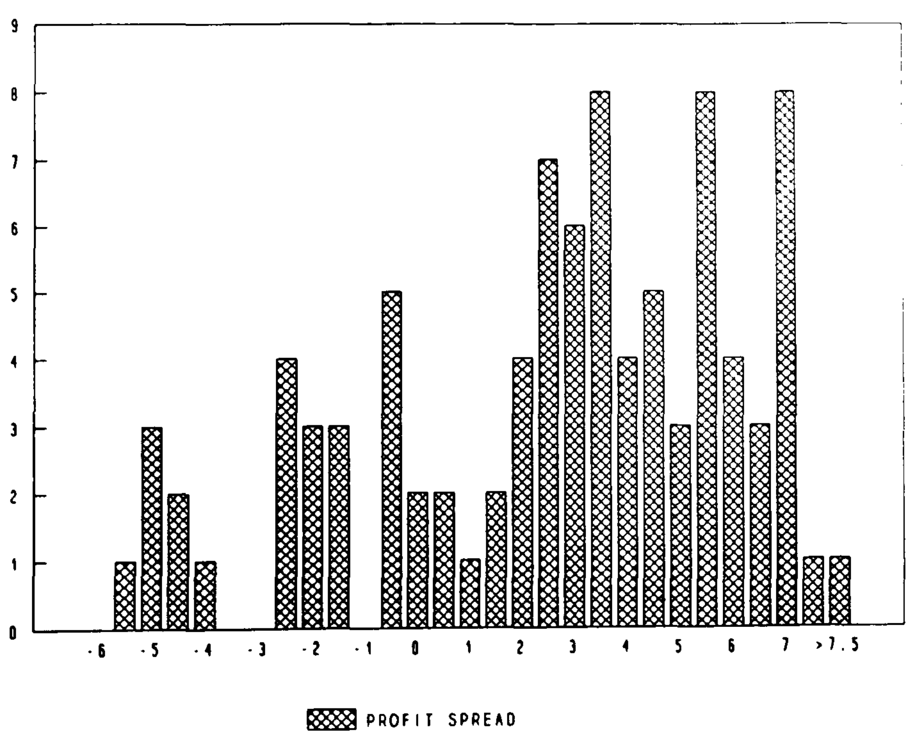


Figure 25 Japanese yen twelve month forecasts



walk approximately breaks even as the same number of profitable forecasters earn what we term excess profits. A prediction of no change proves very profitable for the pound over both three and twelve month horizons. Thus the number of forecasters earning excess profits is substantially lower than the relatively high count of profitable forecasters.

Excess profits are, in the main, not significant. Some care is needed in interpreting this, however, as the excess returns series are frequently characterised by a long run of zeros (i.e. the forecast puts the trader on the same side of the market as the random walk model and thus earns the same profits) and a few profits/losses. The series is thus very heteroscedastic, and though our test procedure should take account of both heteroscedasticity and the overlapping observations problem, the residuals may be too non-normal to invoke standard statistical assumptions.

3.2.3 ACCURACY VERSUS PROFIT AS A PERFORMANCE METRIC

Examination of individual forecaster results provides some interesting insights. Naturally enough, there does seem to be a correspondence between accurate and profitable forecasters. For the three month Deutsche mark, for example, all four forecasters with RMSE ratios less than unity have positive profit spreads. However, the relationship does not always hold in reverse since several forecasters are particularly profitable yet have RMSE ratios greater than unity. Table 9 presents the correlations between profit spread and our two error ratios for each currency/horizon combination.

Table 9
Error Measures and Profit Correlations

	Simple correlations		
	RMSE-MAE	RMSE-Profit	MAE-Profit
DEM 3mth	0.936	-0.608	-0.597
STG 3mth	0.929	-0.529	-0.556
JPY 3mth	0.963	-0.399	-0.371
DEM 12mth	0.967	-0.837	-0.804
STG 12mth	0.957	-0.895	-0.832
JPY 12mth	0.981	-0.865	-0.885
	Spearman's rank correlations		
	RMSE-MAE	RMSE-Profit	MAE-Profit
DEM 3mth	0.862	-0.369	-0.363
STG 3mth	0.768	-0.306	-0.308
JPY 3mth	0.884	-0.183	-0.168
DEM 12mth	0.898	-0.742	-0.660
STG 12mth	0.848	-0.766	-0.600
JPY 12mth	0.962	-0.794	-0.789

Although all of these correlations have the expected sign and are significant, the relatively weak relationship between profit and forecast error, at least over the shorter horizon, is evident. Further evidence is given in Figures 26 to 31. The body of forecasters in the upper right quadrant (i.e. relatively profitable but inaccurate forecasters) are of particular relevance. Why is it that these panel members make large errors yet still return profits in excess of the random walk alternative? This anomaly is also noted by Leitch and Tanner (1991), who calculate a range of error measures together with profit from speculation, using methods akin to ours, to evaluate a range of forecasting systems, including a single company's forecasts of US Treasury bill rates. Based on correlation analysis, they show that profits derived from forecasts bear little relationship to measures of forecast error, but that they are closely related to directional accuracy. Leitch and Tanner conclude from their results that

Figure 26 Deutsche mark three month forecasts

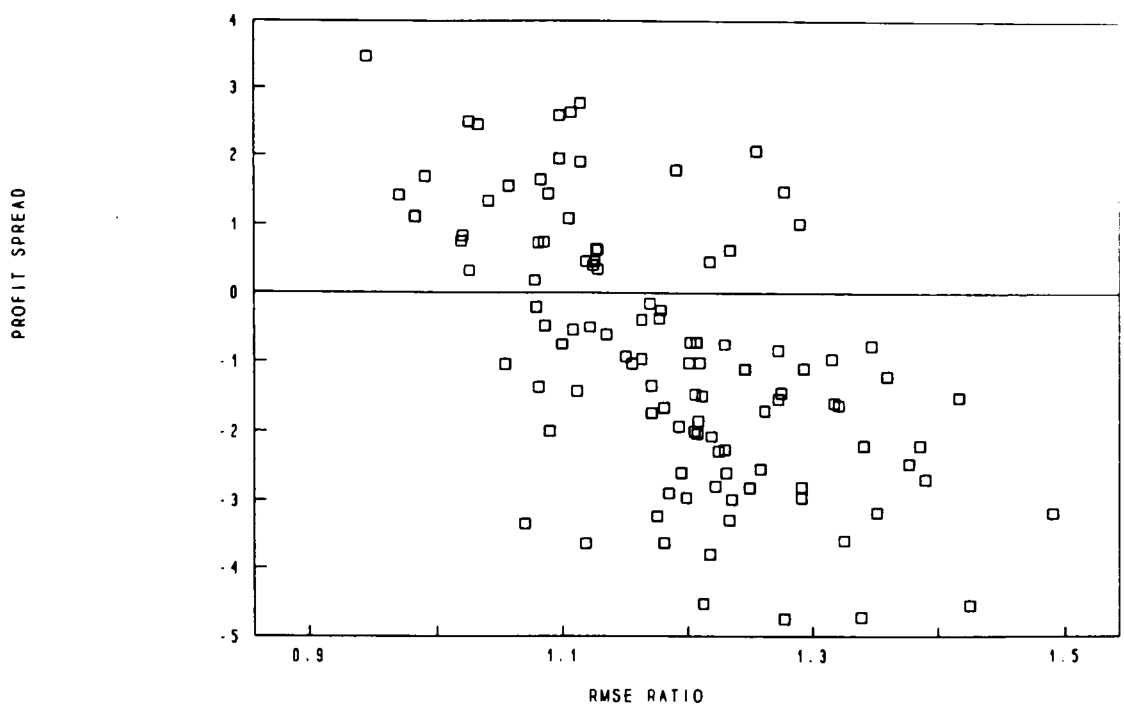
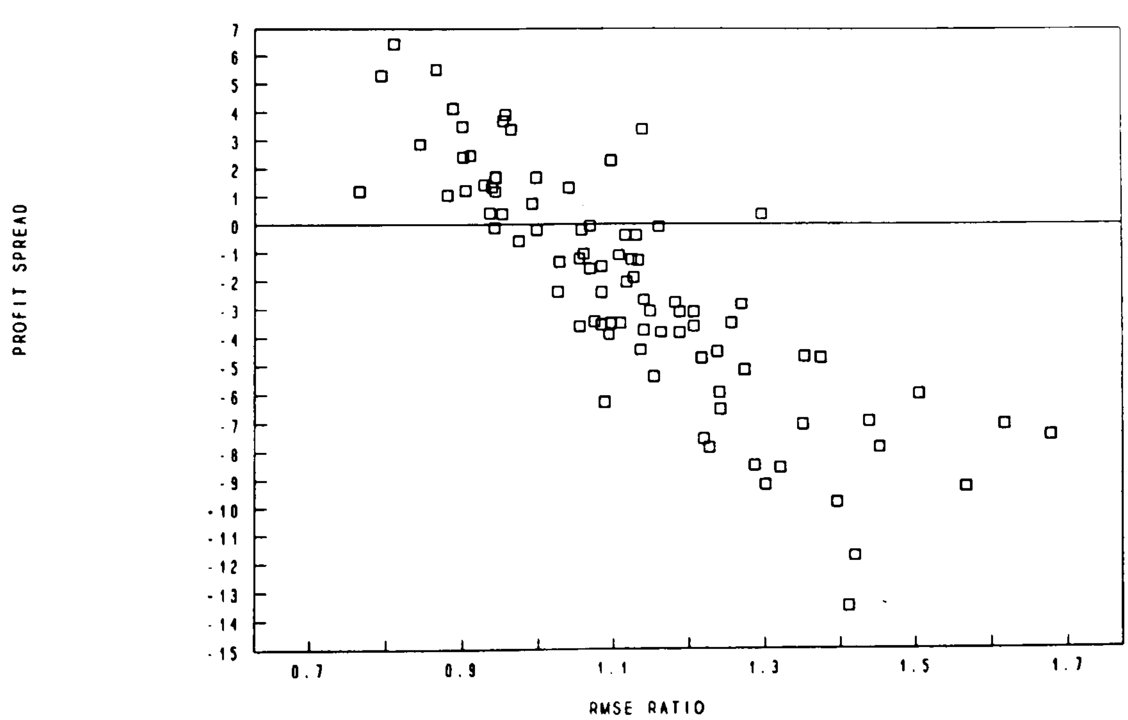


Figure 27 Deutsche mark twelve month forecasts



speculative profits are a better method of financial forecast evaluation. However, a possible explanation of the apparent inconsistency of profitable but inaccurate

Figure 28 Pound sterling three month forecasts

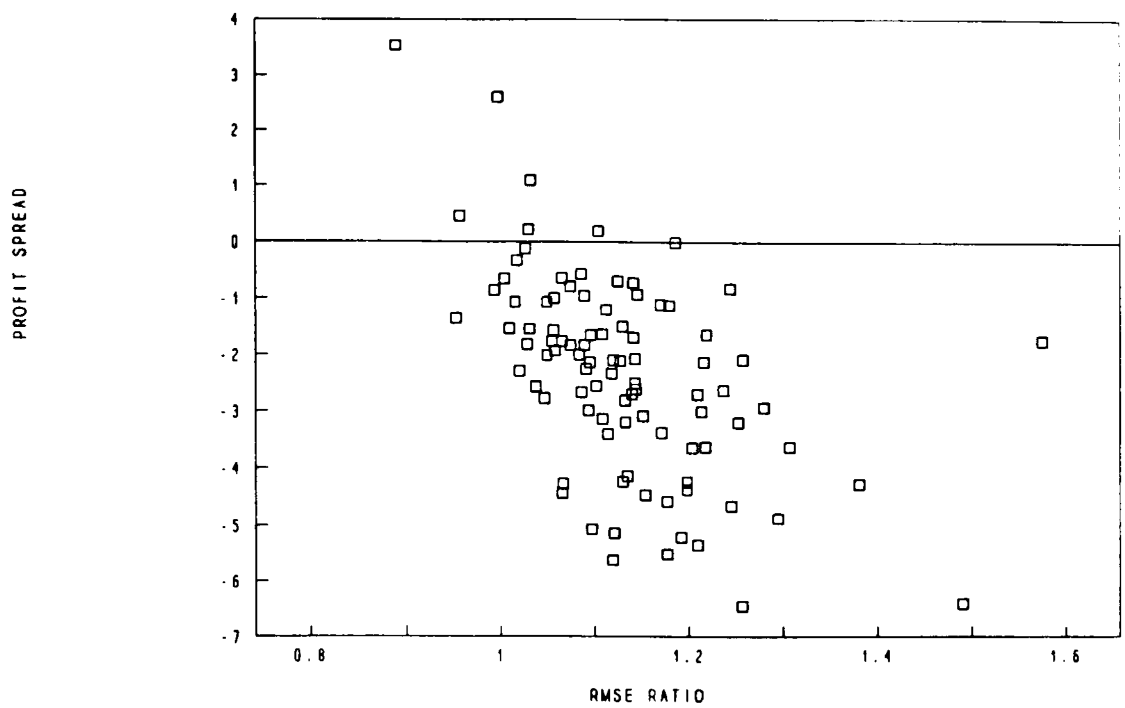
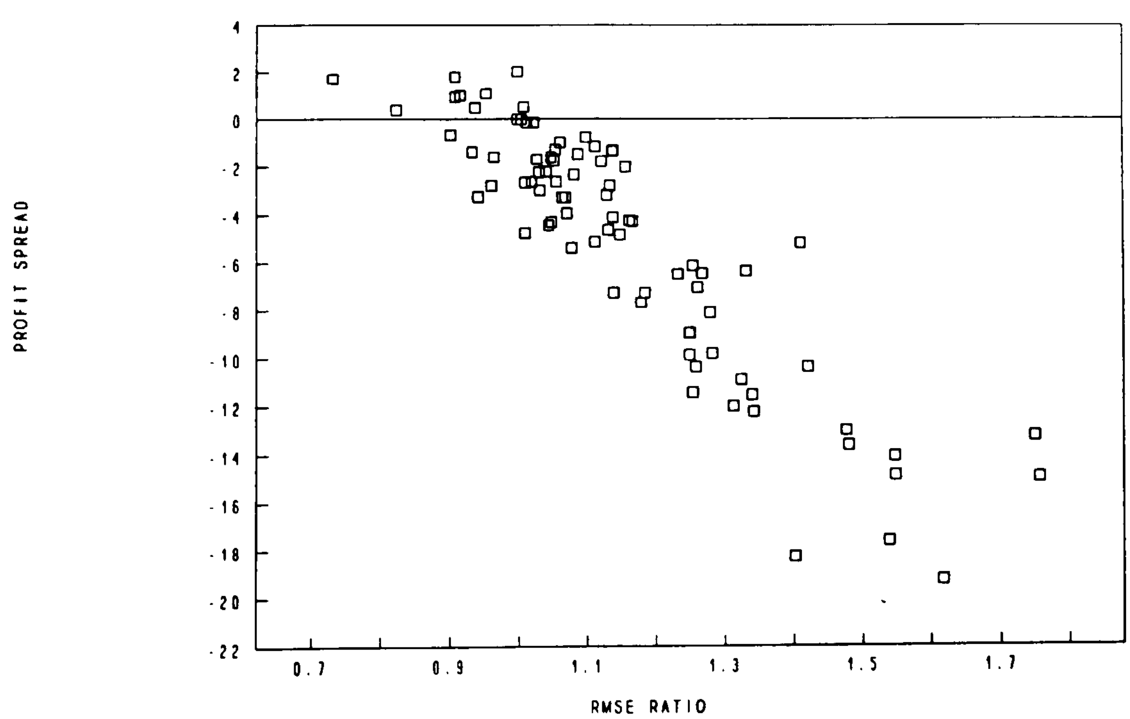


Figure 29 Pound sterling twelve month forecasts



forecasters is that our speculative strategy, in common with that of Leitch and Tanner, takes no account of risk. Since risk is generally related to some measure of

Figure 30 Japanese yen three month forecasts

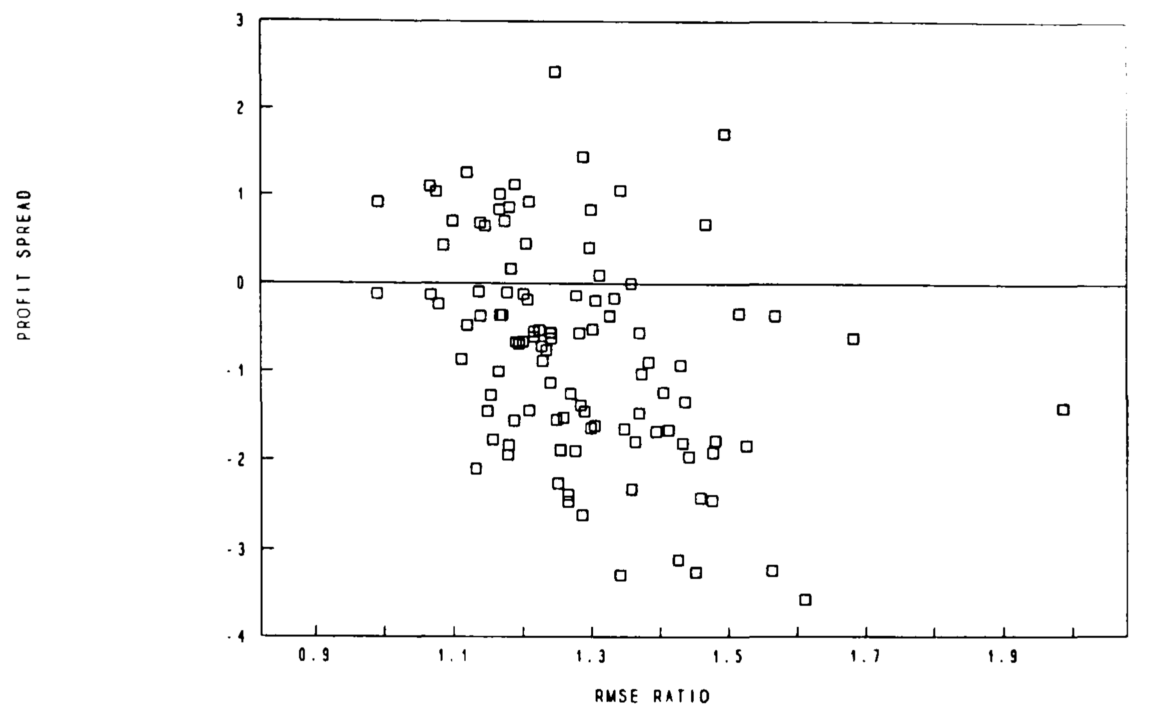
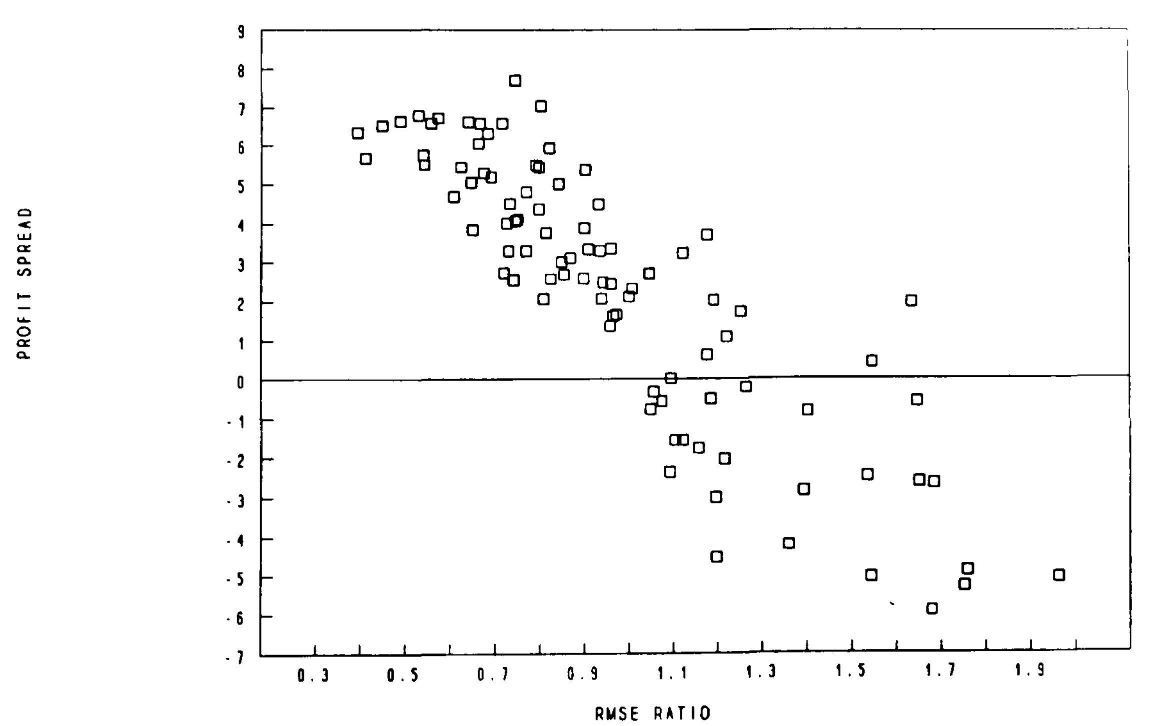


Figure 31 Japanese yen twelve month forecasts



forecast error, the fact that we find only a relatively weak negative correlation between forecast accuracy and profit suggests that both types of evaluative criteria are important in assessing predictive performance: profit alone is not a good measure of forecast ability if it is not always accompanied by small errors.

It is at this point worth emphasising two limitations of our data set. First, our sample period is short compared with the full floating exchange rate period and hence our conclusions may be sample specific. Second, particularly in the case of the twelve month forecasts, the overlapping nature of our data implies that we have relatively few independent observations.

So, qualified by these two limitations, what conclusions can we make based on the results of our first two methods of evaluation? From the summary tables presented we can say that whilst in terms of statistical accuracy (RMSE, MAE) the short horizon forecasts are typically poor when compared with a random walk, a large number of them prove profitable to follow. Whether they are as profitable as a random walk depends on the currency under consideration. Over the longer horizon, a large number of our forecasters prove to be both profitable and more accurate than the naive alternative. Again, the existence of profits over and above those earned by a trading strategy based on a random walk depends on the currency being examined. Nevertheless, the existence of significantly positive profits earned on the basis of the twelve month forecasts of a large proportion of our forecasters strongly violates the efficient markets theory. As noted above, this evaluation is based on the zero mean return benchmark and assumes risk neutrality. A more stringent test would be one of zero risk-adjusted mean returns, tested via the CAPM. The lack of a benchmark market return makes this a problematic exercise, however, and we leave our discussion of risk to section 3.4 where a more comprehensive analysis is undertaken on a sub-sample of our panellists. We first turn to rationality tests of forecaster accuracy. Derivatives of the standard regressions are presented that shed further light on the nature of our panellists' errors.

3.3 EFFICIENCY, BIAS AND DIRECTIONAL ABILITY - DO OUR FORECASTERS EVER GET IT RIGHT?

The efficiency of survey expectations series is often gauged by testing whether they obey two properties (see, for example, MacDonald (1992)): they should be unbiased predictors of the actual price and their implied forecast error should be orthogonal to the conditioning information set. These properties may be summarised with reference to regression equations (42) and (43)

$$\Delta s_{t+k} = \rho + \delta \Delta s^{e}_{t+k} + \varphi_{t+k} \tag{42}$$

$$s^{e}_{t+k} - s_{t+k} = \phi_0 + \phi_1 X_t + \zeta_{t+k} \tag{43}$$

where s denotes the (logarithm) of the exchange rate, the superscript e denotes an expectation, k is the forecast horizon $\Delta s_{t+k} = s_{t+k} - s_t$, and X_t is the period t information set available to agents at the time their forecasts were formed. If agents form optimal forecasts of the future spot rate, then in equation (42) ρ should equal zero and δ should equal 1 (the unbiasedness property) and, furthermore, the Φ coefficients in (43) should jointly equal zero (the error orthogonality property).[30] Forecast series for which all properties hold are said to be rational forecasts. Since the observational frequency of our data is greater than the forecast horizon this imparts a moving average error of order equal to k-1. Whilst OLS estimation produces unbiased and consistent coefficient estimates they are inefficient. We therefore use Hansen's (1982) Generalised Method of Moments (GMM), in its heteroscedasticity-consistent form, to correct the coefficient covariance matrix.[31]

We perform the three tests of rationality on our panellists' forecasts and report the results in Table A5 in the appendix. For convenience, they are summarised in Table 10. For the error orthogonality tests in equation (43) the information set is potentially limitless, and we chose to only include the forward premium.

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[30] In the presence of non-overlapping data the error terms in equations (42) and (43) should also be serially uncorrelated, but our use of monthly sampled three and twelve month forecasts makes this further test invalid.

[31] Further details are given in chapter 2.

Table 10
Forecaster Rationality

		Equation (42)			Equation (43)	
	No.	$\rho=0,\delta=1$	$\delta=1$	$\delta>0$	$\Phi_0=0,\Phi_1=0$	Rational
DEM 3mth	107	14	17	27	100	8
STG 3mth	93	35	34	39	75	23
JPY 3mth	107	5	3	22	85	1
DEM 12mth	89	33	39	47	55	21
STG 12mth	81	23	44	58	54	17
JPY 12mth	91	1	7	81	66	0

NOTES: The figures in each column give the number of forecasters for which the null hypothesis in the column headings cannot be rejected at the 5% level. The exception is the column headed $\delta>0$ which is concerned solely with the number of forecasters whose point estimate of δ is positive.

Our results indicate that few forecasters can be said to be rational, with no clear forecast maturity distinction being evident. For three month forecasts, the estimate of δ in equation (42) is more often closer to minus one than plus one, implying that many of the panellists get the direction of future movements (weighted by the square of their forecast error) wrong. However, the fact that some return positive δ coefficients and a few even pass the unbiasedness tests suggests that the movements were forecastable (at least for the pound and Deutsche mark). This is an important point, since MacDonald and Macmillan (1992) point out that if a significant minority body of forecasters display rationality it is hard to invoke the existence of peso problems to justify the failure of the majority, unless we are willing to argue that the seemingly irrational forecasters have access to superior information.

Merton (1981) reasons that for a forecast to have value it must cause a rational investor to change his subjective beliefs about the probability distribution of future exchange rate changes based on all other available information. Henriksson and Merton (1981) provide a contingency table-type test of this on the assumption that the probability of a correct directional forecast (up, down or no change) is independent of the subsequent realised change in the rate. Two problems mean that such a test is inapplicable to our data set. First, the overlapping forecasts rule out contingency table analysis, and second, the fact that our forecasters are believed to take technical analysis into account when forecasting means that the independence assumption is violated. Cumby and Modest (1987) argue that the simplest technical trading rule is the filter rule, studied previously by, *inter alia*, Poole (1967) and Dooley and Schafer (1983). In a market dominated by long-swings the filter rule will do well, placing the forecaster on the correct side for much of the move. However, if the market is trading in a narrow range relative to the filter, the forecaster will make several small losses. Thus the assumption of independence of correctness and future spot price change is invalid. Cumby and Modest propose an alternative regression-based test that instead assumes that the magnitude of the price change depends linearly on the forecast; that is, the probability of a correct forecast is greater for larger price movements. Continuing Merton's (1981) original reasoning they consider the following equation

$$\Delta s_{t+k} = \rho' + \delta' Z_{t+k} + \omega_{t+k} \tag{44}$$

where Z_{t+k} takes the value +1 if the exchange rate is forecast to rise over the subsequent k months, -1 if a fall is predicted and zero if no change is forecast. A forecaster who is able to predict the direction of the change in the spot rate relative to its unconditional sample mean will be revealed by positive estimates of δ'. Intuitively, the Cumby and Modest approach allows a forecaster to provide value if he correctly predicts the sign of subsequent large changes, even if it gets the direction wrong on average. That is, a big 'win' once in a while can offset several small 'losses'. In an asset price framework this clearly makes more sense than a contingency table-type analysis in which a forecast is judged to be right or wrong regardless of the magnitude of the subsequent movement. The regression format also allows us to avoid the problems associated with overlapping data as we can again use GMM to compute robust standard errors.

Comparison with equation (42) makes it clear that (44) discards potentially valuable information, namely the magnitude of the forecast change. This can be justified on the grounds that speculators using these forecasts will not be overly upset to find that a currency they have bought has appreciated by 12% rather than the forecast 15% (or even less worrying, the currency may have risen by 20%). Of course, whilst the difference between 12 and 15 percent may not be relevant, a realised appreciation of 15 percent following a forecast rise of 1 percent could be of importance, especially to a small trader whose cost of dealing is 2 percent and who decided not to trade following the forecast. Since the neutral or no change band will be of different widths for different end-users we compute equation (44) with Z_{t+k} set equal to zero if the absolute value of the forecast change (i) exactly equals zero, (ii) is less than 1% and (iii) is less than 5%.[32] We return to a discussion of forecast rate changes below. The results of estimating equation (44) are summarised in Table 11 and given in Table A6 in full.[33]

Once more the pattern emerges that few of our forecasters demonstrate forecasting ability in the short-run, but over the twelve month horizon a core group of panellists are revealed as being able to predict the direction of subsequent spot rate movements. Comparison with the rationality test results reported in Table 10 is instructive. Over the short-term forecast period more forecasters were revealed as rational than now appear to have directional forecast ability. Conversely, over the longer horizon there were no rational forecasters of the Japanese yen, but now over one-quarter seem to provide useful qualitative forecasts of this currency.

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[32] A further reason for specifying a neutral band is that our panellists make their predictions at different times of the day. If a currency has appreciated by one percent from the time the forecast is made to when we measure the spot rate, a forecast small appreciation will be recorded as a predicted depreciation.

[33] We were unable to perform this test for some forecasters since they consistently predicted a depreciation or appreciation of the dollar. Similarly as the band width increased some forecasters were found to be consistently neutral, which again precluded this form of testing.

Table 11
Directional Forecast Ability

	Max. No.	Width of Neutral Band			Common
		0%	1%	5%	
DEM 3mth	107	3	2	4	0
STG 3mth	93	2	4	7	0
JPY 3mth	107	2	3	11	1
DEM 12mth	89	22	24	24	12
STG 12mth	81	28	30	30	17
JPY 12mth	91	37	37	44	25

NOTES: The figures in the columns headed 0%, 1% and 5% give the number of forecasters for whom a test of $\delta'=0$ is rejected at the five percent level, against the alternative that $\delta'>0$. The tests were computed using GMM standard errors. The final column gives the number of forecasters for whom the null is rejected for all three neutral band widths.

Hartzmark (1991) evaluates the trading record of several commodities futures traders using the Cumby and Modest methodology. Since he has information regarding the number of contracts opened by each trader he assumes that the expected return is positively related to the exposed position. In Hartzmark's analysis, 'big-hit' ability is implied if the trader holds his largest positions when there are the largest favourable price movements. In our situation, where open positions associated with each forecast are not available, in altering the neutral band width we are incorporating information about the magnitude of forecast changes. Specifically, when the band is wide (say five percent) only the periods when a relatively large change in the exchange rate is forecast have an impact in determining δ'. In effect, while still assuming that the probability of a correct forecast depends on the subsequent change in the rate, we determine whether this probability is also related to the forecast rate change. Since we observe that a significant proportion of forecasters exhibit directional forecast ability over the twelve month horizon, and that this proportion increases as the band widens, we conclude that our panellists would appear to have our version of 'big-hit' ability - when predicting large movements a greater proportion of our forecasters display directional forecast ability.

3.4 PORTFOLIO ANALYSIS, RISK AND GEARING

So far we have examined the performance of many individuals' forecasts of individual currencies. However, a forecasters' prediction of one currency is probably not made independently from his contemporaneous prediction of another. In this section we use simple finance theory to produce portfolios based on the forecasts of a sub-sample of our panel, that incorporate the links between currencies. Two alternative methods of computing optimal portfolio holdings based on these forecasts are compared. The first is that used by Bilson (1981) to outline his speculative efficiency hypothesis. Our second method, used by Bilson and Hsieh (1987) amongst others, follows a similar procedure but internalises the gearing of the portfolio whereby the size of the positions established depends on the expected return of each currency. This extension is comparable to the earlier tests of big-hit ability - that is, would our panellists make big profits when they see a potentially favourable situation?

Obviously, in order to construct a portfolio of investments we need our forecasters to have provided predictions for all three currencies over a reasonably long period. To ensure sufficient independent observations to evaluate our panellists we restrict our analysis to the three month forecast horizon and have only included those panellists who responded to at least 35 out of 36 surveys for all three currencies. This results in a reduced panel of 22 forecasters who come from six different countries. Since our comparison is primarily with the performance of the random walk model, any missing values have been replaced with the current spot exchange rate.

3.4.1 PORTFOLIO FORMATION

We shall construct two portfolios for each of our reduced panel members. Both are standard and have been used widely in the literature. The first is designed to minimise the risk (variance of profits) of a portfolio subject to producing a specific and constant expected profit each month. The necessary speculative positions are taken in the forward market analogous to the simple single-currency forward speculation exercise carried out above. Our second portfolio is one that optimises a utility function incorporating both profits and risk. In this case, the gearing (size of the forward positions) in the portfolio is endogenised - a portfolio manager who foresees large profits per unit of exposure to a currency will scale up his positions accordingly. The analogy to the big-hit ability test above should be clear.

The formation of these two portfolios can be demonstrated as follows. The expected profit from the set of speculative positions opened in any period is defined as

$$E(\pi) = q' \bar{r} \tag{45}$$

where q is a column vector whose elements are the dollar value of the forward purchases adopted, and $\bar{r}$ is the vector of expected (dollar) profit per one dollar long forward position in each currency. Short sales of a currency are not restricted. Each element of this latter vector is the difference between the spot rate of a currency forecast to hold at time $t+k$ and the k period forward rate holding at t. Actual profits are then defined as

$$\pi = q' r \tag{46}$$

where r is the actual profit per long dollar forward position (i.e. the difference between the spot rate prevailing at $t+k$ and the time t forward rate).

If we define Ω as the covariance matrix of profits, which will be discussed more fully below, the first portfolio is the solution to the following problem

$$Min\ L = q'\Omega q + \lambda(q' \bar{r} - \tilde{\pi}) \tag{47}$$

In this equation, λ is the Lagrange multiplier which can be interpreted as the marginal increase in variance associated with a marginal increase in the target profit level, $\bar{\pi}$. The solution is then

$$\tilde{q} = \Omega^{-1}\bar{r}[\bar{r}'\Omega^{-1}\bar{r}]^{-1}\bar{\pi} \tag{48}$$

An important implication of this model is that the efficient frontier is a ray through the origin, since equation (48) is clearly homogeneous of degree 1 in nominal magnitudes and an investor can avoid risk (and profit) by not entering the market ($\bar{\pi}$=0). The conclusions we reach are therefore not altered if a different level of target profit is specified. This portfolio specification is explained in some detail in Bilson (1981) and is discussed in Hodrick and Srivastava (1984).

In subsequent papers (Bilson (1984) and Bilson and Hsieh (1987)) Bilson and his collaborators employ a more standard portfolio model where a utility function defined over expected profits and risk (the variance of profits) is maximised. We shall use this as our second, endogenously geared portfolio. The specific utility function is defined as

$$\begin{aligned} U &= E(\pi) - \left(\frac{1}{2\eta}\right)V(\pi) \\ &= q'\bar{r} - \left(\frac{1}{2\eta}\right)q'\Omega q \end{aligned} \tag{49}$$

where η represents the degree of risk tolerance of the portfolio manager. The optimal portfolio that maximises equation (49) is

$$q^{*} = \Omega^{-1}\eta\bar{r} \tag{50}$$

Akin to the target profit level in the previous portfolio, we can see that the positions taken are proportional to the risk tolerance parameter, and hence the precise value of η assumed does not affect our conclusions.

We now turn to the important question of the determination of Ω. In Bilson (1981) and Bilson and Hsieh (1987) the covariance matrix is computed using the forecast errors of the particular model being tested. In our context this is immediately very appealing since it would allow the formation of each panellist's portfolios to depend not only on his forecasts but also his own previous accuracy. Unfortunately, the relative paucity of data restricts our ability to do this whilst leaving sufficient data points to evaluate performance. A more important set of problems is that the computed covariance matrices are clearly not robust. For a given number of m initial forecast errors, the addition of subsequent observations alters the covariance matrix substantially, while increasing m also results in significantly different matrices. This indicates that the covariance matrix of errors is imprecisely measured in such a small sample.

Fortunately, more traditional finance theory provides an alternative. Using an historical data set that predates our sample we construct a covariance matrix of returns to forward investment in each currency. However, in a finite sample with fallible forecasters, using this returns-based matrix is less than ideal since it does not take into account all of the available information. In particular, suppose a forecaster is particularly poor at predicting the yen. Optimisation around a matrix based on historic returns will result in large positions whenever a large move in the yen is forecast, whereas using the matrix of forecast errors would result in a smaller position since his previous inaccuracy forms part of the optimisation. In mitigation, Consensus Economics when requesting the forecasts ask that panellists only supply predictions for those exchange rates they are best able to estimate. On balance, the problems of matrix instability mentioned above appear more important and we shall use a returns-based covariance matrix in formulating the portfolios.

Estimating this matrix is still not without its problems. Currencies floated in the early 1970s but reliable data on forward rates needed to construct the returns series are not available for the yen until the 1980s. However, under the assumption of covered interest parity we can construct the three month forward premium for each currency from the appropriate eurocurrency interest rates that are available for each currency from January 1978. The return at time t is defined as the time $t+3$ spot rate less the time t three month (constructed) forward rate. Once again, the nature of our data means that we have to take account of the overlapping structure of these returns.

In practice, complicated procedures akin to the GMM method designed to use the maximum number of observations add little to our conclusions, because the composition of each portfolio is driven by the forecast returns rather than the covariance structures (see Cumby, Figlewski and Hasbrouk (1991) and Solnik (1993)). Computing the covariances by sampling our data quarterly, using the March-June-September-December rotation, produces a precisely estimated matrix which we use in subsequent work.

The difference between the two portfolios can be demonstrated with a simple two period, two currency example. At time 0 a forecaster predicts that neither the change in the pound nor in the mark over the subsequent period will be much different to the change implied by the forward premium. That is, the expected returns to a unit long position in both currencies will be small. At time 1, however, he predicts large positive returns to a long position in the pound but no profit opportunities in the mark. Using portfolio method 1, positions expected to return a fixed profit level have to be made in both periods. Subject to the correlation between the pound and mark returns, large positions (in absolute terms) will be taken at time 0 in both currencies, whilst at time 1, a small long sterling position will be opened together with zero exposure to the mark. In the endogenously geared portfolio, where no large profit opportunities present themselves (e.g. time 0) only small positions will be taken, but at time 1 a large positive holding of sterling would be established together with a flat mark position.

Though the choice of appropriate benchmark is a perennial problem in evaluating performance (see Roll (1978)), widely known indices such as the FT-SE 100, S&P 500 or the many Morgan Stanley products can be used for equity and bond portfolios. In the currency markets no such index exists, but continuing the reasoning of the earlier part of this chapter, we note two simple comparisons that can be made - first, does the portfolio prove profitable, and second, how does it perform relative to the random walk alternative? Additionally, there is a measure of performance developed by Cornell (1979) that does not rely on a benchmark in the traditional sense, and which has an intuitive appeal given our hypothesis of heterogeneous performance based on differential information interpretation. A 'superior' investor (whether his skill is due to private information or better interpretation of common information) can be defined by his ability to earn higher profits than an uninformed investor would have expected given the portfolio holding. The uninformed investor's expected profit on a unit long position in a currency is defined simply as the unconditional mean profit from forward speculation in that currency, calculated over the same period as the covariance matrix.[34] This mean value is assumed to provide a measure of the required profit from investment in a currency given the risk of so doing, and hence bypasses the need for an explicit model of risk pricing such as the CAPM. If the portfolio weights of an investor are known, which they of course will be since we are computing them, superior forecasting can be tested by following a simple two-step procedure. First, calculate the actual profit of the portfolio, together with the profit an uninformed investor would have expected given these portfolio holdings. Then, defining the excess profit as the former minus the latter, test whether the mean excess profit is significantly greater than zero.[35,36] An alternative motivation for this measure is that it tests for a positive covariance between the profit from an open position in a currency and the share of exposure to that currency in the total portfolio. That is, an superior investor is one who will slant his exposure towards those currencies that offer risk premia in excess of the equilibrium level.

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[34] Copeland and Mayers (1982) argue that a posterior sample should be used to generate the naive expected profits since the forecasters may use prior returns to formulate their expectations, which would systematically bias the inferences made. We cannot use a posterior sample due to the dating of our test period, but do not feel that this is an important problem in our situation since we find that the naive expected profits are very small relative to the actual profits made. This implies that the forecasters do not appear to be using past returns to make their forecasts and so any bias is likely to be small.

[35] Since we use the GMM procedure when performing this test we take into account not only the moving average nature of this series but also the possibility of heteroscedasticity.

[36] If risk premia are time varying it would be appropriate to compute the covariances and uninformed expected returns over a shorter "window". However, given that the excess profits are almost identical to the raw profits (i.e. the uninformed expected profits are very small) this adjustment is of second order importance.

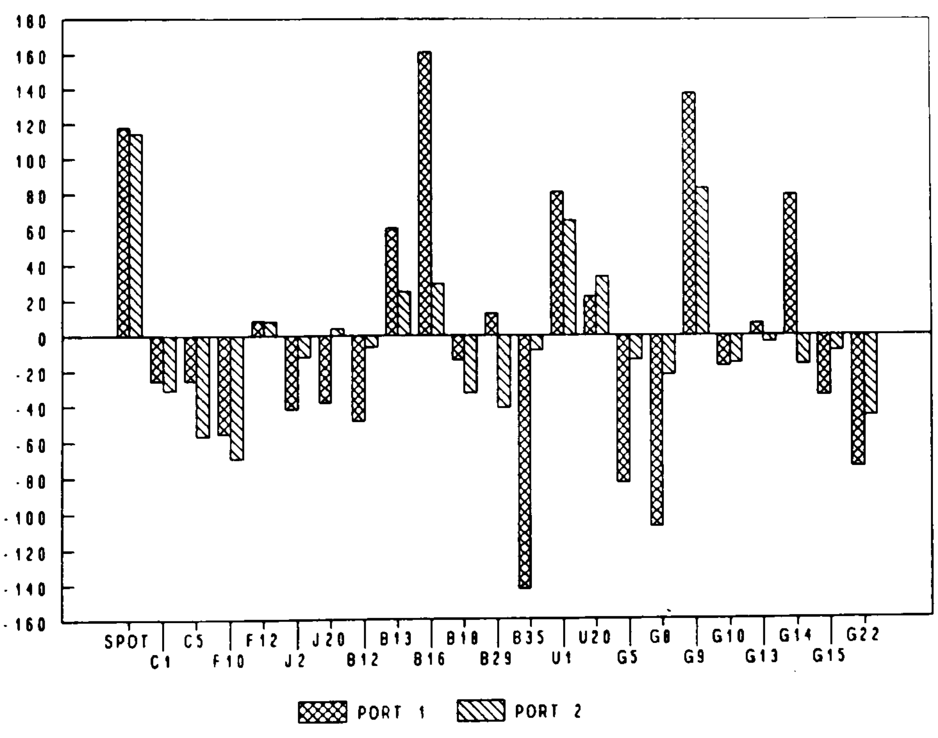
Table 12
Portfolio Performance

	Portfolio 1				Portfolio 2			
	Profit	Signif.	Excess Profit	Signif.	Profit	Signif.	Excess Profit	Signif.
R.W.	118.15	0.229	117.38	0.234	114.19	0.285	110.69	0.289
C1	-25.29	0.476	-25.33	0.479	-30.74	0.358	-28.97	0.383
C5	-25.86	0.669	-44.82	0.467	-56.61	0.176	-66.62	0.112
F10	-55.16	0.247	-59.06	0.208	-69.19	0.021	-69.33	0.020
F12	8.40	0.863	8.59	0.862	7.78	0.760	4.56	0.857
J2	-41.56	0.393	-46.12	0.352	-12.40	0.724	-10.96	0.753
J20	-38.17	0.654	-43.60	0.605	4.09	0.853	1.99	0.926
B12	-48.12	0.329	-50.53	0.320	-6.78	0.757	-6.40	0.759
B13	60.35	0.091	59.85	0.102	24.94	0.085	25.02	0.087
B16	161.05	0.080	146.69	0.110	29.14	0.261	21.34	0.426
B18	-13.75	0.655	-19.90	0.520	-32.70	0.204	-37.43	0.151
B29	12.13	0.706	5.66	0.859	-40.89	0.401	-43.74	0.372
B35	-142.79	0.209	-152.19	0.211	-8.53	0.610	-12.03	0.481
U1	80.88	0.587	61.63	0.673	64.86	0.272	65.63	0.283
U20	22.34	0.481	31.75	0.296	33.47	0.228	39.45	0.172
G5	-83.07	0.111	-75.78	0.146	-14.11	0.438	-10.26	0.590
G8	-107.44	0.042	-118.50	0.030	-22.24	0.277	-25.65	0.205
G9	138.06	0.014	145.62	0.009	83.08	0.004	92.97	0.002
G10	-17.24	0.716	-19.43	0.681	-15.52	0.608	-13.45	0.656
G13	6.36	0.780	1.54	0.945	-4.31	0.834	-6.66	0.743
G14	79.51	0.142	67.05	0.191	-16.57	0.395	-19.00	0.351
G15	-34.62	0.146	-38.47	0.119	-9.16	0.607	-11.79	0.524
G22	-74.46	0.089	-80.85	0.071	-46.06	0.155	-50.95	0.113

NOTES: *See text for details.*

This procedure is performed for our reduced panel of 22 forecasters, using the two portfolio formation techniques. The performance of our forecasters is graphically described in Figure 32. To aid comparison, the average expected profits for each forecaster have been set equal to \$100 from both portfolios. That is, the target profit level $\bar{\pi}$ is set to \$100 in portfolio 1, and the risk aversion parameter η is adjusted such that the average *ex ante* expected profit $q'\bar{r}$ is \$100 in portfolio 2 (remember that these portfolios are linear in such nominal magnitudes because of the absence of restrictions on short-selling currencies, and so these assumptions do not affect the conclusions made). The profits of the random walk model, where the implied forecasts are the current spot rate, are also shown. In Table 12 we report the average actual and excess profits of each forecaster using both of our portfolio formation techniques, together with the associated marginal significance levels computed using GMM.

Figure 32 Average portfolio profits



From results reported earlier in this chapter we can see that the majority of our sub-group of 22 forecasters are unprofitable to follow when individual currencies are being considered.[37] A significant number (F12, B12, B13, B16, B35, U1, U20 and G9) however prove to be profitable to follow for at least two of the three currencies. Looking at Table 12 we see that the portfolios based on the predictions of these forecasters are mostly profitable, though to vastly different degrees and with notable exceptions. Furthermore, other forecasters with less impressive single currency records can also produce profitable portfolios (i.e. J20, B29, G13 and G14).

Considering the full group of 22, two forecasters actually do better than they expected (i.e. average profits of more than $100), but the majority underperform their expectations. For both portfolios, slightly fewer than one-half return positive average profits, and very few produce profits that are statistically greater than zero at any reasonable level of confidence.

There is frequently a marked disparity between the profits produced by the two different portfolio formation techniques, including instances of one portfolio producing a profit and the other a loss. This reflects the introduction of endogenous gearing in portfolio 2. For the majority of profitable forecasters fully endogenising the size of positions taken reduces the size of average profits, leaving only two forecasters (B13 and G9) with significantly positive average profits at the 10% level.

The portfolios based on the spot exchange rate are a noticeable counter-example, producing average profits slightly in excess of *ex ante* expectations irrespective of portfolio formation technique. Only two forecasters produce greater profits than this random walk model, and then only using the first portfolio method. It would appear that the random walk model is still a relatively powerful alternative even in a multicurrency context. However, despite their large magnitude, profits from the random walk are not statistically significant; the p-values are 0.229 and 0.285 from the respective portfolios.

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[37] Remember that the simple profitability measures reported above explicitly exclude missing forecasts whereas we now assume a no change forecast when predictions are missing.

Whilst we are examining a smaller proportion of our total database the results based on the portfolio 2 profits complement the big-hit ability results of section 3.3. In effect, the single currency Cumby and Modest directional ability test examines whether a forecaster correctly predicts the direction of large movements, and big-hit ability requires that the likelihood of this increases when he predicts a large change (a slightly weaker condition than rationality). The portfolio 2 profit measure tests whether a big change in a currency in the correct direction occurs when the forecaster predicts a large move. Both sets of results indicate that the majority of forecasters display no directional forecast ability over the three month horizon.

For almost all forecasters the excess profit series (defined as profits over and above those that an 'uninformed' investor would have expected from a simple extrapolation into the future on the basis of historic exchange rate performances) are only slightly different to the raw series, as can be seen by the similarity between the two pairs of Profit and Excess Profit columns in Table 12. This finding indicates that the uninformed investor's expectation of the profits accruing from the portfolios is small,[38] and therefore that the profits (and losses) made are primarily due to the forecasting (in)ability of the panellists. They are not merely taking long positions in a currency that has historically appreciated, and as such would be expected to yield a profit by an uninformed investor, but are actively switching positions between currencies. However, the significance of the excess profit series are also disappointingly low. Only the portfolios based on the forecasts of B13 and G9 produce excess profits that approach meaningfully high levels of significance.

Our results indicate that whilst some of these forecasters were on average profitable to follow, their forecasts implied very volatile portfolio holdings which in turn led to large variances in profits. These variances were sufficiently large to make average profits statistically indistinguishable from zero. However, for portfolio 2 where expected (let alone actual) profits are volatile it could be argued that the significance of average profits is not a valid test of ability. For example, suppose a

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38 In fact, the naive expected profits of some portfolios are negative (excess profit greater than profits).

forecaster who has perfect forecasting ability produces profits of $10 for 35 periods and a profit of $3,250 in just one period. His average profit is $100, his average expected profit is $100, he never makes a loss and yet statistically we cannot say his average profit exceeds zero.

Bilson (1984) and Bilson and Hsieh (1987) argue that a more appropriate test is whether the cumulative total profit is significantly positive. From equation (49) the variance of the profit in any one period, σ_t, is defined as $q'\Omega q$ and some elementary algebra shows that this is equivalent to $E(\pi)\eta$. Assuming that the actual profit at time t is drawn from a normal distribution with the appropriate variance, the null hypothesis that the sum of profits is zero can then be tested by computing

$$Z = \frac{\sum_{t=1}^{T} \pi_t}{\sqrt{\sum_{t=1}^{T} \sigma_t^2}} \tag{51}$$

which has a t-distribution with T-1 degrees of freedom.

However, Bilson and Hsieh (1987) find that this measure substantially underestimates the actual variance of profits earned by their forecasting model, and pose an alternative specification whereby the variance depends not only on the level of expected profits but also on expected profits squared, as intuition would suggest. We follow their suggestion and estimate the following regression

$$Var(\pi)_t = (\pi - E(\pi))_t^2 = \alpha + (\beta + \eta)E(\pi)_t + \gamma E(\pi)_t^2 \tag{52}$$

The null hypothesis is that the empirical variance equals the theoretical variance, which would imply that $\alpha=\beta=\gamma=0$. If this is not rejected we infer that the theoretical variance is the true variance. In fact, for four of the seven profitable forecasters we find that the null hypothesis is strongly rejected. We therefore take the fitted values of equation (52) as an alternative, empirical estimate of the variance of the portfolio for each forecaster and re-test the null of zero cumulated profits.

This full procedure is carried out for the seven forecasters who return positive cumulated profits together with the random walk, using both estimates of the portfolio variance where appropriate. The *t*-statistics and associated marginal significance levels results are reported in Table 13.

Table 13
Significance Of Cumulated Profits

		Portfolio Variance			
		Theoretical		Empirical	
Forecaster	Sum profits	*t*-stat.	Signif.	*t*-stat.	Signif.
R.W.	4,110	2.339	0.025	NA	NA
F12	280	0.502	0.619	NA	NA
J20	147	0.220	0.827	0.128	0.899
B13	897	1.602	0.118	0.930	0.359
B16	1,049	1.262	0.215	NA	NA
U1	2,335	2.118	0.041	1.320	0.195
U20	1,205	1.563	0.127	NA	NA
G9	2,989	3.425	0.002	2.634	0.012

NOTES: See text for details. NA entries in the empirical variance columns imply that the theoretical variance cannot be rejected as the true measure.

Using this more appropriate test of forecast ability we see that two of our forecasters (U1 and G9) and the random walk model produce significantly positive cumulated profits when theoretical variances are maintained, but that the theoretical variance measure is rejected for U1, whose cumulated profits are no longer significant under the alternative model. These results suggest that only one of our original 22 forecasters has any significant forecasting ability, and that the random walk is a strong competitor, returning higher though more volatile profits.

3.5 SUMMARY AND CONCLUSIONS

The received wisdom on exchange rate forecasting is that economists' models cannot outperform a random walk out of sample, except over relatively long horizons (one year or more). A popular excuse for this failure is the fact that the foreign exchange market comprises a large number of people, some of whom may be acting irrationally. The bulk of this group are commonly thought of as technical analysts or chartists who pay no attention to economic fundamentals. Their influence may at times be large enough to drive the exchange rate away from its fundamental level and may in turn account for the failure of economic models. Another group of possibly irrational participants, smaller in number but arguably more influential, is the club of central bankers. These people are trading not necessarily to make profits (though many do make substantial currency gains) but to manage the exchange rate as part of government policy. Intervention at crucial times may help account for forecasting failure, particularly if central banks are leaning against the wind of a fundamentally justified change in the exchange rate. A further reason may be that economic models do not account for all possible fundamentals. Academics may find it difficult to incorporate some factors into their models which practitioners see as important, particularly if these influences might be termed fads. Since, by the very definition of a fad, the effect of a certain variable on the exchange rate is only felt over a relatively short period of time, estimating constant parameter regressions over a long data set will fail to find significant effects from this variable. Econometricians will exclude such variables due to lack of full sample significance, and an important factor in determining exchange rate movements is lost to the final model.

The use of practitioners' forecasts should help to avoid all of these problems. Since the survey respondents are close to the market they can be expected to incorporate into their forecasts the expected actions of central bankers, the predictions of chartists, and any fundamental, political or even astrological variables to which the market appears to be responding. If these influences are important practitioner forecasts should be more accurate than those from academic models and may be more accurate than a random walk.

Over the short horizon while the former may be true, the latter is not. The RMSE ratios derived from Meese and Rogoff's results indicate that their pound sterling and yen models perform poorly relative to our panellists. However, it is difficult to get excited when only eleven out of over three hundred forecaster/currency combinations are more accurate than a random walk. In line with prior expectations the performance of our panellists over twelve month forecast horizons is much better, in that a large proportion are significantly more accurate than the naive alternative.

In an attempt to rescue their inaccurate models economists have justifiably argued that accuracy may not be the most appropriate test criterion. If the predictions are used as the basis for speculative positions, some form of profitability measure is important. We examined the profitability of our panellists' forecasts in two ways. A simple switching model shows that profits in excess of those earned from a random walk model are possible even over three months, though finding significant returns proves difficult. We interpret the relatively low correlation between profit and accuracy measures as indicating that some element of risk needs to be brought into the assessment. Since risk and forecast error are closely related concepts we feel that our results indicate that both are important in evaluating asset price forecasts.

To incorporate both risk and the relationship between contemporaneous predictions made by the same forecaster, we also investigated the performance of portfolios of speculative positions. Although over a reduced panel the results are consistent with earlier findings - only one forecaster showed any significant forecasting ability. Throughout the chapter we have used the performance of a random walk as a benchmark. Our portfolio analysis allows us to note that it a very competitive model, capable of returning significant cumulated profits. The use of a no change prediction as an alternative model would appear to be a testing criterion.

Thus, we have not been able to overturn the conventional wisdom based on the analysis of the predictions of professional forecasters. It seems that with very few exceptions even those closely associated with the market are unable to dominate the performance of a random walk over short forecast horizons. Over twelve months good performance is frequently observed but the limited number of independent observations in our panel rendered a complete analysis impossible.

CHAPTER 3 - APPENDIX

ERM CREDIBILITY RE-EXAMINED: EXPECTATIONS FROM AROUND THE WORLD

3A.1 INTRODUCTION

So far in this thesis we have concentrated our attention on the forecasts of the pound, mark and yen against the US dollar because of the relatively poor response rates seen for the other two main currencies in our panel, the French franc and the Italian lira. In this appendix, however, we shall use cross-sectional evidence from our survey panellists to examine the experiences of the pound, franc and lira within the Exchange Rate Mechanism of the European Monetary System. Specifically, we shall be examining the question of whether our panel of forecasters predicted the partial breakdown of the ERM in September 1992. In the UK, the events were termed either Black or Golden Wednesday, depending on the viewpoint of the writer. We shall maintain the former though no inferences on the degree of europhobia exhibited by this author should be made.

The seminal work on target zones is Krugman (1991), and this and other important (largely theoretical) papers are gathered in Krugman and Miller (1992). Though the theory has advanced dramatically since the basic models were produced, empirical support for models of a credible target zone is practically non-existent. The most damning applied paper is probably Flood, Rose and Mathieson (1990) which demonstrates that most of the empirical regularities expected to appear in a credible target zone simply do not hold for even the most credible of currency links.

The applied literature has turned away from testing the predictions of these models and instead is working on the presumption that the zones may not in fact be fully credible. Bertola and Svensson (1990) detail a method of extracting the expected mean reversion of a currency in a target zone, which when subtracted from the expected total change in the exchange rate gives the expected realignment of that currency. The expected total change in the exchange rate is typically assumed to be given by the interest differential, under an assumption of uncovered interest rate parity. Several papers have used the Bertola and Svensson (1990) or related methods to examine the credibility of ERM exchange rates, including Rose and Svensson (1991), Weber (1992) and Rose (1993). The latter paper is of particular ineterest since it concentrates on the experience of sterling in the run-up to Black Wednesday. Using daily interest rate data, Rose shows that there was little evidence that the UK government's exchange rate policy was lacking in credibility until mid-September, just a matter of days before the pound was ejected from the Mechanism. In this appendix we examine whether a more direct measure of credibility based on our survey data confirms this hypothesis. We also consider the experience of two other currencies, one of which also devalued and one of which retained its parity, at least for another nine months.

3A.2 THE SURVEY DATA

Using each panellist's forecasts of the pound, mark, franc and lira against the dollar we were able to construct the implied cross rate forecasts of the British, French and Italian currencies against the mark. This procedure was carried out regardless of the number of predictions each panellist made - if a forecast of the Deutsche mark and another European exchange rate has been made in any period by any forecaster, a cross rate forecast is produced. The procedure results in an average of around 90 forecasts each month for the pound-mark exchange rate, of which around one-third are from continental European forecasters (ie French, German or Italian-based institutions). A lower response rate occurs for the franc and lira due in particular to a lack of predictions for these currencies from Japanese and Canadian forecasters.[39]

Our measure of devaluation expectations in each month is simply the percentage of total respondents whose cross rate forecasts lie below the ERM lower

[39] For the franc, around 65 forecasts per month are prodcued (35 from continental forecasters) and around 45 for the lira, the majority of which are from the continent.

limit of the relevant currency. A rise in this measure indicates that a higher proportion of forecasters predict that the spot exchange rate prevailing in three months will lie below the current limit - ie a higher proportion predict a devaluation.[40] This methodology is more akin to the "simplest test of target zone credibility" of Svensson (1990), that asserts that if the forward rate for a currency lies outside the target zone then the zone is not fully credible over the corresponding time horizon.

More sophisticated measures have been proposed that correct for the expected mean reversion of a currency in a target zone. This is said to be necessary since the total expected change in the exchange rate is composed of the sum of the expected change of the band (the devaluation part) and the expected change within the band (the mean reverting part). If a currency lies on the weak edge of the band, absent any devaluation it will be expected to appreciate (or at worst remain where it is if there is no expected element of mean reversion). Thus for a weak currency, the expected devaluation will be higher than (or equal to) the total expected change. We have no way of decomposing the total expected change in the exchange rate forecast by our panelists and feel that it is inappropriate to impose the constraint that all participants have the same expectations of the degree of mean reversion as is implied by the existing methods of econometric decomposition. Thus by ignoring this adjustment, we must note that our measure of credibility is a rather conservative one. Even so, can it still offer insights into the behaviour of the ERM?

3A.3 STERLING DEVALUATION EXPECTATIONS

Our measure of devaluation expectations for the pound sterling is plotted in Figure 33 From sterling's accession to the ERM in October 1990 to the summer of 1992, this metric fluctuated in a range between zero and ten percent. In both the May and June 1992 surveys, none of the respondents predicted a spot rate below the

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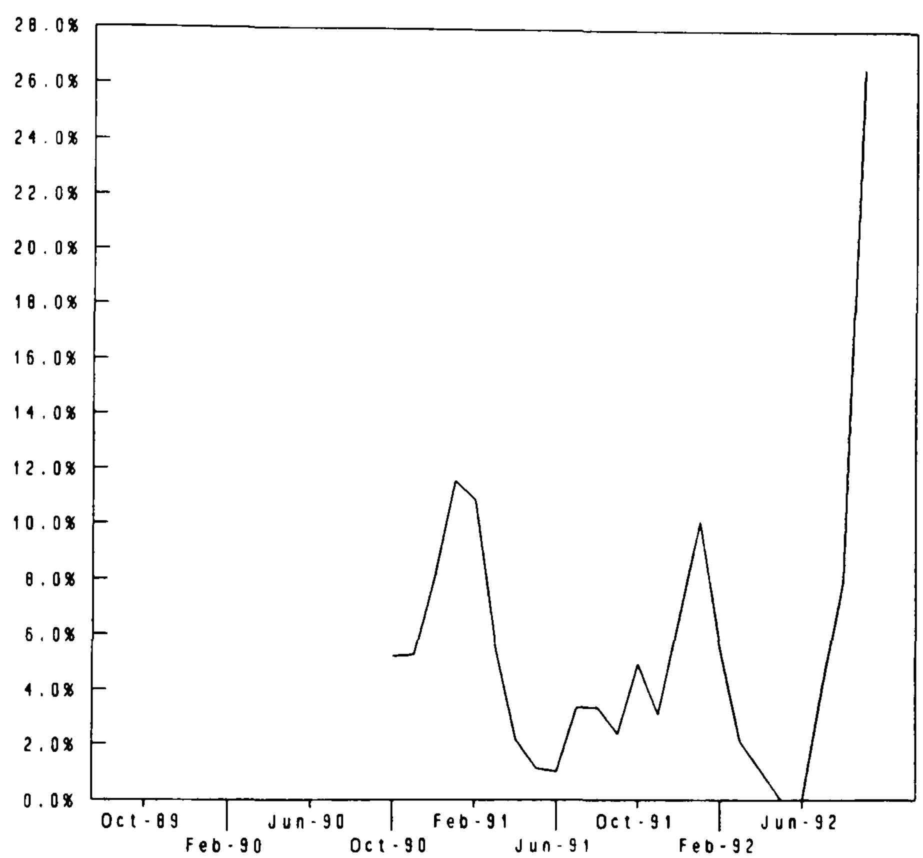
[40] It could be that because of rounding errors, an implied cross rate lies marginally below the ERM floor. Recalculating our measure of devaluation expectations with these marginal cases excluded made no difference to our conclusions.

prevailing ERM floor - the System was seen as fully credible.[41] This is consistent with the results of Rose (1993), who also noted low levels of realignment expectations in June. From this point on credibility declined somewhat, and of the 88 respondents to the August 3rd survey, about eight percent predicted a devaluation. However, this is below the two previous peak levels, neither of which seriously threatened to force sterling out of the ERM.

Figure 33 Devaluation expectations - pound sterling

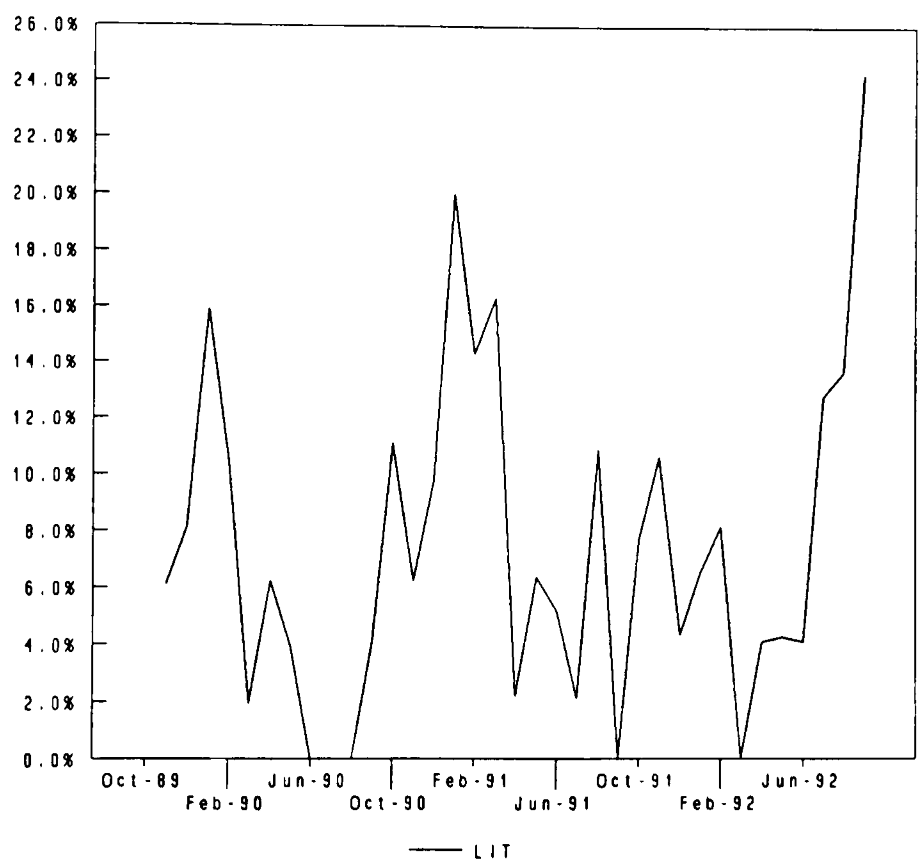


The September survey was conducted on the 7th, nine days before Black Wednesday, when the prevailing spot rate was DM2.80. By now the warning signal had strengthened. More than one-quarter of respondents (26.7%) predicted a

[41] Strictly speaking, for the band to be fully credible the full distribution of the expected future spot rate must lie within the band for every forecaster. However, the panellists provide only point forecasts. In making our statement we are assuming that the variance of each forecast is zero.

devaluation - over twice the level of the previous high. The most extreme forecast (from an American institution) was for a drop in the cross rate to DM2.66. This turned out to be a remarkably accurate prediction of the immediate fall in sterling, which was quoted at noon in London on Thursday, September 17th at DM2.6592, but less reliable as a three-month forecast since sterling had fallen to DM2.48 by December 7th. All other forecasters vastly underpredicted the actual three-month decline in the value of the pound.

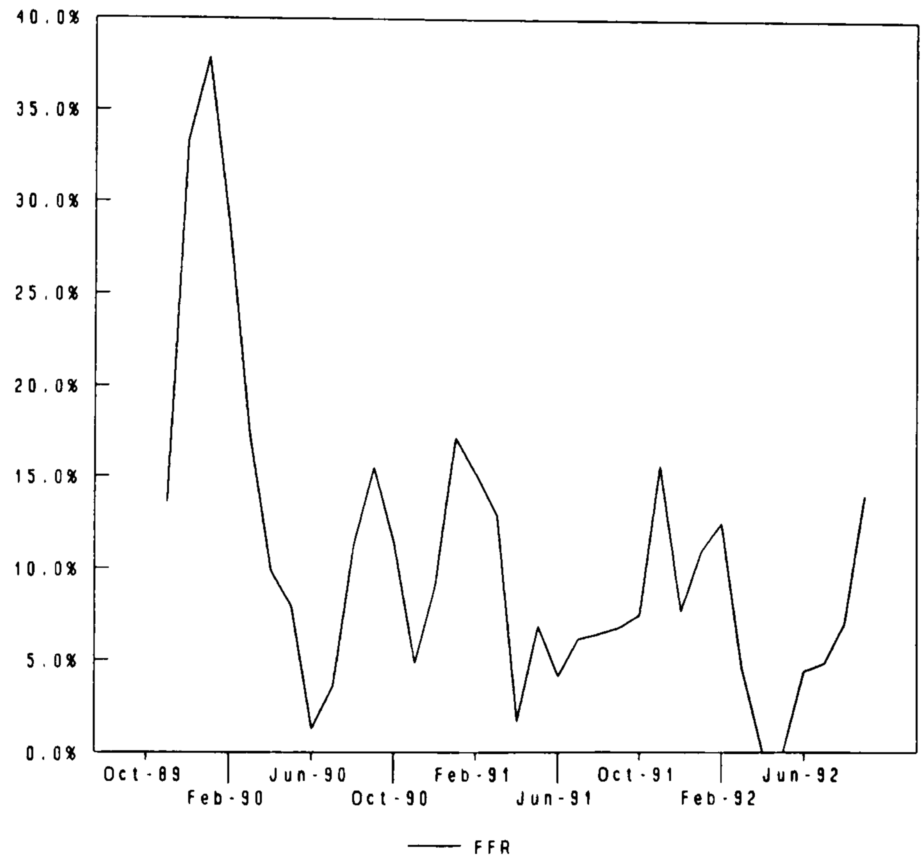
Figure 34 Devaluation expectations - Italian lira



3A.4 EVIDENCE FROM OTHER ERM COUNTRIES

Figures 34 and 35 show the devaluation expectations associated with the Italian lira and French franc. The pattern for the lira is very similar to that of the pound. Devaluation expectations had peaked in January 1991 before falling to very low levels in the summer of 1992. In July and August, the proportion of forecasters predicting a devaluation was above average but still below previous peaks, and only in the September forecast was a new high of almost 25% reached. The most extreme forecast for the lira came this time from a British institution and was for a fall to Lit822 from the then current level of Lit763. Again this was a good prediction of the initial drop as the lira was quoted at Lit816 on 16th September, but underestimated the actual three-month fall quite substantially.

Figure 35 Devaluation expectations - French franc



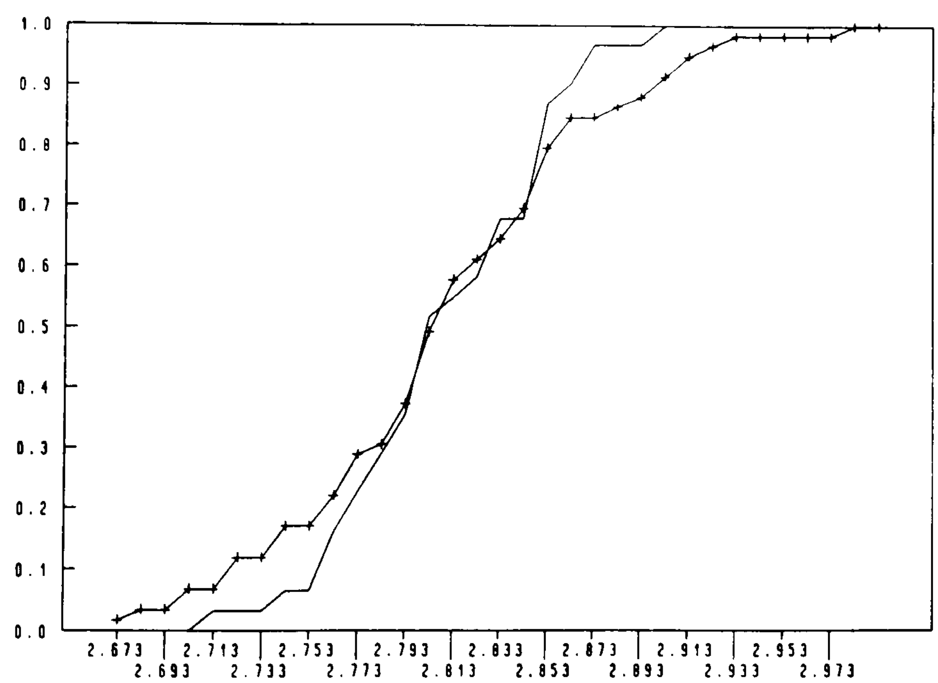
The franc is the odd-man-out in this triumvirate since it did not devalue in this speculative attack. Our survey-based method of assessing credibility also appears to have correctly forecast this turn of events. While devaluation expectations were climbing from summer lows, the proportion predicting a franc devaluation in the September survey was still only fourteen percent, lower than most previous peaks and well below levels seen and weathered at the end of 1989.

3A.5 NATIONAL BIAS AND THE ANGLO-SAXON PLOT HYPOTHESIS

Fuelled by the statements of various politicians, rumours that market participants in the United States and United Kingdom were manipulating the currency markets have circulated since Black Wednesday. Somewhat more believably, it could also be argued that greater scepticism about the merits of a fixed exchange rate system may have led North American, Japanese and UK observers to have more pessimistic expectations about the stability of the ERM.

The disaggregate nature of our database allows us to examine differences in the forecasts of panellists from different countries, which we term 'national bias'. Specifically, we investigate whether the non-continental forecasters were more inclined to predict devaluations of the three main European exchange rates than their continental-based counterparts.

Figure 36 Cumulative distribution of sterling forecasts



Two cumulative distribution functions of September forecasts of the pound are presented in Figure 36. We have split the panel into two groups, one representing continental-based forecasters and another the 'Anglo-Saxons' (the UK and US forecasters plus the few Japanese and Canadian forecasters who provided cross-rate forecasts). The tail of this curve to the left of the ERM floor (DM2.7730) is indeed larger for the Anglo-Saxons, but not by much. Furthermore, the right hand tail - those expecting the pound to move back towards the centre of the band - is also larger for the non-continental group of forecasters.

Using the Kolmogorov-Smirnov two-sample procedure we can test the null hypothesis that the two series are samples from the same distribution function. The Kolmogorov-Smirnov statistic measures the maximum vertical distance between these two distributions and compares this to a critical value (see Daniel (1990)). The results of applying this test to the three currencies for the months of August and September 1992 are given in Table 14.

Table 14
Kolmogorov-Smirnov Two Tail, Two Sample Tests

	STG-DEM	LIT-DEM	FFR-DEM
August 1992	0.089	0.233	0.181
	(0.304)	(0.421)	(0.363)
September 1992	0.139	0.228	0.226
	(0.302)	(0.468)	(0.363)

Notes: The figures in parentheses are the 5% critical values which depend on the two sample sizes.

It is clear that we cannot reject the hypothesis that the continental and Anglo-Saxon forecasts were drawn from the same distribution for any currency in either month.[42] Other groupings of forecasters were also examined but no evidence of distribution biases could be unearthed.

[42] We also computed the Cramer-Von Mises test for identical populations which gave similar results and so are not reported.

3A.6 CONCLUSIONS

The concept behind the analysis in this appendix is different to that of the rest of chapter 3. In the main body of the chapter, an individual's set of forecasts has been evaluated, and though we have noted the likelihood of a relationship between both an individual's forecasts of a range of currencies, and between the forecasts (or more likely the errors) of a range of individuals at the same point in time, this is the first time that the cross-sectional information contained in our data set has been utilised.

It is encouraging, therefore, to note that our analysis of an international disaggregated database of exchange rate forecasts has confirmed the results of Rose (1993). Neither interest rate movements (Rose's study) nor survey responses (this appendix) gave any indication of an impending crisis for the pound or lira in the months before Black Wednesday. When they finally came, however, the survey-based signals of impending devaluations for these two currencies were stronger than had been given before. At the same time, no real alarms were sounded for the French franc, which was successfully defended from this attack.

We found no significant evidence of differences in the distribution of expectations across groups of forecasters during the crisis. The hypothesis, repeated widely in the press, that US and UK financiers were conspiring to cause the collapse of the EMS and hence EMU therefore finds no support from our data.

CHAPTER 4

METHODS OF FORECAST COMBINATION - ARE 'N' HEADS BETTER THAN ONE?

4.1 INTRODUCTION

Chapters 2 and 3 of this thesis have established that our panel members, and therefore we would argue, foreign exchange market participants in general, hold heterogeneous beliefs of the future value of exchange rates. These differences of opinion are caused, at least in part, by different interpretations of potentially important information, such as the forward premium. Furthermore, Bates and Granger (1969) note that the complexity of the economic system means that different forecasters will, in general, employ different information. While it would be best to combine this information and produce a forecast based upon this wider pool of knowledge, in practice only the forecasts themselves are available. The second best solution is then to combine these forecasts, and in this chapter we use a variety of methods to try to improve upon the performance of the individuals. We shall judge performance by RMSE accuracy. Although we noted in chapter 3 that there are reasons why other metrics may be preferable, we persist with an accuracy criterion because it is (i) very simple, (ii) commonly used in the literature and (iii) probably the toughest test.

4.2 IS THERE AN OPTIMAL WAY OF COMBINING FORECASTS?

One of the first papers to consider methods of pooling the raw information embedded within forecasts to provide better predictions is Bates and Granger (1969). Research in the early 1960's notes the strong performance of averages of forecasts, and Bates and Granger extend this idea by weighting the forecasts in various ways dependent on the quality of predictions in recent periods. The weights are restricted to sum to one, under the assumption that the forecasts are unbiased.

Newbold and Granger (1974) take up this theme empirically, and demonstrate that the in-sample (RMSE) performance of a weighted average forecast can indeed be superior to both individual forecasts and the simple average. In contrast, however, later studies have found little advantage from sophisticated combination methods over simple averaging of forecasts.[43]

In his third major contribution to this area, Granger, with Ramanathan, (1984) demonstrates how to analyze forecast combinations in a regression format.[44] Bates and Granger's earlier work, with presupposed unbiased forecasts, is seen to be equivalent to a linear regression of the actual variable on a set of forecasts with no constant under the constraint that coefficients sum to unity. However, this is an inefficient combination, because, as Granger and Ramanathan prove, when forecast errors are stationary and the covariance matrix is constant, optimal weights can be retrieved from an unrestricted regression with a constant included, even if forecasts are biased. By construction, this optimal combination will perform at least as well, in terms of accuracy, as the simple average within sample.

Holden and Peel (1989) make a further major contribution to the theory of forecast combination. They show that the Granger-Ramanathan method of unconstrained regression with a constant term implicitly includes the unconditional mean of the dependent variable as an additional forecast, as well as correcting for bias. Though for a stationary series the mean is an unbiased forecast, it is also typically a poor one. Hence Holden and Peel propose that a restricted regression should be run whereby the sum of the weights is constrained to equal unity. The constant in this restricted regression then only removes the mean error bias in the individual forecasts and does not include the mean as an extra forecast.

Empirical work has, however, cast doubt on the practical use of regression-based methods out-of-sample, when it cannot necessarily be assumed that the structure of forecast errors and the covariance matrix are invariant (see, for example, Figlewski and Urich (1983) and Winkler (1984)). The most often cited reasons for

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[43] See, for example, Makridakis and Hibon (1979).

[44] This is not a totally innovative idea as it had been suggested as early as 1967 in the work of Crane and Crotty, and revived by Reinmuth and Guerts (1979).

this breakdown are the actions of forecasters themselves. The performance of individual forecasters often determines their continued employment,[45] theoretical developments lead to major changes in the equations underlying the macroeconometric models of the economy,[46] and when a substantial amount of judgment is incorporated in a forecast there is no reason to suppose that optimal weights will remain constant through time. A variety of alternative methods for dealing with potentially changing correlations are discussed and evaluated in section 4.5.

4.3 EXCHANGE RATE FORECASTS

Our results in chapters 2 and 3 support the generally accepted conclusion that in the short run the majority of individual forecasters have little to add to a naive prediction of no change. Only over the longer horizon do our panellists appear to have a forecasting advantage. However, we have demonstrated that even over the three month horizon the performance of our forecasters is not randomly distributed - some are systematically more accurate than others. This may be related to the demonstrated differences in interpretation of common information, but the notably superior performance of the minority may also be due to them having access to superior private information (or information processing/forecasting techniques). In the rest of the chapter we empirically investigate whether combining forecasts allows us to extract the skills and private information of the individuals, and use them to create better forecasts.

Researchers have in the past examined the performance of exchange rate forecast combinations but with little success. The original Meese and Rogoff study (1983) reports that constrained combinations of the forecasts from all their models

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[45] Cyriax (1978) points out that over 70 organisations make macroeconomic forecasts in the UK alone, and while it needs few qualifications to provide such predictions, competition from the large organisations whose forecasts are widely reported in the press should force the correction of biases through time (see Webb (1984)).

[46] See, for example, Ball, Burns and Warburton (1979) for a history of the changes made to the London Business School model.

(weights forced to sum to unity) fail to improve performance. Pairwise constrained combinations beat a random walk over a one month horizon, but no one pair could do so for more than one of the four exchange rate considered. Guerard (1989) combines a time series forecast, the forecast from a single US bank and the forward rate using a ridge regression technique but finds the forward rate itself very hard to beat. Blake, Beenstock and Brasse (1986) investigate the performance of three British, economics-based forecasters but are unable to reject the hypothesis of unbiasedness in both the individual forecast series and in an optimally combined series.

4.4 DISAGGREGATED INTERNATIONAL FORECASTS

To date, researchers have not systematically examined the performance of individuals who speculate in the foreign exchange market. We cannot, unfortunately, correct for this deficiency here, as market participants are, not surprisingly, reluctant to reveal their trading record.[47] What we can offer is an analysis of predictions made by the traders and economists in banks, financial houses and corporations from around the world, gathered in our panel. These predictions differ from the forecasts examined elsewhere in the literature since our data consist of the survey respondents' subjective and potentially time-varying combinations of fundamentals-based forecasts, chartist predictions and other considerations.[48] Given the impressive record of technical forecasters noted above, there is obvious appeal to using forecasts that incorporate both economic and technical inputs. Many participants in the foreign exchange market see the influence of central banks as growing (despite their widespread failure on Black Wednesday) and economists are finding that, contrary to conventional wisdom, sterilised intervention can affect currency movements in the

[47] Hartzmark (1991) analyzes daily futures positions of large volume traders in a variety of US exchanges using non-parametric techniques. He finds that returns to futures traders are randomly generated. However, he does not have any data on currency futures trades.

[48] In fact Goodman (1979) neglects to analyze the performance of thirteen of his total sample of 23 forecasting agencies on the grounds that they combine both econometric and technical methods in making their forecasts.

medium term (see, for example, Catte, Galli and Rebecchini (1992) and Dominguez and Frankel (1993)). The actions of central banks in carrying out government policy is another important factor that our forecasters can incorporate. A further advantage of our global data set is that whilst most previous studies have concentrated on forecasters from one country, typically the United Kingdom or the US, a primary reason for combining forecasts is to capture a wider set of information. Focusing on a single country (or even worse, a single financial centre), where traders have largely common information sources, will limit potential gains.

For this chapter we only study the three month forecasts to ensure that sufficient independent observations are used to evaluate our combinations. We have only included those panel members that responded to at least 35 out of 36 surveys for a currency. We have also excluded specialist forecasting companies whose responses are likely to be model determined and not a mix of a variety of inputs. This has left us with 31 forecasters for the mark-dollar, 25 for the dollar-sterling and 29 for the yen-dollar exchange rates. 22 of these are common to all three currencies.

4.5 THE PERFORMANCE OF FORECAST COMBINATIONS

We have noted that ideally we would like to pool the information sets on which the forecasts are conditioned. As this data is clearly not available, the next best method is to combine the forecasts themselves. In order to evaluate these composite forecasts we note that within sample, unconstrained combinations of forecasts must match or outperform the components in terms of accuracy (though not necessarily profitability). The only true test of performance is an out-of-sample comparison.

4.5.1 GRANGER AND RAMANATHAN UNCONSTRAINED REGRESSION METHOD

We shall start with the simple Granger-Ramanathan method to optimally combine the forecasts, whereby the following regression is run

$$\Delta s_{t+k} = \alpha + \Sigma\beta_i \Delta s^e_{it+k} \quad , i = 1, \ldots, m \tag{53}$$

That is, the actual change in the (log) spot exchange rate is regressed on a constant and a set of *m* forecast changes. Due to the substantial location and scale biases[49] in these forecasts noted in chapter 2, no constraints are imposed on equation (53). Running this regression to combine a number of forecasts will often result in negative weights on some of the components. This is not necessarily a comment on the forecaster's ability but, rather, indicates the way the predictions should be combined given the correlations between forecasts. This same situation occurs in constructing stock portfolios - some stocks are held whilst others are shorted so as to minimise the variance of expected returns, even though all stocks may be expected to appreciate. It should be noted that running equation (53) with just one forecast is equivalent to unbiasing that forecast. We have a total of 36 observations available, 12 of which are saved for the out-of-sample tests. Our in-sample period, then, is October 1989 to September 1991, while our test period is October '91 through September '92. However, a researcher looking to combine forecasts for October, the first of our test months, would only have outcome errors for the months up to July.[50] This leaves 22 in-sample observations with which to construct the weights. For each currency we have at least 25 forecasters - a severe shortage of degrees of freedom. We choose to split our forecasters into sub-groups to overcome this problem. For example, for

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[49] A location bias indicates a constant non-zero mean error ($\alpha \neq 0$), whilst a scale bias occurs when a forecaster systematically under- or overpredicts ($\beta \neq 1$).

[50] It is in fact possible that June's forecast error is the latest available as the July forecast day may be later than the day on which the October predictions are made (see MacDonald (1992) for more detail). In practice we ignore this point as the overlap is only of the order of a couple of days.

forecasts of the mark exchange rate we formed three groups consisting of 11 German, 12 other European and 8 Other (Canadian, Japanese and US) forecasters.

We note that in seeking to pool information, grouping homogeneous forecasters will not yield maximum benefits. Indeed Holden, Peel and Thompson (1990) conclude that optimal combination methods work better when forecasters are more heterogeneous. While we have found evidence of heterogeneity within countries in chapter 2, combining forecasters from the same nation or continent is unlikely to maximise the informational disparities that we hypothesise to be a possible cause of differential performance. We address this problem in two ways. First, we split our core group of 22 into two equal sized sub-groups that contain at least one forecaster from each country (except Italy, where no individual panellist predicted sterling regularly enough to enter the reduced sample).[51] We also combine the forecasts of the best five forecasters (in terms of in-sample RMSE) for each currency. (Details of the groups are given in the appendix.)

From equation (53) we retrieve the optimal weights attached to each forecast and use them to construct a set of out-of-sample 'optimal' forecasts. Three 'optimal' forecasts for each grouping of forecasters were constructed. In the first instance, the initial in-sample weights are taken as fixed throughout the out-of-sample period. We also compute weights that are updated as new information about the performance of our forecasters is received, using the full set of historical information. Finally, following Diebold and Pauly (1987), we update the weights using only the last T^* observations in a rolling regression, in an attempt to lessen the effect of any shifts in the structure of the forecast errors or covariance matrix. We use the most recent 22 observations to ensure well defined correlations and for comparability with the simple fixed-weights method.[52]

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[51] The core group is made up of two forecasters from each of Canada, France, Japan and the United States (the first of each being placed in sub-group I), together with six British and eight German forecasters (the first, third, fifth and, where appropriate, seventh being placed in sub-group I). The remaining panellists form sub-group II.

[52] Smaller values for T^* typically result in very large error statistics as the correlation matrix becomes less well defined.

As their name would suggest, Consensus Economics, the source of our data, also produce a consensus measure of the forecasts. We follow their practice, computing a simple mean of our restricted data set, a averages of each of our smaller sub-groups.

The results from these computations, given in Table 15, are striking. For two of the three currencies, no combination method results in a lower RMSE than the random walk alternative. For the pound sterling, four of the six groups produce lower error statistics, but only one grouping - the Best 5 - does so across a range of combination methods.

The second notable factor of these results is the impressive relative performance of simple averages of our groupings. In all but three of the eighteen cases, taking the mean forecast of the group results in a lower RMSE than the supposedly sophisticated weighting procedures. The implication is that the correlations between forecasters are not stable. The method of using a rolling regression proves unsuitable in this case since a relatively long window is needed to compute the correlations accurately, which conflicts with the need to change weights substantially.[53]

Though less clear cut, there is also evidence against using fixed weights computed over an initial test period. This method, which ignores recent information about forecaster correlations, more often than not results in the worst performance confirming the problem of changing relationships between forecasters.

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[53] In fact, for small groups, notably that of the Best 5, the rolling regression method proved worthwhile. For the larger groups, however, there is little to choose between using the full information set of correlations or just the most recent 22.

Table 15

Root Mean Squared Error Performance Of Unrestricted Forecast Combinations

	Fixed	Updated	Rolling	Average
Deutsche mark				
Random walk	7.71%			
Best 5†	9.98%	9.10%	9.37%	8.06%
German†	15.82%	12.10%	12.29%	9.30%
European	10.55%	9.55%	11.55%	8.74%
Rest of World†	12.76%	10.19%	12.12%	8.84%
Group I	21.21%	11.83%	11.95%	8.61%
Group II	14.15%	12.55%	11.31%	8.94%
Sterling				
Random walk	10.85%			
Best 5†	11.07%	10.38%*	9.04%*	10.47%*
German†	15.47%	11.25%	11.24%	10.62%*
British	16.55%	15.31%	17.38%	10.89%
Rest of World†	16.34%	11.27%	11.08%	10.89%
Group I	20.04%	10.53%*	11.43%	10.91%
Group II	14.89%	15.73%	15.13%	10.47%*
Japanese yen				
Random walk	4.16%			
Best 5†	5.47%	5.14%	4.54%	4.73%
German†	8.31%	7.71%	7.85%	5.92%
Japanese	12.53%	7.80%	7.24%	4.79%
Rest of World†	8.49%	9.37%	8.16%	4.68%
Group I	7.47%	7.69%	8.23%	4.75%
Group II	10.50%	11.58%	12.63%	5.05%

NOTES: *The first column gives the approximate percentage out-of-sample RMSE with weights computed over the first 22 observations. The second column gives the RMSE with the weights recomputed each month as a new observation becomes available. The third column gives the RMSE with weights calculated over a rolling window of 22 observations, and the final column gives the RMSE of a simple average of each group. A * denotes a lower value than the random walk alternative whose RMSE is given in the first row of each panel. Note that the groups marked † are not comparable across currencies due to different composition - see appendix.*

Table 16
Root Mean Squared Error Performance Of Restricted Forecast Combinations

	Fixed	Updated	Rolling	Average
Deutsche mark				
Random walk	7.71%			
Best 5†	9.78%	8.93%	9.33%	8.06%
German†	15.82%	11.95%	12.09%	9.30%
European	11.42%	9.85%	9.74%	8.74%
Rest of World†	13.90%	11.23%	13.53%	8.84%
Group I	20.02%	11.66%	11.46%	8.61%
Group II	12.57%	12.11%	11.30%	8.94%
Sterling				
Random walk	10.85%			
Best 5†	8.01%*	9.98%*	9.33%*	10.47%*
German†	14.60%	10.21%	11.05%	10.62%*
British	17.36%	15.38%	17.32%	10.89%
Rest of World†	8.87%*	7.86%*	7.19%*	10.89%
Group I	20.38%	10.77%*	11.96%	10.91%
Group II	14.83%	12.79%*	13.09%	10.47%*
Japanese yen				
Random walk	4.16%			
Best 5†	3.89%*	4.05%*	4.33%	4.73%
German†	8.13%	7.91%	6.85%	5.92%
Japanese	6.62%	5.78%	7.37%	4.79%
Rest of World†	8.43%	9.33%	7.72%	4.68%
Group I	7.57%	7.56%	7.42%	4.75%
Group II	14.03%	12.09%	9.47%	5.05%

NOTES: *See notes to Table 15.*

4.5.2 HOLDEN AND PEEL RESTRICTED REGRESSION METHOD

Our next step is to run the constrained regression proposed by Holden and Peel (1989). Remember that this forces the weights to sum to one and does not include the unconditional sample mean of the change in the exchange rate as an additional forecast. The inclusion of the constant removes the location bias in the forecasts but the restriction on the weights means that any scale biases are not fully accounted for. Whether the gains accruing from excluding the mean outweigh this loss is obviously dependent on the data, and the results from our set of currency forecasts are given in Table 16.

Slightly better performance can be detected using this constrained method, with some combinations of forecasters of the pound still outperforming a random walk (and by a higher margin than under an unconstrained regression) while for the yen, combining the Best 5 forecasters proves effective. However, it is still not possible to outperform a no change alternative for the Deutsche mark, and a simple average of predictions still performs better than most of the optimal combinations.

Figure 37 Individual Deutsche mark RMSE performance

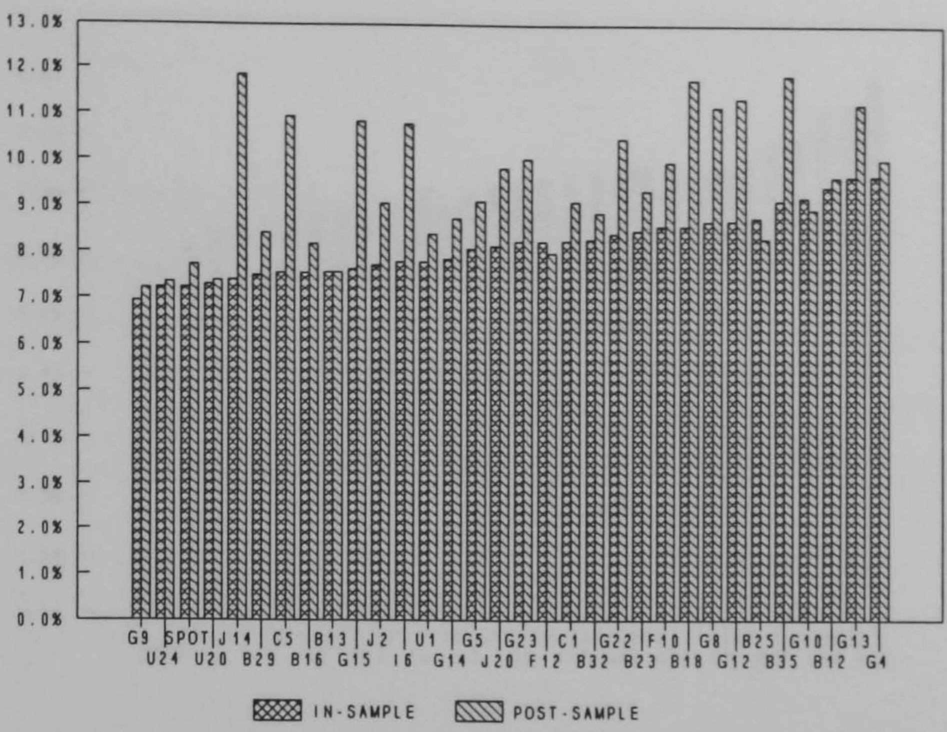
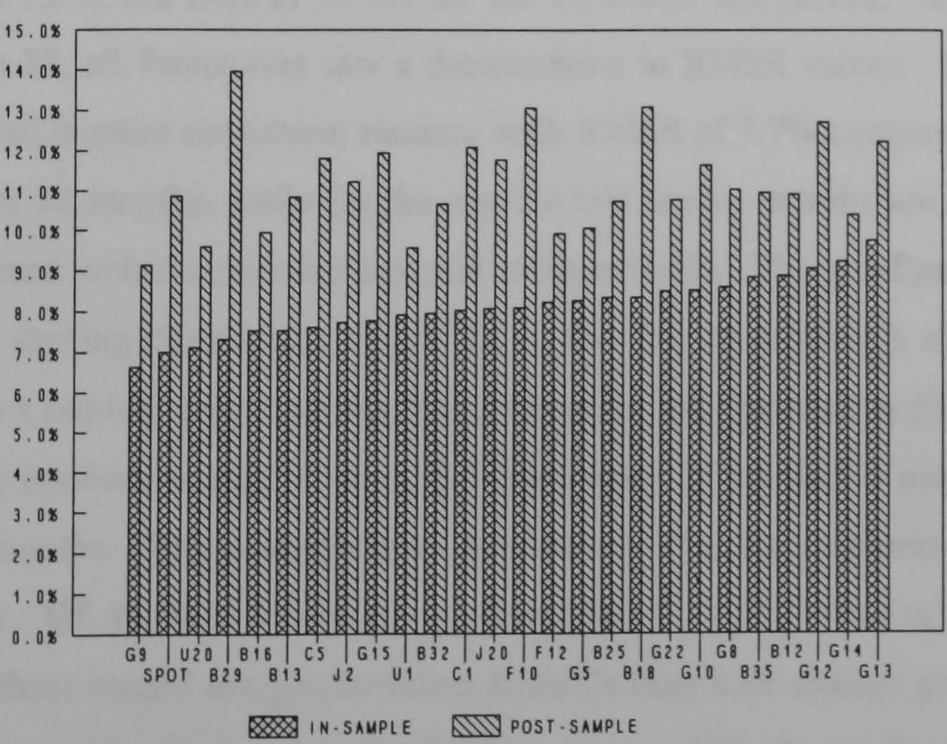
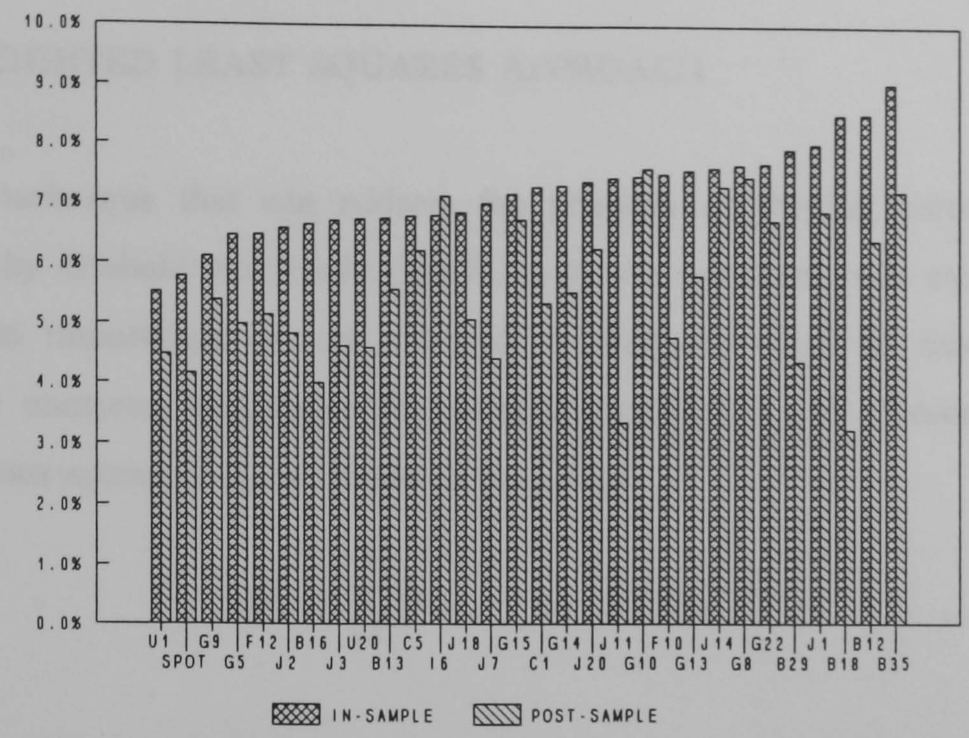


Figure 38 Individual pound sterling RMSE performance



One point to note in considering these results is that during the out-of-sample

Figure 39 Individual Japanese yen RMSE performance



testing period, the pound is more volatile than the within-sample average. The random walk RMSE for the in-sample period over which weights were originally estimated is 7.0%, but rises to 10.9% for the 12 month test period. As can be seen from Figure 38, all forecasters saw a deterioration in RMSE values. For the mark, the test period is more consistent; random walk RMSE of 7.7% compared with 7.2% over the first 22 months, while for the yen the last twelve months are more stable - 4.2% compared with the in-sample period value of 5.5%. The good performance of the Best 5 sterling forecasters results from the fact that though only one, G9, outperforms a random walk over the first 22 months, four manage to do so in the test period. The opposite is true for the yen, where none of the Best 5 outperform over the last 12 months. The Deutsche mark best exemplifies the problems with forecast combination. Of the Best 5 forecasters chosen for their performance over the first 22 months, three record marginally lower RMSE's than a no change prediction over the 12 month test period. One is slightly worse, while the performance of J14 deteriorates dramatically (see Figure 37). In order for some combination of these five to perform well, the weight on J14 must decline dramatically. Not even the moving window approach of a rolling regression is enough to capture this shift in performance.

4.5.3 WEIGHTED LEAST SQUARES APPROACH

A technique that can address the problem of shifting correlations, also suggested by Diebold and Pauly (1987), is to use weighted least squares (WLS). Here, more importance can be attached to recent forecasts in determining the covariance matrices, and hence the weights attached to each forecaster. Using ordinary least squares β^{*}_{OLS} is chosen to minimise

$$e'e = \sum_{t=1}^{T} \left(\Delta s_{t+k} - \alpha - \Sigma \beta_i \Delta s^{e}_{it+k}\right)^2 \tag{54}$$

but with weighted least squares $e'We$ is minimised, where W is the diagonal weighting matrix $W = \text{diag}(\omega_{11,}, \omega_{22}, ..., \omega_{TT})$. Weighted least squares chooses β^{*}_{WLS} to minimise the weighted sum of squares

$$\sum_{t=1}^{T} \omega_{tt}\left(\Delta s_{t+k} - \alpha - \Sigma \beta_i \Delta s^{e}_{it+k}\right)^2 \tag{55}$$

The degree of attenuation provided by this weighting matrix is variable and can include no decrease (equivalent to OLS), linear and geometric decreases in importance. Intuitively, in the face of changing relationships between panellists we would expect the most recent forecasts to contain a higher proportion of correct information about accuracy and cross-correlations than more distant predictions. We report the results of using weights that decline linearly with time, and weights that decline with the square root of time. The latter scheme, one of a set dubbed t-Lambda by Diebold and Pauly (where in our example λ=1/2), results in weights that decline slowly at first but with ever increasing rapidity. Table 17 details the results of experiments with WLS.

Table 17
RMSE Performance Of Forecast Combinations - Weighted Least Squares

	Fixed		Updated		Rolling	
	$\omega=t$	$\omega=\sqrt{t}$	$\omega=t$	$\omega=\sqrt{t}$	$\omega=t$	$\omega=\sqrt{t}$
Deutsche mark						
Random walk	7.71%					
Best 5	12.24%	10.02%	10.38%	10.02%	10.32%	9.94%
German	23.18%	11.02%	14.68%	13.24%	15.21%	13.89%
European	26.72%	20.46%	14.95%	11.69%	16.39%	13.23%
Rest of World	17.81%	16.08%	13.75%	12.48%	13.79%	13.07%
Group I	35.59%	24.92%	17.03%	13.14%	17.15%	13.56%
Group II	26.42%	19.28%	18.14%	14.88%	17.36%	13.89%
Sterling						
Random walk	10.85%					
Best 5	8.66%*	9.63%*	9.61%*	9.68%*	9.50%*	9.22%*
German	17.30%	17.17%	11.89%	11.43%	12.10%	11.68%
British	15.24%	16.12%	17.82%	16.67%	18.55%	18.09%
Rest of World	11.16%	14.02%	9.13%*	9.79%*	9.27%*	9.89%*
Group I	36.05%	26.41%	13.02%	11.41%	13.59%	12.24%
Group II	14.09%	14.34%	13.78%	14.82%	13.57%	14.45%
Japanese yen						
Random walk	4.16%					
Best 5	5.49%	4.92%	5.50%	5.27%	5.49%	5.26%
German	6.45%	7.16%	5.91%	6.42%	5.95%	8.18%
Japanese	10.71%	11.51%	8.04%	7.51%	9.49%	8.18%
Rest of World	9.21%	8.80%	6.83%	8.58%	6.36%	7.28%
Group I	9.06%	8.26%	7.41%	7.72%	7.93%	8.11%
Group II	13.68%	13.54%	12.68%	12.82%	12.82%	12.84%

NOTES: The first column of each pair gives the RMSE of optimal forecasts computed using the methods detailed in Table 15 with linearly declining WLS weights. The second column reports results based on WLS weights equal to $\sqrt{t}$, a variant of t-Lambda weightings.

The results are mixed. In some cases weighted least squares marginally improves the performance, but still does not lead to lower RMSE values than the naive alternative for the yen or mark. In many cases, WLS is detrimental to performance. Slightly better performance occurs when the WLS weights are the square root of a time trend, ie a less than proportional t-Lambda scheme, rather than a linear decline. Though not detailed in the table, geometrically declining weights were also tried and were uniformly found to worsen RMSE's. Since no one weighting scheme appears to improve performance universally, and no method results in forecasts that outperform a random walk for two of our three currencies, we conclude that for our data the use of WLS does not adequately address the problem of changing correlations.[54]

4.5.4 'CORRECTED' INDIVIDUAL FORECASTER PERFORMANCES

We noted above that running equation (53) with only one forecaster is equivalent to unbiasing the predictions and projecting these forward. We carried out this exercise for our panellists using the three OLS methods noted above. Table 18 shows that this simple correction often works well as the 'corrected' forecasts frequently outperform a random walk. Furthermore, though the more sophisticated methods can improve performance, the most basic method of computing the bias correction over just the first 21 months often proves to be the best technique.

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[54] Constrained WLS regressions akin to those we perform under OLS add little to our conclusions and so are not reported.

Table 18

'Corrected' Individual RMSE Performance

	Deutsche mark			Sterling			Japanese yen		
	Fixed	Updated	Rolling	Fixed	Updated	Rolling	Fixed	Updated	Rolling
R.W.	7.7%			10.8%			4.2%		
C1	6.3%*	6.5%*	6.2%*	10.4%*	10.5%*	9.9%*	3.5%*	3.7%*	3.9%*
C5	7.9%	8.3%	7.7%*	11.1%	11.8%	11.1%	4.4%	4.6%	4.8%
F10	6.3%*	6.4%*	6.5%*	9.7%*	10.0%*	9.4%*	4.0%*	4.3%	4.6%
F12	7.8%	8.0%	7.8%	12.3%	12.3%	11.5%	4.8%	4.6%	4.6%
I6	7.5%*	8.1%	7.9%				3.7%*	3.9%*	4.1%*
J1							3.8%*	4.1%*	4.7%
J2	7.1%*	7.8%	7.8%	12.0%	12.1%	11.7%	4.2%	4.4%	4.7%
J3							4.5%	4.8%	4.7%
J7							4.0%*	4.2%	4.3%
J11							4.2%	4.4%	4.7%
J14	8.6%	8.2%	8.0%				3.8%*	4.0%*	3.9%*
J18							4.1%*	4.2%	4.2%
J20	7.3%*	7.9%	7.7%	11.7%	11.7%	11.1%	6.0%	5.1%	5.3%
B12	9.0%	8.5%	8.4%	13.0%	12.2%	11.6%	3.9%*	4.2%*	4.4%
B13	7.7%	7.8%	7.9%	13.6%	12.2%	11.4%	4.0%*	4.3%	3.9%*
B16	7.6%*	7.8%	7.9%	11.2%	11.4%	11.0%	5.7%	5.6%	5.6%
B18	6.7%*	6.6%*	6.3%*	10.7%*	10.7%*	10.0%*	4.9%	5.1%	5.3%
B23	6.6%*	6.7%*	6.5%*						
B25	9.1%	9.1%	8.9%	12.4%	12.2%	11.9%			
B29	7.5%*	7.8%	7.8%	11.9%	13.0%	12.5%	5.9%	5.6%	5.0%
B32	8.0%	8.5%	8.3%	11.5%	11.7%	11.2%			
B35	9.8%	9.6%	10.2%	13.3%	12.8%	12.5%	4.0%*	4.5%	4.7%
U1	7.5%*	7.8%	7.7%	10.8%*	10.9%	10.2%*	4.0%*	4.0%*	3.9%*
U20	7.4%*	8.2%	8.4%	10.5%*	10.9%	10.0%*	3.9%*	4.2%	4.4%
U24	7.4%*	7.9%	7.9%						
G4	7.4%*	7.6%*	7.5%*						
G5	7.8%	7.8%	7.7%*	12.8%	12.3%	11.9%	4.1%*	4.3%	4.3%
G8	11.8%	10.6%	10.4%	16.5%	13.8%	13.4%	5.7%	5.4%	5.3%
G9	7.3%*	7.5%*	7.5%*	8.8%*	9.1%*	8.1%*	4.2%	4.1%*	4.0%*
G10	9.0%	8.8%	8.4%	12.4%	12.1%	11.7%	5.1%	4.4%	4.4%
G12	6.9%*	7.2%*	6.9%*	11.4%	11.4%	10.8%*			
G13	11.9%	10.7%	10.2%	16.9%	14.2%	13.6%	4.3%	4.6%	4.8%
G14	7.5%*	7.9%	8.0%	11.4%	11.7%	11.2%	3.8%*	4.0%*	4.1%*
G15	7.5%*	8.2%	8.4%	11.1%	11.5%	11.0%	4.0%*	4.2%	4.1%*
G22	11.5%	9.8%	9.8%	15.8%	13.7%	13.3%	7.3%	6.5%	6.9%
G23	8.2%	8.6%	8.8%						

NOTES: *A * denotes a lower RMSE measure than the random walk.*

We conclude from this that in combining our forecasts we are actually losing information, or at least not taking it into account properly. We would do better to unbias individual forecasters and use these corrected predictions. The question of which forecasters we choose to do this to, however, is not clear. Taking the Best 5 group members works sometimes, notably G9, but better performance can be extracted from initially poor forecasters. For example, forecaster C1 performs merely averagely for all three currencies over the first 21 months and little different in the subsequent test period (see Figures 37 to 39). However, correcting the bias in C1's forecasts (using any of the three methods) results in lower errors than a random walk. This is true for many of our panellists. However, we would doubt whether such simple methods would work indefinitely. MacDonald and Marsh (1993*b*) also found that corrected forecasts perform well using the first two years of our data set, but comparison shows that the number of bias adjusted forecasters who can outperform a no change alternative is falling as the data and test periods extend.[55] Forecasters can be expected to learn from their mistakes which will lead to changes in the biases. Of course, the question then becomes one of whether the time-varying parameter approaches discussed above will capture these developments.

4.5.5 GRANGER AND NEWBOLD ERROR WEIGHTING METHOD

The inability of regression-based combination methods to perform consistently well could be due to the fact that forecasters are continually revising their methods leading to time-varying correlations between panellists. These are likely to be more violent changes than the individuals' shifts in bias (since all elements are moving relative to each other in a probably uncoordinated manner) and so are harder to correct for. Thus in a final attempt to release latent information within these

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[55] Since different selection criteria are used in the earlier paper strict comparisons are difficult, but in MacDonald and Marsh (1993*b*) 83%, 68% and 80% of forecasters outperformed a random walk for the mark, pound and yen respectively, compared to 55%, 24% and 52% in this study. Both sets of percentages here have been calculated based on the simple, fixed approach.

individual forecasts we use a method suggested by Granger and Newbold (1977) that ignores the covariance information in determining the weights applied to each forecaster. These two approaches can be illustrated with reference to the following two equations

$$\Delta s_{t+k}^{COMB} = \sum_{i=1}^{m} \phi_{it}(\Delta s_{t+k}) \qquad (56)$$

where ϕ_{it} equals

$$\phi_{it} = \frac{\left(\sum_{t=j}^{T} e^{2}_{it}\right)^{-1}}{\sum_{k=1}^{m}\left(\sum_{t=j}^{T} e_{kt}^{2}\right)^{-1}} \qquad i = 1, \ldots, m \qquad (57)$$

From equation (56) we see that the combined forecast is a weighted average of *m* forecasts. The weights are derived according to equation (57) whereby each forecaster is weighted according to his previous forecast errors. As before, these weights can be computed over the in-sample period, an extending sample or a moving window according to the values of *j* and *T*. Furthermore, since no parameters are being estimated the window size can be reduced. Table 19 presents the results with weightings based on the fixed, updated and rolling periods as above (together with the simple average), while Table 20 calculates the weights using the most recent 15, 10 and 5 observations.[56]

[56] As noted in footnote 37, there is a two month lag in calculating these errors.

Table 19

Root Mean Squared Error Performance of Weighted Error Forecast Combinations

	Fixed	Updated	Rolling	Average
Deutsche mark				
Random walk	7.71%			
Best 5	8.02%	7.86%	7.87%	8.06%
German	9.18%	9.17%	9.17%	9.30%
European	8.65%	8.63%	8.62%	8.74%
Rest of World	8.81%	8.71%	8.72%	8.84%
Group I	8.49%	8.49%	8.49%	8.61%
Group II	8.85%	8.80%	8.79%	8.94%
Sterling				
Random walk	10.85%			
Best 5	10.45%*	10.47%*	10.45%*	10.47%*
German	10.45%*	10.49%*	10.45%*	10.62%
British	11.12%	11.02%	11.12%	10.89%
Rest of World	10.79%*	10.84%	10.79%*	10.89%
Group I	10.89%	10.91%*	10.89%*	10.91%
Group II	10.48%*	10.49%*	10.48%*	10.47%*
Japanese yen				
Random walk	4.16%			
Best 5	4.71%	4.73%	4.73%	4.73%
German	5.1%	5.82%	5.82%	5.92%
Japanese	4.70%	4.68%	4.85%	4.79%
Rest of world	4.69%	4.66%	4.69%	4.68%
Group I	4.69%	4.68%	4.68%	4.75%
Group II	5.30%	5.29%	5.29%	5.05%

NOTES: *See notes to Table 15.*

Table 20
Root Mean Squared Error Performance Of Weighted Error Forecast Combinations

	Last 15 obs.	Last 10 obs.	Last 5 obs.
Deutsche mark			
Random walk	7.71%		
Best 5	7.87%	7.69%*	7.81%
German	9.17%	9.12%	9.17%
European	8.62%	8.65%	8.60%
Rest of World	8.76%	8.50%	8.56%
Group I	8.48%	8.44%	8.45%
Group II	8.84%	8.76%	8.76%
Sterling			
Random walk	10.85%		
Best 5	10.50%*	10.74%*	10.61%*
German	10.43%*	10.48%*	10.42%*
British	11.08%	11.32%	11.26%
Rest of World	10.84%*	10.77%*	10.76%*
Group I	10.92%	11.07%	10.95%
Group II	10.54%*	10.57%*	10.52%*
Japanese yen			
Random walk	4.16%		
Best 5	4.77%	4.93%	5.22%
German	5.81%	5.79%	5.71%
Japanese	4.74%	4.53%	4.73%
Rest of World	4.60%	4.69%	5.02%
Group I	4.58%	4.58%	4.69%
Group II	5.29%	5.33%	5.61%

NOTES: *See notes to Table 15.*

While no significant improvement is apparent from this method using any window size, the error measures are uniformly small irrespective of the number of forecasters within the grouping. With the regression-based approaches, though the resulting RMSE may be greatly reduced for some currency/forecaster group combination, the error measure for another grouping may be particularly poor. In a relatively small sample, combining large numbers of forecasts can be particularly hazardous, and as we have noted above, the simple average often performs relatively well. The Granger and Newbold method 'tweaks' this simple average according to historical accuracy but never gives such extreme weights that a sudden deterioration in forecaster accuracy biases the combined forecast. In particular, this method can never give negative weight to a forecaster and therefore no forecaster can get a weight exceeding unity, unlike all of the regression methods. As the number of forecasters being combined rises, the combined forecast approaches the simple average. We would therefore expect to see better performance under this method when a small number of good forecasters are being combined, and indeed, the Best 5 groupings all produce a lower RMSE value for the Granger and Newbold method than a simple average using a rolling window.

4.6 COMMENTS, CONCLUSIONS AND RECOMMENDATIONS

What can we conclude from our investigation of forecast combination? We know from previous chapters that some forecasters are more accurate than others but that most are not as accurate as a simple 'no change' alternative prediction. We have investigated various ways of combining these typically mediocre forecasts in an attempt to release the parcels of information that they may contain. These attempts have generally failed. It is very hard to outperform a random walk no matter which forecasters are combined for two of our three currencies. The exception is the pound sterling-US dollar exchange rate, where some combinations produce acceptable improvements. In terms of the efficiency of the foreign exchange market, these results bolster those of the previous chapter. Forecasters, even when their expertise is combined, are typically unable to predict the change in the exchange rate over the short-term, which is consistent with the hypothesis that all available information is discounted in the current spot price.

In terms of recommendations regarding the appropriate method of forecast combination a rough ordering of techniques can be determined from our results. A constrained regression (weights sum to unity with a constant included) produces the best results when it works. For those groups where this method does not provide an improvement, however, it frequently results in a severe deterioration in performance. Unconstrained Granger-Ramanathan regressions are also subject to this criticism.

Weighted least squares approaches, designed to allow time-varying weights prove to be too *ad hoc*. Though many weighting methods are examined and some result in good performance, none produce a consistency of results wthat could lead to a recommendation. Similarly, unbiasing individual forecasters and projecting these corrected predictions can reduce forecast errors, but it is by no means obvious with which forecasters this method will work best and, furthermore, the robustness of this method over large samples and forecast periods is questionable.

The simple average performs well, at least in terms of never being too far wrong. For the pound, the mean forecast outperforms a random walk, and for all currencies produces RMSE statistics no more than two percentage points higher than a random walk (and frequently within one-half percent). Not surprisingly, therefore, if one method is to be preferred, the Granger-Newbold procedure would appear to be the most reliable, especially when small numbers of forecasters are combined. Since it ignores the rapidly changing correlations between forecasters it is less liable than the regression approaches to produce large and incorrect weights. Specifically, since all weights are constrained to be non-negative and to sum to unity, Granger-Newbold will tend to make small adjustments to the simple average weight and so never give such an extremely large weight (in absolute terms) to any one forecaster that a marked change in his accuracy can badly affect the combination forecast.

However, it is impossible to give a positive recommendation to a particular approach when no method is able to consistently outperform the simple alternative. Furthermore, there is little evidence to suggest that combining predictions has revealed the nuggets of information that we hypothesised in the introduction might lie behind the differences in our forecasts. The conclusion to which we are somewhat reluctantly drawn is that the heterogeneity in three month forecast performance revealed in chapter 2 is not the result of private information that lies in the hands of a select few. Rather, there are some very bad forecasters in our panel that make the merely poor look good by comparison. To some extent this is borne out by the RMSE/MAE calculations in chapter 3 where for the three month forecast horizon, very few individuals produce lower error values than a random walk, but many perform significantly worse. The apparent facts that the information available to foreign exchange market participants is largely common and that it is idiosyncratic interpretation that leads to forecast heterogeneity confirms the conclusions reached in chapter 2 based on the results reported in Tables 2 and 3.

The problems and advantages of working with a consensus measure are thus apparent. A simple average performs well compared to many other forecast combination methods, but by hiding the relatively good forecasters in a larger mass of indifferent or downright bad forecasters, the superior techniques of the minority are obscured. Accordingly, the ability to predict more accurately than the current spot rate is lost.

Finally, we note that these conclusions apply only to the short-horizon forecasts. Data constraints mean that we are unable to perform a combination exercise for the twelve month forecasts, though the results of earlier chapters indicate that this may prove more positive.

CHAPTER 5

THOSE THAT CAN, DO; THOSE THAT CAN'T, EVALUATE

5.1 INTRODUCTION

The previous chapters of this thesis have concentrated on the forecasts of professional exchange rate forecasters. We hypothesised that their forecasts would contain extra information not normally included in conventional, academic models of the exchange rate, such as chartist influences, the psychology of the market and private information (notably customer orders). We thought that this might allow us to refute the conventional wisdom that exchange rates are not predictable in the short-run.

The performance of our forecasters perhaps did not justify such optimism. Our panellists appear to interpret common information differently, which translates into systematic differences in performance - some forecasters are significantly more accurate than others. However, over a three month forecast horizon the vast majority of forecasters were no more accurate than a prediction of no change, and most were substantially worse. Even combining predictions in a variety of ways to produce composite forecasts based on a wider pool of information could not outperform the naive alternative.

For the longer, twelve month predictions the picture was somewhat sunnier. Many forecasters proved to be both more accurate and profitable than the random walk, and some exhibited big-hit ability - the capacity to predict the big swings in the market. A fuller analysis of the twelve month forecasts proved impossible because of the lack of independent observations and the relatively short sample. However, the prospects for combining forecasts and portfolio evaluation of predictions look good. We leave this on the agenda for future research.

In the following chapters we turn to making some predictions of our own, based on simple economic models, but using advanced econometric techniques. We shall evaluate these forecasts over the same period and for the same currencies as our panellists, using some of the techniques employed in chapter 3. The fact that these forecasts are being made after the fact means that a true and fair comparison is not possible. However, where possible we shall restrict the model to information available when our panellists were forecasting.

We begin with a discussion of the post-Meese and Rogoff attempts at exchange rate forecasting. In sections 5.3 and 5.4 we detail our econometric and economic methodologies. We estimate the models and investigate their out-of-sample forecasting performance in the following four chapters.

5.2 ACADEMIC APPROACHES TO EXCHANGE RATE FORECASTING

Two of the most frequently cited papers in the field of exchange rate forecasting are those by Meese and Rogoff (1983*a*, 1983*b*).[57] Standard, commonly-used models of the exchange rate based on the asset market approach are assessed in terms of their out-of-sample forecasting ability. The equations estimated correspond to the flexible price monetary model (Frenkel (1976)), the sticky price monetary model (Dornbusch (1976)), and the sticky price asset model (Hooper and Morton (1982)). Both papers conclude that these exchange rate models cannot out-predict a random walk over horizons less than one year.

Several researchers have since challenged these results, both on economic and econometric grounds.[58] Two examples are Wolff (1987*b*) and Schinasi and Swamy (1989) who allow for coefficient variation, though with differing degrees of success. Though Wolff (1987*b*) manages to outperform the random walk for just the Deutsche mark-dollar exchange rate (over the same forecast period as Meese and Rogoff),

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[57] The original 1983 *Journal of International Economics* paper has been cited in more than 230 journal articles in the ten years since its publication according to the Social Science Citation Index.

[58] Conversely, several authors have also confirmed these results using different data periods or econometric techniques. Alexander and Thomas (1987), for example, rework the Meese and Rogoff models and test their performance over the first half of the 1980s. They find that structural models still perform badly over horizons up to two years.

Schinasi and Swamy (1989) find across the board improvements using a less restrictive technique. However, in common with most of the papers in this area, and following the practice set by Meese and Rogoff (1983), they use the actual realised values of explanatory variables in the out-of-sample evaluation. This convention was established because Meese and Rogoff were evaluating the applicability of the models, not the ability to forecast. By substituting realised values of explanatory variables they were giving the models the benefit of the doubt, removing the suspicion that poor performance was due to an inability to predict the independent variables. In the terminology used in the rest of this thesis these forecasts are said to be partially dynamic, since they use the predicted value of some explanatory variables (the exchange rate) together with the realised values of other explanatory variables in computing multi-step-ahead forecasts. Fully dynamic forecasts are those where all explanatory variables are forecast, usually by companion equations. An additional term that will be used is that of an *ex ante* forecast. This would denote a prediction made over a horizon consisting entirely of future periods. The forecasts of our panellists are true *ex ante* predictions and are therefore also fully dynamic.

Finn (1986) and Woo (1985) examine a rational expectations formulation of the monetary model (see Hoffman and Schlagenhauf (1983)) and produce fully dynamic forecasts. Both papers find that the rational expectations model fits the data well in-sample and is better specified than the simple monetary version. Finn's results for the pound-dollar exchange rate indicate that the out-of-sample forecast performance is equally as good (or bad) as the random walk over horizons between one and twelve months. Although Woo's model outpredicts the naive alternative over all horizons, the improvement only becomes marked over twelve months when just nine overlapping forecasts are evaluated. For example, the RMSE ratio for the best of his alternative formulations at three months is 0.97, which is unlikely to be significantly less than unity.

Somanath (1986) notes the beneficial effect demonstrated in Woo (1985) of including lagged adjustment effects to the monetary model. He adds such terms to the full range of models considered in Meese and Rogoff (1983) (plus two additional structural models) and evaluates their performance over a range of out-of-sample periods for the Deutsche mark-dollar rate. On the basis of this extensive set of partially dynamic forecasts he concludes that models with a lagged dependent variable can outperform a random walk. As Pentecost (1991) states, this procedure essentially changes each structural model into a random walk plus additional explanatory variables. To the extent that these additional terms are significant, this is a valid improvement over a random walk from a forecaster's point of view. Unfortunately, many of the variables are not significant, and from an economist's point of view many are also incorrectly signed.

Gandolfo *et al* (1991) reject the Meese and Rogoff results because they are based on single equation semi-reduced form models. Instead, they advocate the use of "suitable economy-wide macroeconometric models capable of capturing all the complex associations between the exchange rate and other variables....of a modern economy." They present some stunning results to back up their assertion based on a continuous-time model of the Italian economy. While only marginally outperforming the random walk over a one month horizon, the RMSE ratio drops to 0.41 over three months and a mere 0.13 over one year. Howrey (1994) comments that it is difficult to determine whether these surprising results are due to focusing on "the Italian economy or are due to the use of an economy-wide model, a continuous-time model, *the particular variables that are taken to be exogenous for purposes of the out-of-sample forecasts*, or the particular sample period that was examined" (our italics). His results, also based on an economy-wide (discrete-time) model (of the US), show that better out-of-sample forecasts are possible. This indicates that the Italian and continuous time factors are not crucial for the Gandolfo *et al* results. However, the "decided edge" in favour of the US model's predictions is entirely dependent on the nomination of certain variables as exogenous which are then replaced by their actual values in the forecasting exercise.[59] If these variables are to be predicted in advance the ability to outperform a random walk disappears.[60]

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[59] The critical variable in Howrey's paper is the import deflator which is also taken as exogenous in Gandolfo *et al*.

[60] Partially dynamic forecasts based on the complete macromodel produce RMSE ratios of 0.25 and 0.31 for three and twelve month forecast horizons respectively. When the

While Howrey's (1994) results cast some doubt on those of Gandolfo *et al* (1991), the impressive performance of the partially dynamic forecasts from these large macromodels is suggestive. Gandolfo *et al* attribute their results to the sound theoretical basis and long-run conditions of their model. In the field of exchange rates in particular, economists would admit that they have only scant knowledge of the short-run dynamics of the market, caused at least in part by the actions of chartists and other "non-rational" participants discussed in chapter 3. They would, however, feel much more at home in discussing long-run relationships. Isolating these long-run effects has been made much easier by the development of cointegration theory.

MacDonald and Taylor (1991, 1994), Cheung and Lai (1993*b*), MacDonald and Marsh (1994*a*), and MacDonald (1994) have all found support for various long-run equilibria in a range of exchange rates using multivariate cointegration techniques. The MacDonald and Taylor papers find cointegration among the set of variables that enter the monetary model of the exchange rate for the Deutsche mark against the US dollar. The signs of the relationships are consistent with the model, although it could be argued that the coefficients are not of the order of magnitude that might be expected. The remaining papers all look at purchasing power parity (PPP) between a number of countries. All find considerable evidence of cointegration with variables carrying their hypothesised signs. Equally, however, the papers reject degree one homogeneity of the exchange rate with respect to prices (i.e. $s \neq p - p^*$) and symmetry of the coefficient on the price terms (i.e. $s \neq \alpha(p - p^*)$) for the majority of exchange rates, irrespective of the price index chosen. These results indicate that whilst purchasing power parity might have something to say about the long-run behaviour of exchange rates, something more needs to be added to get the full picture. We return to this question below.

Two of these papers, MacDonald and Taylor (1994) and MacDonald and Marsh (1994*a*), augment long-term relationships with complex short-term dynamics to produce single equation-based, partially dynamic forecasts, that are able to

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forecasts are made fully dynamic the ratios fall to 1.16 and 1.36.

outpredict a random walk for a range of exchange rates. The RMSE ratios are seldom very far from unity over horizons upto three months, but in some cases fall significantly below one as the forecast horizon extends. No tests of significance of this outperformance are reported.

It is important to note that the long-run modelling methodology alone is not responsible for this apparent forecasting prowess. Diebold *et al.* (1994) model model a system of seven spot exchange rates. Long-run relationships between these exchange rates are allowed for (though evidence of their existence is at best weak) and equations are formulated with short-term dynamics. They find that a random walk model with drift substantially outpeforms all of their models over a wide range of forecast horizons. Their work shows that merely adding complex, data-determined dynamics to a model will not necessarily result in improved performance.

In summary, the literature appears to be slowly overturning one of the main Meese and Rogoff conclusions. It now appears that the standard economic models, augmented by better dynamics, long-term constraints or time-varying coefficients, do have value in forecasting the exchange rate if the purpose of the exercise is to test the validity of the theory. Both the monetary model and PPP (in its weakest form) find support from the data as long-run conditions, and can form the basis of forecasting models capable of outperforming the random walk in terms of partially dynamic forecasts. However, only the paper by Woo (1985) has demonstrated any ability to outperform a random walk with fully dynamic forecasts, and then only over reasonably long horizons and solely for the Deutsche mark against the dollar. Good partially dynamic forecast performance must be taken with a large pinch of salt in light of Howrey (1994), whether they come from systems or reduced form equations.

5.3 A DYNAMIC SYSTEMS APPROACH TO FORECASTING

Gandolfo *et al* (1991) persuasively argue that reduced form single equations cannot hope to capture the complex movements of the factors that determine exchange rates. Their preferred approach is to use full scale models of the entire economy. While we agree that single equation approaches are unlikely to improve greatly on previous work, we are less ambitious and shall instead use small systems of equations.

Hendry and Doornik (1994) list ten reasons in favour of the use of systems analysis. For our purposes four are worth discussing. First, and number one in Hendry and Doornik's list, is the fact that "the economy is a system". Potentially, all variables are endogenous and the complex interaction of these variables needs modelling. This is very much in line with the arguments of Gandolfo *et al*, although Hendry and Doornik stress the need to marginalise variables in applied exercises where data availability can be a constraint. Second, and again stemming from the work of Haavelmo (1943), there is the problem of simultaneity. Single equation approaches do exist but in a small system, full information maximum likelihood (FIML) methods are superior. We find that this is a very important consideration when modelling exchange rates, and one that may account for the problems of several earlier studies that failed to take this factor into account. Third, Hendry and Doornik note that cointegration is a system property. We propose to use Johansen's (1988, 1989) tests of cointegration to identify a long-run equilibrium level towards which exchange rates (and some other variables in the system) adjust. Weak exogeneity of the variables included in the cointegrating system can be tested under Johansen's approach. Only when exogeneity cannot be rejected for all but one of the variables can it be valid to model the system as a reduced form single equation. If more than one variable is adjusting to restore equilibrium a systems approach is needed. Finally, as we want to compare our forecasts with those of our panel members, we shall be making fully dynamic forecasts. That is, we shall forecast all explanatory variables in our exchange rate equation rather than use the actual values. While it would be possible to use simple autoregressive models to predict these values, a systems approach nests this alternative and also allows interaction between variables.

The David Hendry/London School of Economics general-to-specific approach to modelling single equations is well known and extensively documented. The methodology is established (see Davidson *et al* (1978), Hendry and Richard (1982), Hendry and Ericsson (1983), and Gilbert (1986)), although it is not without its critics (see Friedman and Schwartz (1983) and Pagan (1987)). Empirical applications are prevalent thanks to the *PC-GIVE* computer suite, and exist in many areas of economics (see Brodin and Nymoen (1992) consumption; Hendry and Ericsson (1991) money demand; Athukorala and Menon (1994) export behaviour; and Juselius (1992) price determination). As we have already stated, financial economists have also used the Hendry single equation method to good effect (see MacDonald and Taylor (1994) and MacDonald and Marsh (1994*a*)).

A systems counterpart to the single equation Hendry approach is now being developed, and the *PC-FIML* econometric package makes such a modelling technique reasonably straightforward to implement.[61] The methodology has been set out and progressively developed in Hendry, Neale and Srba (1988), Clements and Mizon (1991), Hendry and Mizon (1993), and Hendry and Doornik (1994).[62] Money demand and labour market applications of this approach are contained in these papers as well as in Psaradakis (1993), while Johansen and Juselius (1992*b*) includes a less explicitly Hendry-style study of the Australian IS-LM model.

5.3.1 THE ECONOMETRICS OF SMALL, NON-STATIONARY SYSTEMS

The systems approach we follow starts from a relatively small VAR from which the long-run relationships in the data can be extracted. Restrictions on these relationships in accordance with economic theory are tested and imposed if not rejected. The original VAR in levels is transformed to stationarity by first differencing, and the restricted long-run relationships that would otherwise be lost by the transformation are reintroduced. This VAR is made parsimonious by the exclusion of certain lags of some variables from all equations. The final step is to move from this PVAR to the structural econometric model equations, estimated by full information maximum likelihood techniques. Each of these steps is discussed in more detail below.

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[61] All of the dynamic systems modelling undertaken in the following chapters is carried out on *PC-FIML* version 6.1.

[62] Critics of the approach include Kirchgässner (1991), and Sims (1991).

5.3.2 THE UNRESTRICTED VAR MODEL

Sims (1980) advocates the use of vector autoregressions as a way of avoiding the use of incredible identifying restrictions and *a priori* theories in the estimation of econometric models, which he saw as typical of the Cowles Foundation approach to modelling. The VAR approach, in particular, does not ascribe the untested status of exogeneity to any particular variable and captures complex dynamic inter-relationships between the N series by the joint modelling of variables:

$$x_t = \sum_{i=1}^{p} \Pi_i x_{t-i} + \psi D_t + v_t \tag{58}$$

where $\boldsymbol{D}_t$ contains deterministic components (constant, trend, centred seasonal dummies and event dummies) and $\boldsymbol{v}_t$ is assumed to have mean zero, be homoscedastic and be serially uncorrelated. The order of the VAR, p, is assumed finite to exclude moving average components, and the parameters Π_i, ψ, and Σ (the covariance matrix of $\boldsymbol{v}$) are assumed constant. Equation (58) can be usefully reparameterised as

$$\Delta x_t = \sum_{i=1}^{p-1} \Gamma_i \Delta x_{t-i} + \Pi x_{t-1} + \psi D_t + v_t \tag{59}$$

where $\Gamma_j = -\Sigma_{i=j+1}^{p} \Pi_i$ and $\Pi = \boldsymbol{I} - \Sigma_{i=1}^{p} \Pi_i$. Π is interpreted as the matrix of long-run responses.

5.3.3 COINTEGRATION AND THE TESTING OF RESTRICTIONS ON LONG-RUN RELATIONSHIPS

An important consideration is modelling time series is the stationarity of the data. By assumption, $\boldsymbol{v}_t$ is stationary, but the N variables in $\boldsymbol{x}_t$ need not all be stationary. Ignoring deterministic non-stationarity, the rank, r, of Π determines how many variables are $I(0)$. There are three possible cases:

(i) $r = N$ so that all variables in x_t are stationary;

(ii) $r = 0$ so that all variables in x_t are non-stationary; and

(iii) $0 < r < N$ in which case there are $(N - r)$ linear combinations of x_t that act as common stochastic trends, and r cointegrated linear combinations of x_t.

In case (iii), Π can be factored into $\alpha\beta'$ where both α and β are $N \times r$ matrices of rank r. β contains the r cointegrating vectors such that $\beta' x_t$ are stationary, and α the loadings matrix that gives, for all N equations in the system, the weight attached to each cointegrating vector. Johansen (1991) establishes two methods for determining the rank of Π and the estimates of α and β, which we now summarise.

The first step is to concentrate the likelihood function with respect to the parameters Π_i and ψ by regressing Δx_t and x_{t-p} on Δx_{t-1}, ..., Δx_{t-p+1}, and D_t. The residuals of these respective regressions are denoted R_{0t} and R_{pt}, and the product moment matrices

$$S_{ij} = T^{-1}\sum_{t=1}^{T} R_{it}R_{jt}' \qquad i, j = 0, p \tag{60}$$

The concentrated likelihood function takes the form of a reduced rank regression

$$R_{0t} = \alpha\beta' R_{pt} + errors \tag{61}$$

For a fixed β, α can be determined from (61) by the regression

$$\hat{\alpha}(\beta) = S_{0p}\beta(\beta' S_{pp}\beta)^{-1} \tag{62}$$

β can be determined by solving the eigenvalue problem

$$|\lambda S_{pp} - S_{p0}S_{00}^{-1}S_{0p}| = 0 \tag{63}$$

which has the solutions $\hat{\lambda}_1 > ... > \hat{\lambda}_p > 0$ and corresponding eigenvectors $\hat{V} = (\hat{v}_1, ..., \hat{v}_p)$ normalised by $\hat{V}' S_{pp}\hat{V} = I$. Defining $\hat{w}_1$, ..., $\hat{w}_p$ by $\hat{w} = S_{0p}\hat{v}_i$, the maximum likelihood estimator for β is then

$$\hat{\beta} = (\hat{v}_1, ..., \hat{v}_r) \tag{64}$$

which when normalised as above gives

$$\hat{\alpha} = S_{0p}\hat{\beta} = (\hat{w}_1, ..., \hat{w}_r) \tag{65}$$

Since $\hat{V}'S_{pp}\hat{V} = I$ the unrestricted estimate $\hat{\Pi} = S_{0p}S_{pp}^{-1}$ can be written $S_{0p}\hat{V}\hat{V}' = \Sigma_{i=1}^{r}\hat{\alpha}_i\hat{\beta}_i'$ + $\Sigma_{i=r+1}^{N}\hat{w}_i\hat{v}_i'$, and the maximised likelihood function can be shown to be

$$\hat{L}_{max}^{-2/T} = |S_{00}|\prod_{i=1}^{r}(1-\hat{\lambda}_i) \tag{66}$$

Two tests of the rank, r, of matrix Π are given by Johansen. The first, the trace statistic, is the likelihood ratio test of the hypothesis

$$-2\ln Q(rank=r|rank=N) = -T\sum_{i=r+1}^{N}\ln(1-\hat{\lambda}_i) \tag{67}$$

The second, the lambda-max statistic, is the likelihood ratio test of

$$-2\ln Q(rank=r-1\,|rank=r) = -T\ln(1-\hat{\lambda}_r) \tag{68}$$

The non-standard asymptotic distributions are given in Johansen and Juselius (1990) and further refined in Osterwald-Lennum (1992). Note that they are dependent on the assumed existence or otherwise of intercept terms and the other deterministic elements in the model and data generating process. The importance of the intercept term in determining the rank of Π is discussed futher when we examine our models.

These two tests determine the rank of Π and the maximum likelihood estimation factors it into the cointegration vectors and associated loadings matix. The β vectors produced are the most stationary combinations of the N series in a statistical sense and will not usually be economically meaningful. Wickens (1993) notes that even when there is just one cointegrating vector it is not clear whether this is a structural or reduced form relationship. When there is more than one vector "the coefficients of long-run structures, reduced forms and single equation cointegrating regressions will be undetermined linear combinations of the C[ointegrating] V[ectors]" (Wickens (1993) page 1). There is, therefore, an increasing trend towards performing transformations and imposing restrictions on the isolated cointegrating vectors to reveal 'meaningful economic relationships'. In particular, we can bring economic theory to bear on the problem since economic hypotheses in the form of restrictions on the vectors (and possibly the loadings matrix) can be tested once the rank is determined. In the following chapters we perform three different types of restriction, which we now consider in turn.

The first restriction on the cointegrating space, β, we shall consider specifies the same linear restriction on all the cointegrating vectors. Given that $\Pi = \alpha\beta'$, the $N - s$ restrictions are imposed by the matrix H $(N \times s)$ such that $\beta = H\varphi$, where φ is $(s \times r)$. To test this restriction, the eigenvalue problem

$$|\lambda H'S_{pp}H - H'S_{p0}S_{00}^{-1}S_{0p}H| = 0 \tag{69}$$

is solved to yield the ordered eigenvalues $\tilde{\lambda}_1 > ... > \tilde{\lambda}_s$ and associated eigenvectors. Taking the first r of these eigenvectors and the restricted β matrix, the maximum likelihood procedure is repeated yielding

$$\tilde{L}_{\max}^{-2/T} = |S_{00}|\prod_{i=1}^{r}(1-\tilde{\lambda}_i) \tag{70}$$

The restriction is tested by a likelihood ratio statistic equal to

$$-2\ln Q(\Pi = \alpha\varphi'H' | \Pi = \alpha\beta') = T\sum_{i=1}^{r}\ln(1-\tilde{\lambda}_i)/(1-\hat{\lambda}_i) \tag{71}$$

which is distributed χ^2 with $(N - s)\, r$ degrees of freedom.

The second restriction on the cointegrating vectors is that $N - s$ elements of each of r_1 of the r vectors are known $(r_1 \leq r)$. This is a more complex problem that reduces to an eigenvalue problem only when the equality holds, but that can be generally solved by an iterative switching algorithm when $r_1 \leq s \leq N - (r - r_1)$. The proof, given in Johansen and Juselius (1992) will not be repeated here but the restrictions can be tested by a likelihood ratio statistic equal to

$$-2\ln Q(\Pi = \alpha\varphi' G' | \Pi = \alpha\beta') = T\left(\sum_{i=1}^{r_1}\ln(1-\tilde{\rho}_i) + \sum_{i=1}^{r-r_1}\ln(1-\tilde{\lambda}_i) - \sum_{i=1}^{r}\ln(1-\hat{\lambda}_i)\right) \quad (72)$$

where G is the matrix of restrictions imposed, $\tilde{\rho}$ are the eigenvalues of the r_1 restricted cointegrating vectors, $\tilde{\lambda}$ are the eigenvalues of the remaining unrestricted $r-r_1$ vectors, and $\hat{\lambda}$ are the unrestricted eigenvalues. This statistic is distributed χ^2 with $(N - s - (r-r_1))\, r_1$ degrees of freedom.

The final restriction that we impose is on the adjustment coefficients. Specifically, α is restricted to take the form $\alpha = A\varphi$. A is an $N \times m$ matrix imposing m restrictions. If we define $\boldsymbol{B}$, an $N \times (N - m)$ matrix equal to $A_\perp$ such that $\boldsymbol{B}'\boldsymbol{A} = \boldsymbol{0}$, the restriction on the adjustment matrix can be written as $\boldsymbol{B}'\alpha = \boldsymbol{0}$. Again, without repeating the proof given in Johansen and Juselius (1990), the restrictions can be tested by a likelihood ratio statistic equal to

$$-2\ln Q(\Pi = A\varphi\beta' | \Pi = \alpha\beta') = T\sum_{i=1}^{r}\ln(1-\tilde{\lambda}_i)/(1-\hat{\lambda}_i) \quad (73)$$

where again a tilde denotes a restricted value and a hat denotes an unrestricted value. This statistic is distributed χ^2 with $(N - m)\, r$ degrees of freedom.

5.3.4 REDUCING THE SIZE OF THE VAR

The imposition of unrejected constraints on the cointegrating vector or adjustment matrix will change the estimated short-run dynamics of equation (59) and the coefficients of the deterministic variables. These new coefficients are denoted by a tilde. If we also denote the restricted cointegration space by $\tilde{\Pi} = \tilde{\alpha}\tilde{\beta}'$, the constrained VAR (CVAR) can be written as

$$\Delta x_t = \sum_{i=1}^{p-1} \tilde{\Gamma}_i \Delta x_{t-i} + \tilde{\Pi} x_{t-1} + \psi D_t + w_t \tag{74}$$

The CVAR is an intermediate stage in the modelling of the system. The next step is to make the system more parsimonious by restrictions on $\tilde{\Gamma}_i$ (restrictions at this stage on ψ, and $\tilde{\Pi}$ are theoretically possible but unlikely if the original VAR is correctly specified). If we denote the coefficient on the l-th lag ($l \leq p$) of the k-th variable in the j-th equation (k, $j \leq N$) of the CVAR by $\tilde{\Gamma}_{j,k,l}$, we test for valid reductions in the dimensions of the system that take the form of the restriction that $\tilde{\Gamma}_{j,k,l}$ equals zero for all $j = 1$ to N. That is we test the restriction that the coefficient on the l-th lag of variable k equals zero in all N equations, which is distributed as an F-test. After the imposition of all such unrejected restrictions the restricted system or parsimonious VAR (PVAR) can be written as

$$\Delta x_t = \sum_{i=1}^{p-1} \breve{\Gamma}_i \Delta x_{t-i} + \breve{\alpha} \tilde{\beta}' x_{t-1} + \breve{\psi} D_t + u_t \tag{75}$$

where a breve denotes a new matrix of coefficients following these restictions.

5.3.5 STRUCTURAL MODELLING AND ENCOMPASSING TESTS

The final stage is to model the individual equations in the form of structural econometric models (SEMs). The structural models are not unique and are governed by economic considerations rather than statistical distributions, but can be given, for instance, by

$$A_0 \Delta x_t = \sum_{i=1}^{p-1} A_i \Delta x_{t-i} + a \tilde{\beta} x_{t-1} + \breve{\varphi} D_t + \mu_t \tag{76}$$

The set of relationships between the parameters of equations (75) and (76) include the following: $\Gamma_i = A_0^{-1} A_i$, $\breve{\alpha} = A_0^{-1} a$, $\mu_t = A_0^{-1} u_t$, and $\breve{\psi} = A_0^{-1} \breve{\varphi}$.

The crucial test of the validity of competing SEMs is based on the notion of encompassing. Suppose two such SEMs exist, which we may call models A and B, both of which are reductions from equation (75). When the underlying data generating process for x_t is unknown, the VAR is the natural framework within which the properties of the two models can be evaluated.

To simplify notation and following Hendry and Mizon (1993), express the UVAR (equation (59)) in companion form as

$$f_t = \Pi^* f_{t-1} + v_t \tag{77}$$

Similarly, the competing structural models (alternative forms of equation (76)) are expressed as

$$\Phi_A f_t = \mu_{At} \tag{78}$$

and

$$\Phi_B f_t = \mu_{Bt} \tag{79}$$

Let γ_B denote the vector of parameters in Φ_B that characterises the structural model B. Let γ_P denote what model A predicts γ_B to be when model A is assumed to be the true data generating process. Model A encompasses model B if and only if $\gamma_B - \gamma_P = \boldsymbol{0}$.

Hendry and Mizon (1993) show that for model i to encompass the VAR it must be dynamically well specified and its errors be innovations relative to the history of the process. Mathematically, it is required that $\Phi_i \Pi^* = \boldsymbol{0}$. To see this consider the effect of combining equations (78) and (79)

$$\Phi_A f_t = \Phi_A \Pi^* f_{t-1} + \Phi_A v_t = \mu_{At} \tag{80}$$

If the VAR is a congruent representation of the data such that v_t are innovations with respect to the history of the process, then the SEM errors, μ_{At}, will only be innovations if $\Phi_A \Pi^* = \boldsymbol{0}$. This is the well-known condition for the validity of the over-identifying restrictions on the reduced form parameters implied by the SEM, tested with a standard likelihood ratio test. With two competing models three outcomes are possible. If neither model encompasses the VAR, both are rejected in favour of the VAR. If just one encompasses the VAR it is deemed to be an acceptable parameterisation and the other model is rejected. If both encompass the VAR they are clearly both acceptable, but more to the point, they are observationally equivalent and, with one caveat, it is not possible to choose one ahead of another.

The caveat is that Mizon and Clements (1991) argue that a more meaningful test may be whether the SEM can encompass the PVAR rather than the UVAR. This is likely to be particularly true if the number of coefficients estimated in the UVAR is large relative to the data set and overfitting occurs. The test may also be more stringent if there are several valid restrictions that can be placed on the UVAR in moving to the PVAR. Thus a further step in discriminating between two rival models is to test them relative to the PVAR, supposing that this PVAR is itself a congruent representation of the data. In practice, we only report encompassing tests relative to the PVAR since in all cases this proves to be a slightly more powerful test. Furthermore, we are not searching across a range of alternative models to find the 'best'. With only limited assistance from economic theory about the structure of the short-term dynamics we will be content with any model that encompasses the UVAR, CVAR and PVAR.

To date this systems approach has not been applied to the exchange rate market, and has not been specifically used for forecasting time series, although it is true that one of the major diagnostic tests of these models is of forecast ability. The following chapters rectify the situation.

5.4 SIMPLE SYSTEMS OF MAJOR EXCHANGE RATES

Long-run purchasing power parity will form the basis of our modelling exercise. Since, in one form or another, it is an assumed condition for almost every model of the exchange rate, PPP has received a huge amount of attention in the academic literature. All of this work has, however, failed to produce a consensus view. While there is now general agreement that PPP does not hold in the short-run except for cases of (near) hyperinflation, as a long-run proposition the evidence is mixed. Taylor (1988*b*), Enders (1988) and Patel (1990) test for cointegration using the Engle-Granger two-step methodology and are unable to find a tendency for exchange rates and relative prices to settle into an equilibrium relationship. These papers impose symmetry across the two price series (but not proportionality) which, along with the relatively primitive econometric technique, may be a reason for the failure. Cheung and Lai (1993) and MacDonald (1994) use the more advanced Johansen method and are able to find considerable evidence of cointegration for several exchange rates, but little support for degree one homogeneity of the exchange rate with respect to relative prices.[63] MacDonald and Taylor (1992) and Driver (1994) provide extensive surveys of the recent literature on purchasing power parity, both of which are broadly supportive of the existence of a long-run relationship between prices and exchange rates.

Adopting PPP as a basis for our model also supports our choice of econometric approach. Frenkel (1981) argues that much of the controversy surrounding PPP stems from the fact that it is an equilibrium condition and does not provide any detail on which forces bring about such a relationship. If prices react to competitiveness changes imposed by shifts in the exchange rate, PPP becomes a theory of price setting rather than one of exchange rates. Therefore, Frenkel asserts, PPP should not be viewed as a theory of exchange rate determination. While this lack of a causal link may invalidate the use of PPP in single equation models, it bodes very well for a systems approach. Since dynamic equations are specified for all variables in the system, the effect of goods arbitrage on the exchange rate, and pricing to market/competitiveness effects on price levels will be fully captured.

However, the fact that the majority of empirical papers on PPP reject the restriction of proportionality if not symmetry is worrying. It has been suggested that measurement errors might account for the fact that the coefficients on prices do not exactly equal unity in absolute terms, and indeed the question of which is the most

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[63] More positive results are reported by Huizinga (1987) and Abuaf and Jorion (1990), with both studies finding evidence of mean reversion in the real exchange rate (which imposes proportionality).

appropriate index has been debated since PPP was developed. Experimentation with several different indices has not found any systematic difference between results, with the absolute price elasticities usually significantly greater than unity. This divergence from the theoretical value is sufficiently large for us to conclude that something more than measurement errors is at hand, and in line with Cassel's synthesis of PPP and asset demand approaches to the exchange rate, we shall augment the traditional PPP relationship (see Holmes (1967) for further discussion). According to the asset demand approach to exchange rates, currency values are determined not by the intersection of Marshallian demand and supply scissors but by investors' views on the future value of the currency. This is clearly and repeatedly stated by Cassel:

> "A depreciation of a currency is often merely an expression for discounting an expected fall in a currency's international purchasing power" (Cassel (1922) p. 149)

and

> "As instances of such depressing tendencies [on the exchange rate] we can quote: a distrust in the future of a monetary standard leading to discounting of an anticipated fall in the internal value of the money" (Cassel (1921) p. 41)

As Batchelor (1977) notes, market expectations ought then be based primarily on leading indicators of future purchasing power. There is considerable debate about the variables that enter this leading indicator relationship. The monetary approach limits the explanatory variables to those that enter the money demand functions, while the portfolio balance model advocates the inclusion of further terms that influence the risk premium attached to a currency. A simple yet commonly used proxy for expected inflation within a country is based on the long-term bond rate. If indexed bonds of equivalent maturity (and risk) are traded these give information on the real interest rate. Subtracting the real rate from the nominal gives the inflation premium the market expects over the maturity of the bonds. Since indexed bonds are non-existent in many countries, analysts often look at the nominal rate and subtract a 'best guess' of the real interest rate, typically based on historical real rates, to find the expected inflation rate. Thus, if Cassel's synthesis is correct, the spot exchange rate will react not only to changes in current purchasing power but also to expected future purchasing power which can be captured by movements in real long-term bond yields.

Cassel also repeatedly remarked on the importance of capital flows in keeping the market rate away from the underlying PPP exchange rate:

> "A closer study of the dollar in pounds sterling during the period 1919-24 shows that the origin of the deviations of the actual rates of exchange from the purchasing power parity is to be found essentially in international movements of capital" (Cassel (1932) p. 679)

and

> "the possible influence of international capital movements as a factor deviating the rate of exchange from the Purchasing Power Parity has a primary interest" (Cassel (1928) p. 17)

He generally thought of such flows as stemming from the actions of governments trying to support a target level of the exchange rate, and as such, these flows could maintain merely short-run deviations from parity. However, he appeared to neglect the role of long-term, persistent capital flows which could generate systematic and long-lasting departures from PPP, perhaps because they were less controversial in his day, and perhaps because such flows did not dominate the foreign exchange market to quite the extent that they do now (see chapter 1).

The huge current account imbalances faced by many countries since the start of the current float are evidence of the importance of capital flows, since the persistent trade deficits seen in the US and UK are funded by capital flows from the surplus countries, essentially Japan and Germany. A model of long-run equilibrium when current and capital accounts are not in balance is given in MacDonald and Marsh (1994*b*). This paper also stresses the importance of distinguishing between the long-run relationships found by statistical analysis and the 'true' long-run relationships suggested by economic theory. In particular, during the current float we have certainly not been at the long long-run equilibrium (defined by zero net-capital flows) for any great length of time. Cointegration techniques will not therefore pick out PPP as an equilibrium relationship over this sample, and will instead find a PPP relationship contaminated by capital flows. Clearly, if we are to detect the PPP influence on exchange rates we must account for these capital flows. Empirically, we can proxy these flows with the real interest rate offered in a country, hypothesising that capital is flowing around the globe in search of the best real return.

Thus, we shall use long-dated government bond yields as a proxy for both long-term capital flows (represented by the real interest rate) the expected change in the future purchasing power of a currency (represented by the difference between real and nominal rates). Unfortunately, this mixing of roles gives us no prior expectation of the signs or magnitudes of the coefficients on the interest rates. Only if the domestic and foreign countries are symmetric would we expect the coefficients on the bond yields to be equal and opposite. However, as this thesis is primarily a test of forecasting ability, we will continue as long as the approach to finding a long-run equilibrium is successful.

In the following chapters we execute the modelling strategy outlined for the sterling-dollar, yen-dollar and mark-dollar exchange rates.[64] Chapter 9 contains an evaluation of the forecasts extracted from these models based on some of the methods discussed in chapter 3.

[64] We compute the mark-dollar model last since we experience several problems which are more easily discussed with reference to a succesful model.

CHAPTER 6

THE POUND STERLING EXCHANGE RATE MODEL

6.1 DATA DESCRIPTION AND THE BASIC VAR

Based on the above considerations, our model of the pound-dollar exchange rate is defined over five variables - the spot exchange rate, s_t defined as pounds per dollar (from the IMF's International Financial Statistics, line ae), the UK and US consumer price indices, p_t and p_t^* respectively (IFS line 64), the yield on 10 year UK government gilts (from CSO Financial Statistics), r_t, and the yield on constant maturity 10 year US Treasury bonds (IFS line 64), r_t^*. The data run from January 1974 to December 1992. There is continued debate in the literature about which is the most appropriate price index for analysing PPP. MacDonald and Marsh (1994*a*) find that, for the countries studied in this thesis, consumer prices are marginally superior to wholesale prices. For this reason we shall only examine CPIs.

In order to maintain comparability with the panel members, the initial determination of the model will only use data up to the end of September 1989, i.e. those observations available to the forecasters when they made their first predictions at the start of October 1989. This leaves 189 observations for the estimation of the model.

The five series are plotted in levels and first differences in Figures 40 through 49. Augmented Dickey-Fuller tests indicate that each series is non-stationary in levels but stationary after first differencing.[65]

The price series are seasonally adjusted at source, but there is evidence that this adjustment has failed to eradicate all traces of seasonality in the data (see Figure

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[65] The test statistics for levels and first differences are as follows: Sterling exchange rate -1.707 (2) and -12.749 (0), UK CPI -0.570 (6) and -3.030 (5), US CPI -0.480 (8) and -2.928 (5), UK bond yield -2.051 (2) and -9.439 (1), and US bond yield -1.491 (2) and -9.818 (1). The 5% critical value is approximately -2.89 and the figures in parentheses are the number of lagged differences added to ensure residual whiteness.

Figure 40 Pounds sterling per US dollar

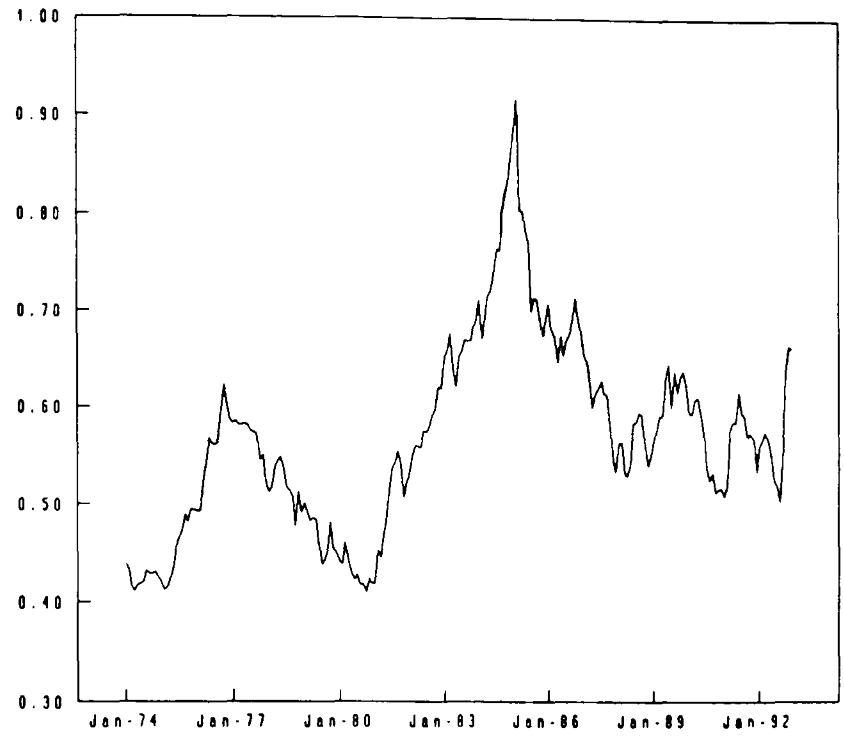
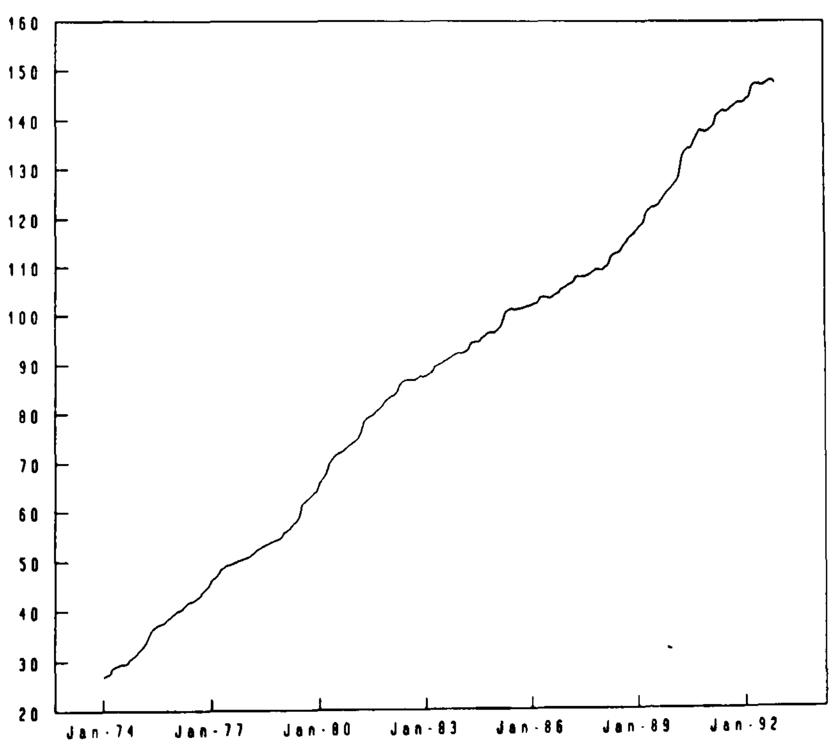


Figure 41 UK consumer price index



46). In all the results therefore, seasonal dummies have been included as additional deterministic series.

Figure 42 US consumer price index

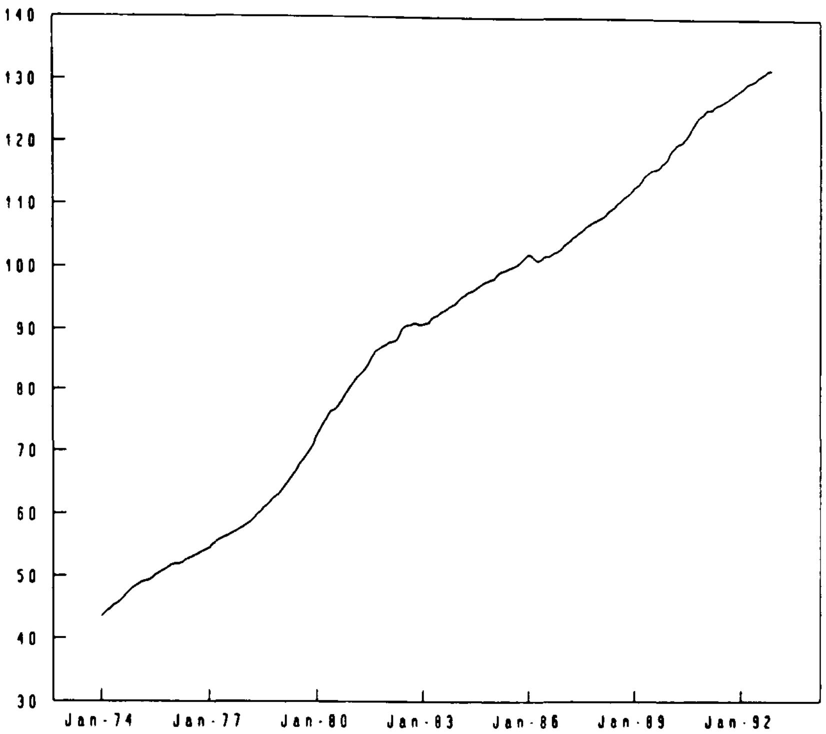
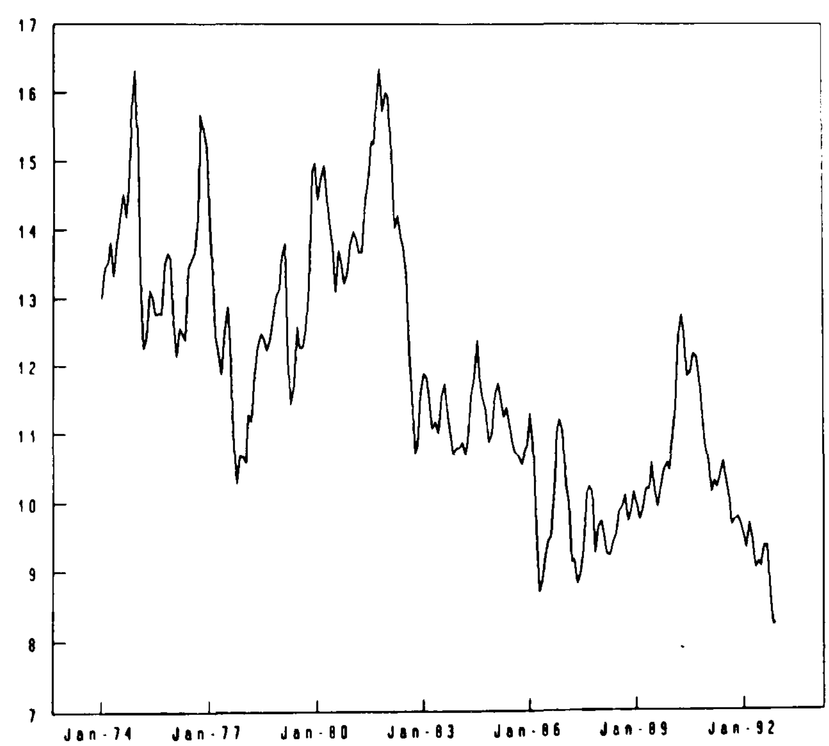


Figure 43 Yield on UK medium-term gilt bonds



Preliminary analysis indicates that a four lag VAR is sufficient to capture the dynamics of the system adequately. However, there is evidence of three substantial,

Figure 44 Yield on US long-term treasury bonds

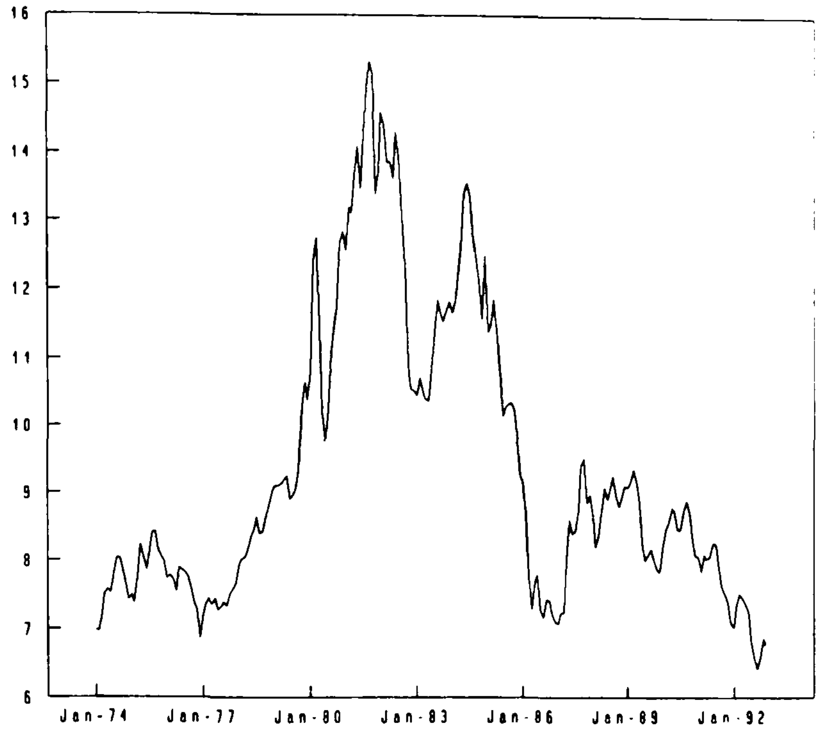
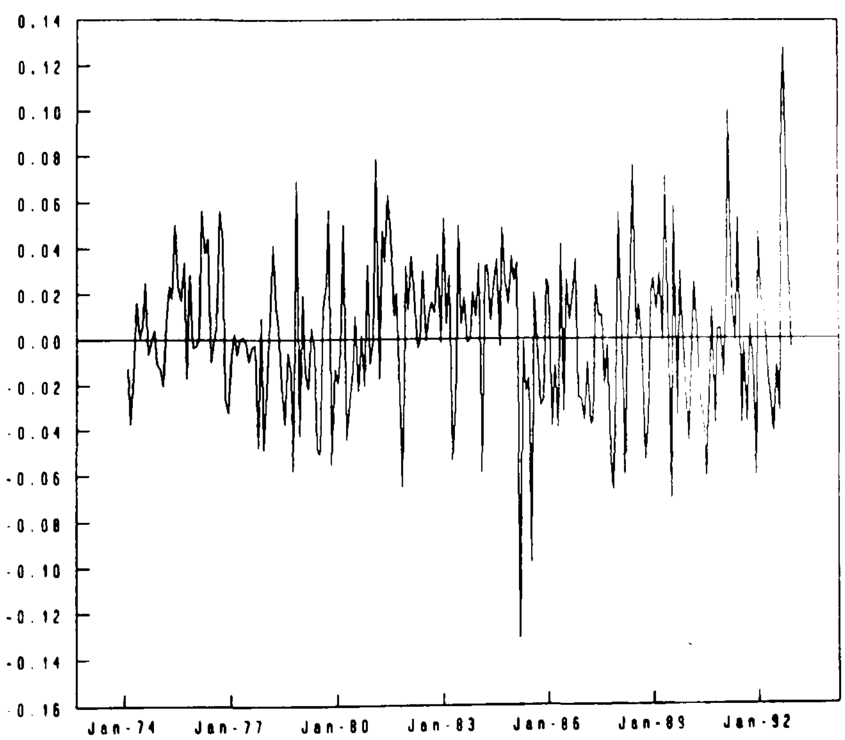


Figure 45 First difference of (log) sterling exchange rate



though explainable outliers in 1976:10 (UK interest rates, probably related to the sterling exchange rate crisis), 1979:07 (UK prices due to the VAT hike), and 1980:05

Figure 46 First difference of (log) UK consumer price index

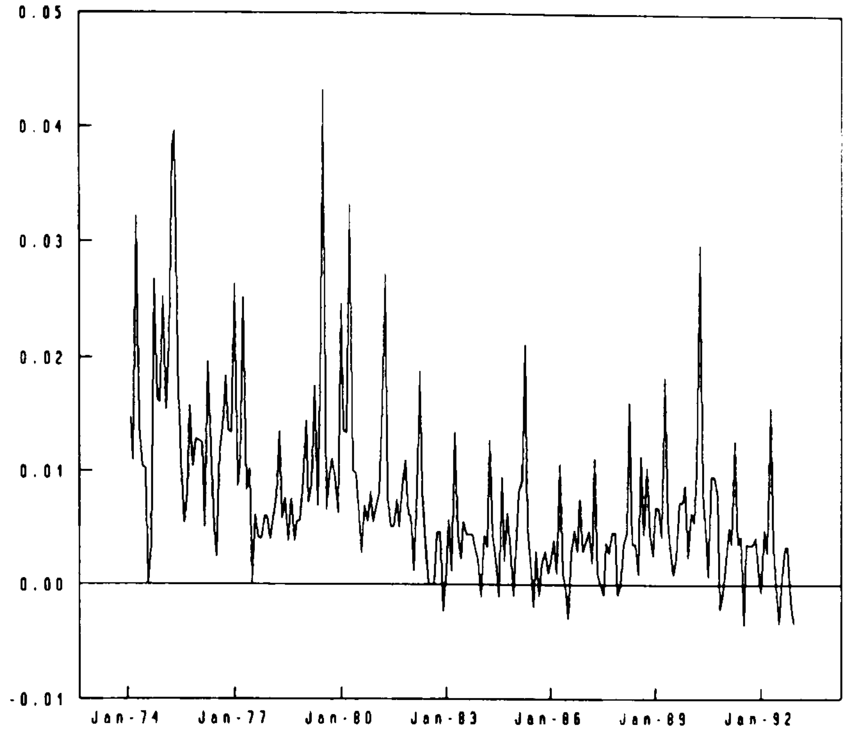
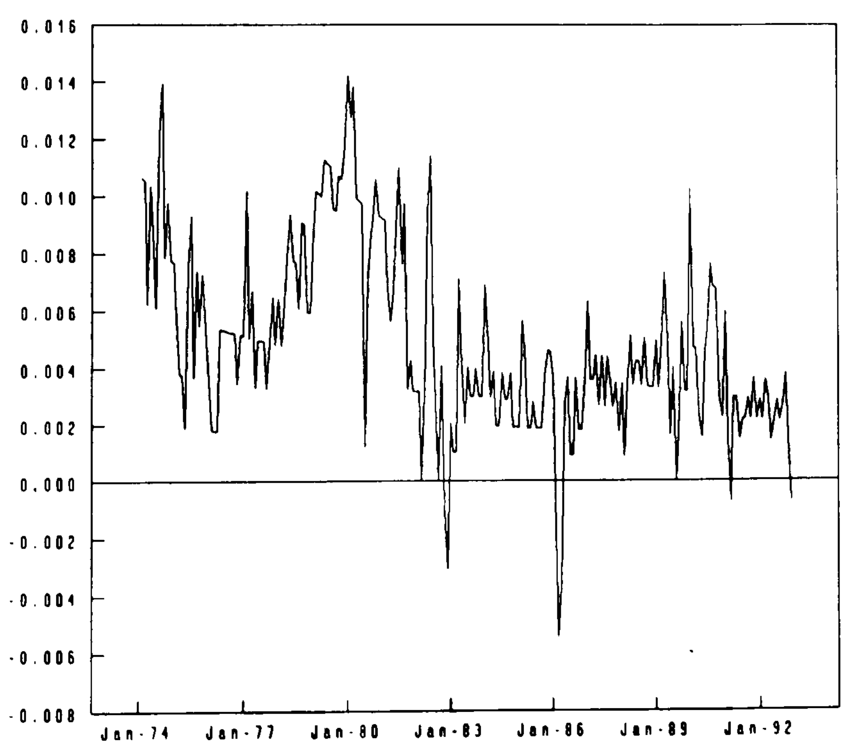


Figure 47 First difference of (log) US consumer price index



(US interest rates following Federal Reserve Board's switch to monetary targeting). These are eliminated by including three dummy variables that take the value of unity

Figure 48 First difference of UK gilt yield

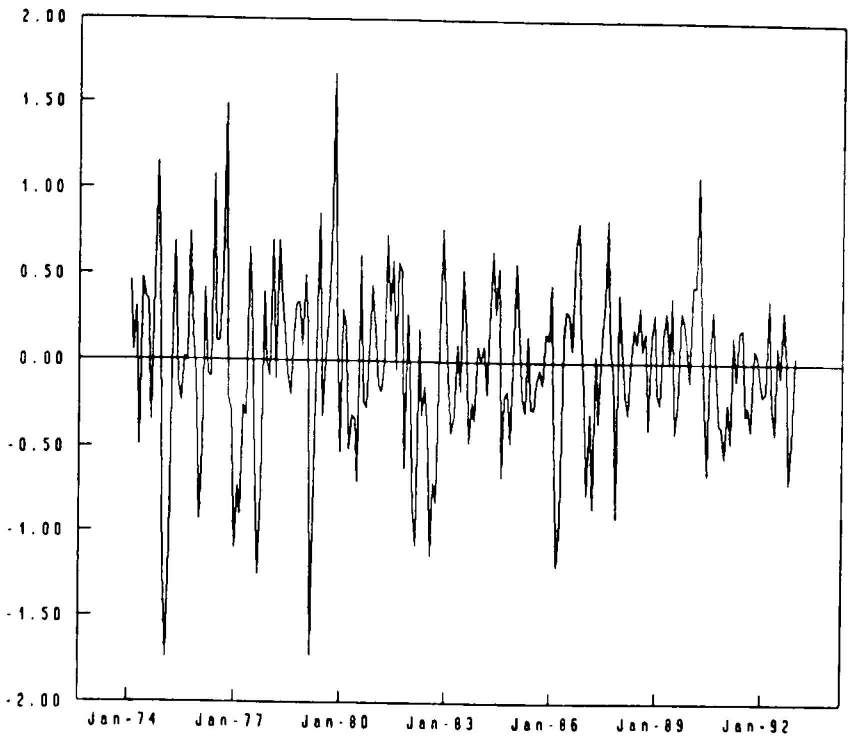
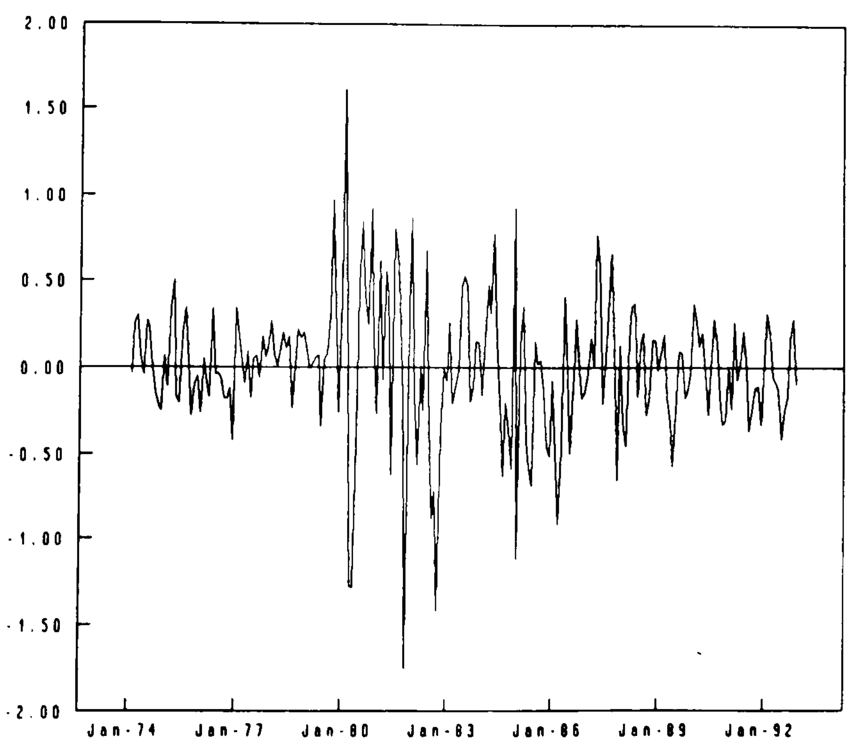


Figure 49 First difference of US treasury bond yield



on one of these dates and zero otherwise. The residuals of the UK price and US interest rate equations still contain a considerable number of relatively large residuals.

Removing these from the US interest rate equation in particular would need many extra dummies. The alternative of enlarging the system to model these influences would certainly be preferable but it is not apparent which variables would do this. Including one likely candidate, the oil price, as an exogenous variable unfortunately makes very little difference, despite success in other papers.

The impact of non-normal residuals on the cointegration test statistics is examined by Cheung and Lai (1993*a*). They conclude that the trace statistic shows little bias in the presence of non-normality and is more robust than the maximal eigenvalue test. Gonzalo (1990) investigates the effect of non-normality on the estimated cointegrating vectors from a range of cointegration procedures. Concluding that the Johansen maximum likelihood approach is superior when the errors are well behaved, he notes that this remains true even when errors are non-normal. This is not to say the approach is without problems as small biases in the estimated vectors can still occur. However, in the absence of any reasonable method for 'correcting' the non-normality we proceed, but stress that our results should always be qualified by a caveat regarding the validity of the long-run estimates.

6.2 COINTEGRATION TESTS AND RESTRICTIONS ON LONG-RUN EQUILIBRIA

The cointegration test statistics, together with the cointegrating vectors (beta) and loadings (alpha) are reported in Table 21.[66] The fitted model contains an unrestricted constant term but we have no way of telling whether the true data generating process also contains a constant. Unfortunately, the critical values of the Johansen test depend on whether the DGP does or does not contain a constant. The only solution is to compare the test statistics with both sets of critical values. The critical values reported in the table are from Osterwald-Lennum (1992) and assume that the model is correctly parameterised (i.e. the DGP also contains a constant term).

[66] The Johansen cointegration analysis carried out in this and the two following chapters is computed with the *CATS in RATS* routine kindly supplied by Katerina Juselius, and run on *RATS* version 3.11.

Both the maximal eigenvalue and trace tests indicate the presence of two cointegrating vectors at the 5% significance level.

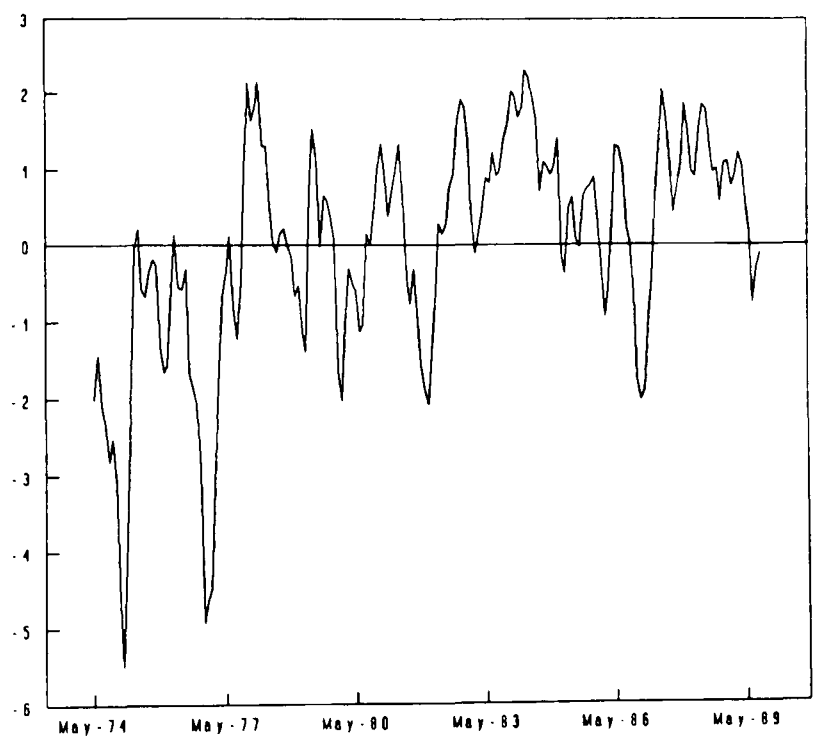
Table 21
Cointegration Analysis - Pound Sterling

		Test statistics		5% Critical values	
	Eigenvalues	Maximal Eigenvalue	Trace	Maximal Eigenvalue	Trace
$r \leq 4$	0.012	2.22	2.22	8.18	8.18
$r \leq 3$	0.069	13.25	15.47	14.90	17.95
$r \leq 2$	0.082	15.88	31.34	21.07	31.52
$r \leq 1$	0.144	28.73*	60.07*	27.14	48.28
$r = 0$	0.214	44.60*	104.67*	33.32	70.60
	Vector 1	Vector 2	Vector 3	Vector 4	Vector 5
	Standardised eigenvectors (betas)				
s	1.000	1.000	1.000	1.000	1.000
p	-2.332	-0.021	4.951	-6.157	1.660
p^*	4.425	0.254	-4.897	7.955	-4.158
r	46.158	0.073	37.233	-7.668	-8.995
r^*	-27.368	-4.177	2.485	11.420	11.765
	Standardised loadings (alphas)				
s	-0.021	-0.064	-0.000	0.010	-0.001
p	0.004	-0.002	-0.001	0.001	-0.000
p^*	0.000	-0.003	0.000	-0.001	0.000
r	-0.003	0.000	-0.002	-0.000	0.000
r^*	-0.001	-0.004	-0.000	-0.002	-0.001

NOTES: An asterisk denotes significance at the 5% level. The vectors are in decreasing order of eigenvalue in the lower section of the table.

If we instead assume that the model is overparameterised, the trace statistic indicates that there may be as many as four significant vectors, although this is very marginal. The maximal eigenvalue test still indicates two vectors. While the non-normality of the residuals make us more likely to trust the trace test results there are two further factors that point towards there being only two significant vectors. First, the test statistics are asymptotic. We have a relatively small sample and can expect the test statistics to rise if we were to take account of this fact, which would point towards fewer significant vectors.[67] Second, Johansen and Juselius (1992*a*) emphasise the use of common sense by plotting the residuals of each vector. The residuals of the third and fourth vectors do not appear stationary, and we proceed on the basis of two significant cointegrating vectors.

Figure 50 Residuals of first cointegrating vector



Deviations from these long-run equilibria are plotted in Figures 50 and 51, and the deviations corrected for short-term dynamics in Figures 52 and 53. Note that the residuals from the second vector do not appear stationary until the dynamics are

[67] Cheung and Lai (1993*a*) provide adjustments to account for sample sizes based on the work of Reinsel and Ahn (1988) but only for the case when the model is correctly specified and contains a constant term.

Figure 51 Residuals of second cointegrating vector

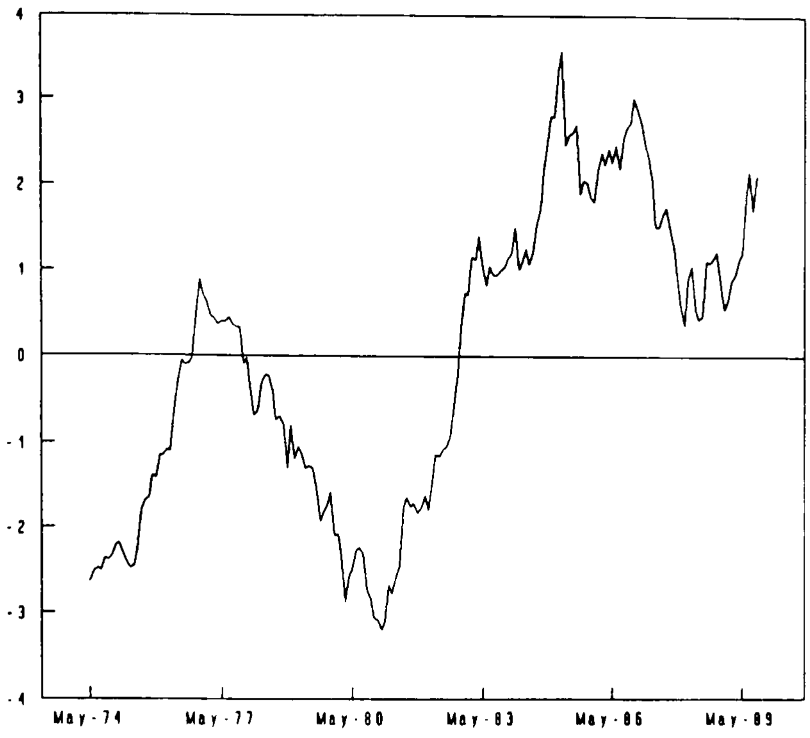
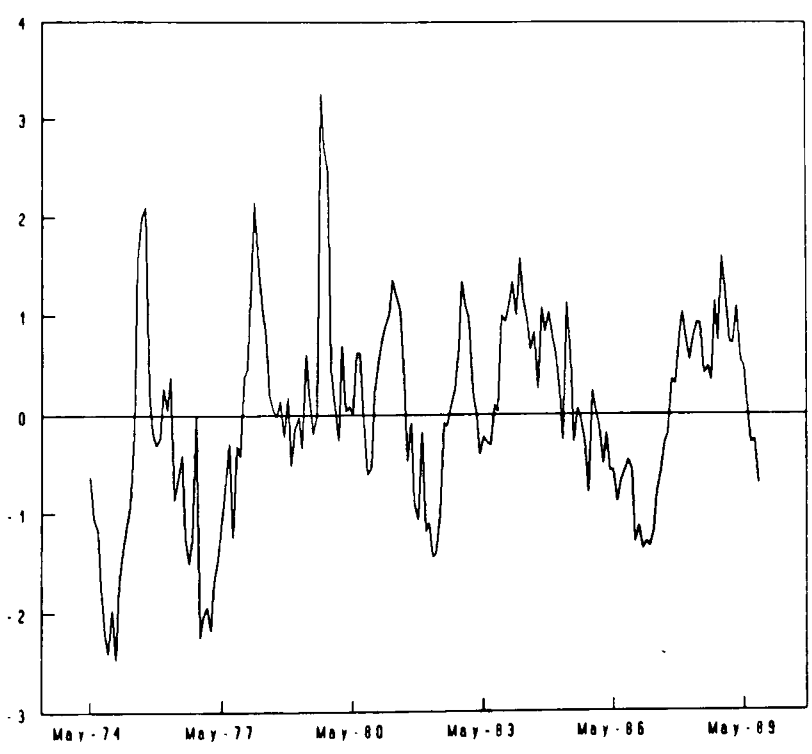
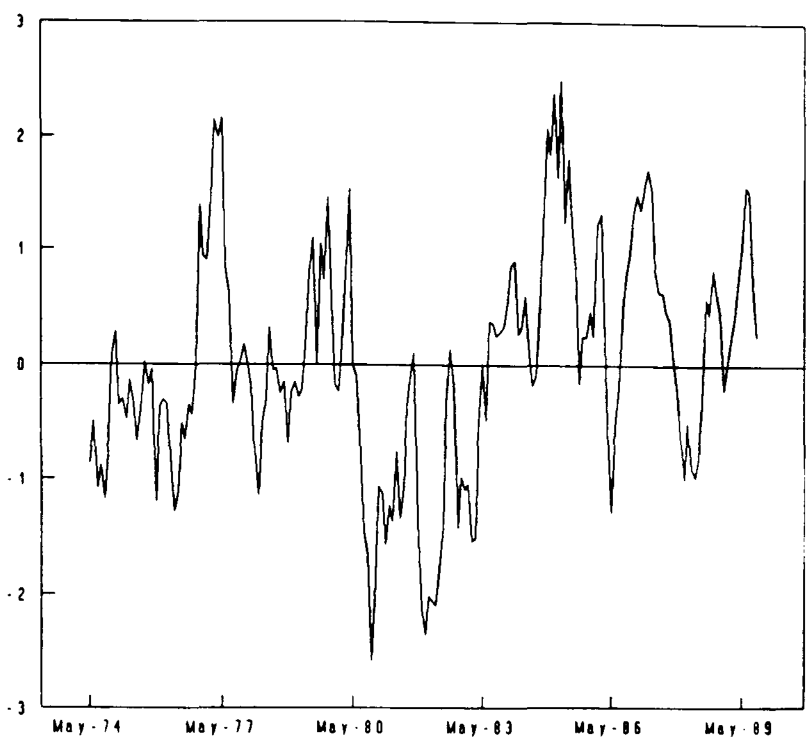


Figure 52 Corrected residuals of first cointegrating vector



corrected for. Johansen and Juselius (1992*a*) recognise that this is likely to be the case if the short-run dynamics are substantially different from those that hold in the

Figure 53 Corrected residuals of second cointegrating vector



long-run. Given the impact of noise traders, government intervention, and the possibility of overshooting, such differences are only to be expected.

The associated loading vectors indicate that the exchange rate is bearing the brunt of the adjustment to any disequilibrium, whereas the effect on prices and interest rates is more muted. The upper panel of Table 22 contains the results of tests that each element of the system is weakly exogenous with respect to the two long-run cointegrating vectors (see Johansen (1992) and Urbain (1992)). This procedure involves testing whether $\alpha_i = 0$ in both significant vectors, where α_i is the i-th element of α. Interestingly, we find that both of the US terms are weakly exogenous. That is, neither US prices nor US bond yields react to restore the system to equilibrium. The burden of adjustment is carried by the exchange rate, UK prices and gilt yields. The fact that UK prices and interest rates are not weakly exogenous indicates that we cannot efficiently analyze the exchange rate in a single equation.

Table 22
Restrictions on Cointegrating Vectors - Pound Sterling

	Weak exogeneity	
	Test Statistic	Marginal Significance
α_s	17.26	0.00
α_p	16.97	0.00
α_{p^*}	4.60	0.10
α_r	7.85	0.02
α_{r^*}	3.52	0.17
	Restrictions on beta matrix	
	Test Statistic	Marginal Significance
Hypothesis A	14.69	0.00
Hypothesis B	13.93	0.00
Hypothesis C	2.74	0.10
Hypothesis D	16.10	0.00

NOTES: See text for details of the tests performed. The weak exogeneity tests are asymptotically $\chi^2(2)$ distributed on the null. Hypotheses A, B, C, and D are asymptotically $\chi^2(3)$, $\chi^2(2)$, $\chi^2(1)$, and $\chi^2(4)$ distributed respectively.

We have hypothesised that PPP may hold in the long-run, and have noted the consistent sign pattern of the price and exchange rate elements of the two significant vectors. If strong-form PPP is itself a cointegrating relationship then the vector (1, -1, 1, 0, 0)' must lie in the space spanned by the two cointegrating vectors (Hypothesis A). From the discussion in section 5.4, we may not wish to be so restrictive and instead allow the interest differential to enter the vector. Hence we test whether (1, -1, 1, a, -a)' forms a stationary relationship (Hypothesis B). Relaxing the constraint on the interest rate terms we also test whether the vector (1, -1, 1, a, b)' lies in the cointegrating space (Hypothesis C). Finally, we test Hypothesis D, that PPP enters both vectors (with the interest rates unconstrained). That is, we test whether the two cointegrating vectors can be restricted to be of the form (1, -1, 1, a, b)' and (1, -1, 1, c, d)'. The results of these tests are given in the lower panel of Table 22. With the exception of the hypothesis that PPP augmented by unconstrained interest rates is stationary, we can reject each restriction at the five percent level.

Table 23 details the cointegrating vectors and the associated adjustment coefficients that emerge from restricting the coefficients on the price terms in one vector. It is noticeable that even the unconstrained vector closely resembles a PPP relationship, even though this restriction is rejected.[68] The residuals from these restricted cointegrating vectors, corrected for short-run dynamics, are given in Figures 54 and 55.

Table 23
Restricted Cointegrating Vectors - Pound Sterling

	Standardised restricted vectors	
	β_1	β_2
s	1.000	1.000
p	-1.000	-1.039
p^*	1.000	1.597
r	-25.218	-1.083
r^*	8.202	-3.747
	Standardised adjustment vectors	
	α_1	α_2
s	0.043	-0.118
p	-0.007	0.011
p^*	-0.001	-0.003
r	0.006	-0.007
r^*	0.002	-0.007

[68] Note that Taylor (1988*b*) and Patel (1990) argue that measurement error and transport costs may drive the coefficients on prices away from unity (in absolute value).

Figure 54 Corrected residuals of first restricted vector

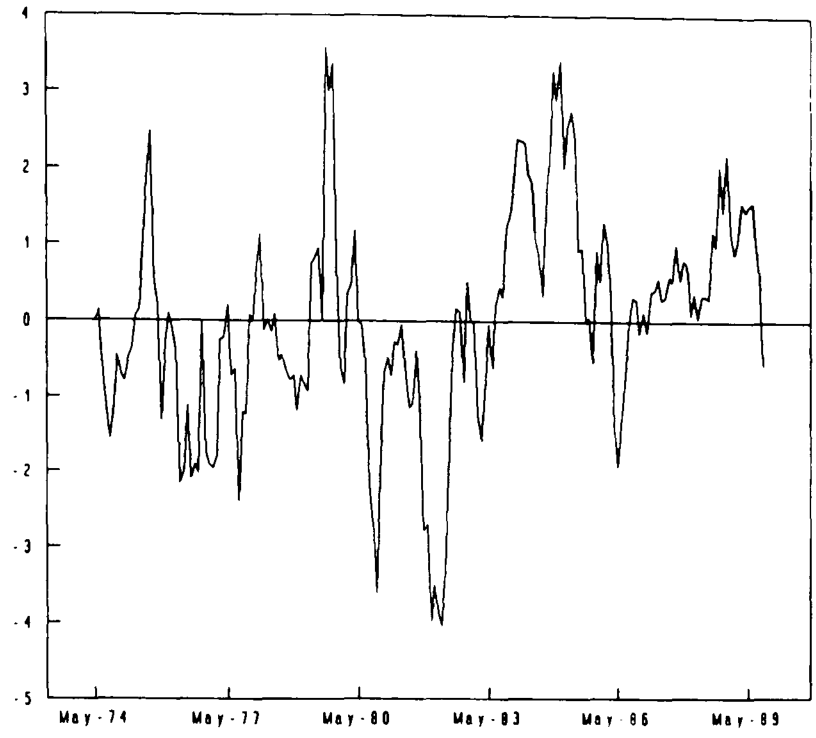
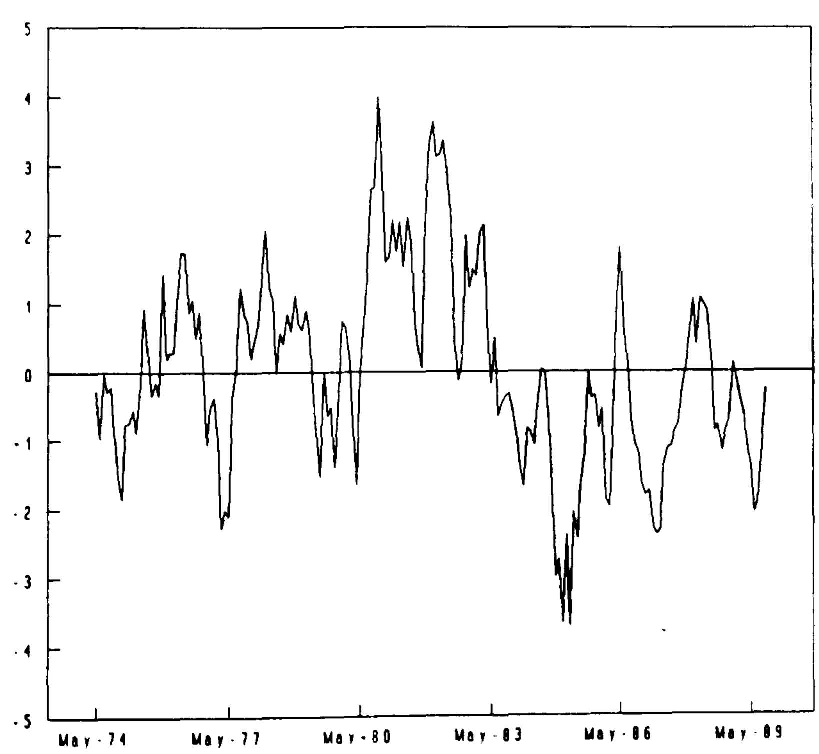


Figure 55 Corrected residuals of second restricted vector



6.3 THE PARSIMONIOUS VAR

Once the long-run economic relationships have been determined, the next step is to establish a more parsimonious representation of the system against which the structural model can be evaluated. The original VAR in levels is transformed to $I(0)$ by first differencing. The two cointegrating relationships termed *ecm1* and *ecm2*, and defined as $ecm1_t = \Delta s_t - \Delta p_t + \Delta p^*_t - 25.218\Delta r_t + 8.202\Delta r^*_t + ecm1_{t-1}$, and $ecm2_t = \Delta s_t - 1.039\Delta p_t + 1.597\Delta p^*_t - 1.083\Delta r_t - 3.747\Delta r^*_t + ecm2_{t-1}$, are introduced as additional $I(0)$ terms. This maintains the long-run information that would otherwise be lost if the data were simply differenced to induce stationarity. This constrained VAR (CVAR) contains seven endogenous variables (Δs_t, Δp_t, Δp^*_t, Δr_t, Δr^*_t, $ecm1_t$, and $ecm2_t$), the three dummy variables, seasonal dummies and constants.[69] The endogenous variables are determined by five stochastic equations and two identities.

Next we simplify the CVAR by removing insignificant lagged variables using standard F-tests of the restriction that the coefficient on a variable is zero in each of the five equations.[70] F-tests on the retained regressors are given in Table 24. Each dummy variable is significant, as are the two error correction terms. Conversely, all lagged changes in the exchange rate prove insignificant. Table 25 presents tests to determine whether the residuals are normally distributed and serially uncorrelated in each equation. There is marginal evidence of autocorrelation in the residuals of the US price equation, and substantial evidence of non-normality in the UK price and US interest rate residuals. The latter remains from the specification of the original VAR. However, the exchange rate equation in particular appears to be free of problems, and there is little deterioration in the standard errors of the equations in moving from the CVAR to a more parsimonious structure. Furthermore, the trace correlation (analogous to $\sqrt{R^2}$) and vector alienation coefficient (analogous to $1-R^2$) are 0.596 and

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[69] The original VAR in levels (or in its equivalent differenced form) is what Hendry and Mizon (1993) term the unconstrained VAR or UVAR. Since we have restricted the parameters of one of the cointegrating vectors we term the first difference version of the VAR the constrained VAR or CVAR.

[70] One extra lag of Δr^* is also included since it proves to be marginally significant in the PVAR, though not in the VAR used to estimate the cointegrating vectors.

0.066 respectively, indicating that this system fits the data well.[71] Fixed-point Chow tests of parameter constancy show that the estimated parameters remain reasonably constant (see Hendry (1989)).

Table 24

F-tests On Retained Regressors [F (5, 159)] Pound Sterling

	$ecm1_{t-1}$	$ecm2_{t-1}$	Δp_{t-1}	Δp^{*}_{t-1}	Δr_{t-1}
F-Test	9.74	7.03	5.16	10.47	4.94
Marg. Sig.	0.000	0.000	0.000	0.000	0.000
	Δr^{*}_{t-1}	Δr^{*}_{t-2}	Δp_{t-3}	Δr^{*}_{t-3}	Δr^{*}_{t-4}
F-Test	2.29	4.73	3.11	2.26	2.26
Marg. Sig.	0.049	0.001	0.011	0.051	0.051
	dum76:10	*dum79:07*	*dum80:05*		
F-Test	14.98	3.03	2.85		
Marg. Sig.	0.000	0.012	0.017		

[71] These are only marginally worse than the equivalent statistics for the CVAR, where the vector alienation coefficient takes the value 0.05 and the trace correlation is 0.625.

Table 25
Diagnostic Tests of the CVAR and PVAR - Pound Sterling

	CVAR			PVAR		
	Std. Dev.	Normality	S.C.	Std. Dev.	Normality	S.C.
Δs	0.02849	2.322	8.328	0.02893	3.472	9.768
Δp	0.00391	242.524*	7.837	0.00403	410.322*	12.653
Δp^*	0.00199	1.056	20.831	0.00200	0.980	21.512*
Δr	0.00396	0.252	14.587	0.00408	0.085	17.060
Δr^*	0.00370	28.426*	18.361	0.00380	44.495*	14.310

NOTES: The columns headed Std. Dev. give the standard deviation of the equation residuals. The normality tests are asymptotically $\chi^2(2)$ distributed on the null. The columns headed S.C. are tests of 12th order serial correlation and are asymptotically $\chi^2(12)$ distributed on the null. An asterisk denotes significance at the five percent level.

Following these simplifications of the system there are 65 coefficients to be estimated in this $I(0)$ parsimonious VAR (PVAR), plus constants and seasonal dummies. The purpose of the intermediary step of constructing the PVAR is to obtain a data coherent system against which structural econometric models (SEM) - a system of potentially simultaneous equations for each variable - can be evaluated (see Hendry *et al* (1988)). On the evidence of the above results, our PVAR has attained this standard. However, despite eliminating 40 insignificant lagged terms this PVAR is still rather large. The next step is to model the individual equations of the system in an effort to reduce the dimensionality and sample dependence of the system whilst increasing its robustness to change (see Hendry and Doornik (1994)).

6.4 THE STRUCTURAL ECONOMETRIC MODEL

Ideally, the SEM equations should be economically meaningful and interpretable. Economic theory and the nature of the foreign exchange market give us certain priors. In the first instance, we would expect a high degree of simultaneity in the system, primarily because it contains three highly related asset prices. We might also suppose that the US variables would react primarily to US events.

However, there is very little economic knowledge that can be applied to determining the dynamic structures, and the almost mechanical general-to-specific single equation approach cannot be followed due to identification problems. Single equation regressions can provide a good starting point but the simultaneity bias frequently proves substantial. Nevertheless, the final equations are, we feel, reasonably robust.[72] Details of each equation, estimated by FIML, are given in Table 26.

The equations are relatively parsimonious with only 27 estimated coefficients in all (excluding seasonals and constants). Each equation contains at least one contemporaneous term which helps to explain the simultaneity bias problems. The dummy variables, although initially included as a result of large residual outliers in a single equation of the VAR are each found to be significant in several of the SEM equations. Encouragingly, the error correction terms are present in three of the five equations, and in each case are highly significant. They do not appear in the equations for the US variables, which accords with the weak exogeneity tests reported above. The coefficients on the error correction terms are very small, however, indicating that the correction of any disequilibrium is slow.

The exchange rate equation is particularly simple with only an error correction term and two contemporaneous variables significant. A rise in US prices has a large negative impact on the exchange rate (an appreciation of sterling), whereas rising gilt yields are associated with a fall in the value of the pound. Note that it is the second, unrestricted error correction term that enters the exchange rate equation. This is in accordance with the sign of the adjustment coefficients of the restricted cointegrating vectors given in Table 23. The value of α_{1s} is positive indicating that, if significant, the exchange rate is moving away from equilibrium. In the second vector, the large negative value of the alpha coefficient points to an exchange rate adjustment to restore equilibrium.

[72] Each model is estimated at least twice. If different equations result, an encompassing equation containing all terms is first estimated and then reduced to parsimony.

Table 26

SEM Equations - Pound Sterling

Equation	Variable	Coefficient	Std. Dev.	t-ratio
Δs_t	Δp^*_t	-5.54149	1.44822	3.826
	Δr_t	2.95911	0.88224	3.354
	$ecm2_{t-1}$	-0.07586	0.01720	4.410
Δp_t	Δs_t	-0.11872	0.03938	3.014
	Δr_t	0.43322	0.17276	2.508
	Δr^*_t	-0.55119	0.23921	2.304
	Δp_{t-1}	0.26558	0.05610	4.734
	Δp_{t-3}	0.15726	0.05231	3.006
	dum79:07	0.03515	0.00416	8.444
	dum80:05	-0.01560	0.00549	2.840
	$ecm1_{t-1}$	-0.00641	0.00105	6.104
Δp^*_t	Δs_t	0.05263	0.01796	2.930
	Δp_t	0.09730	0.04437	2.193
	Δp^*_{t-1}	0.64578	0.06851	9.426
	Δr^*_{t-3}	0.12450	0.04252	2.928
Δr_t	Δr^*_t	0.44136	0.16428	2.687
	Δp_{t-1}	0.12227	0.05425	2.254
	Δr_{t-1}	0.36247	0.06005	6.036
	dum76:10	-0.00842	0.00402	2.095
	dum79:07	0.01591	0.00404	3.939
	$ecm1_{t-1}$	0.00719	0.00125	5.744
	$ecm2_{t-1}$	-0.01041	0.00249	4.178
Δr^*_t	Δp^*_t	0.47557	0.11751	4.047
	Δr^*_{t-1}	0.19461	0.06644	2.929
	Δr^*_{t-2}	-0.29662	0.06860	4.324
	Δr^*_{t-4}	-0.12423	0.06375	1.949
	dum80:05	-0.01151	0.00399	2.885

NOTES: *All equations contain a constant term and seasonal dummies.*

Table 27
Diagnostic Tests of PVAR and SEM - Pound Sterling

	PVAR			SEM		
	Std. Dev.	Normality	S.C.	Std. Dev.	Normality	S.C.
Δs	0.02893	3.472	9.768	0.03135	3.302	11.178
Δp	0.00403	410.322*	12.653	0.00557	359.740*	12.414
Δp^*	0.00200	0.980	21.512*	0.00276	1.729	21.219*
Δr	0.00408	0.085	17.060	0.00399	0.314	14.304
Δr^*	0.00380	44.495*	14.310	0.00375	33.992*	18.020

NOTES: *See notes to Table 25.*

Some comments can be made on the form of the other four equations. Interest rate changes both home and abroad have a large impact on UK prices, with rising UK rates causing prices to rise. In both the UK and US, prices and interest rates seem heavily influenced by their own history. UK bond rates also climb when British prices or US yields rise. US bond rates do not react to gilt yields, although rising US prices push them higher.

Residual diagnostics are given in Table 27. They show no significant deterioration from those of the PVAR, and indeed the standard error of the two interest rate equations has fallen. Furthermore, the encompassing test based on the 38 over-identifying restrictions imposed in moving from the PVAR to the SEM gives a test statistic of 38.624 (see Clements and Mizon (1991) and Hendry and Mizon (1993)). This is well below the $\chi^2(38)$ 5% critical value of 53.38 implying that we cannot reject the hypothesis that the set of structural equations encompasses the statistical system (PVAR).[73] We conclude that the modelling exercise has successfully resulted in a set of structural equations that explain the data well.

The next, and in our view most important, question is whether it can predict the data equally well. Without carrying out the evaluation procedures detailed in earlier chapters, we can get a feel for the validity of the forecasts from two tests of

[73] A χ^2 test on the 78 overidentifying restrictions from the CVAR returns a test statistic of 88.518, also well below the 5% critical value.

one-step-ahead predictions detailed in Hendry (1989). The simultaneous equations are first transformed to a set of reduced form equations from which the single-step forecasts are generated. The cumulative index of parameter constancy over the forecast period ($\chi^2(195)/195 = 0.972$) and the forecast test based on the forecast error variance ($F(195, 159) = 0.882$) are well below their respective critical values indicating sound out-of-sample performance. The predictions of the model are evaluated in more detail in chapter 9.

CHAPTER 7

THE JAPANESE YEN EXCHANGE RATE MODEL

7.1 DATA DESCRIPTION AND THE BASIC VAR

We follow an essentially identical procedure to create a forecasting model of the Japanese yen-US dollar exchange rate (IFS line ae). The US data are unchanged and we use the Japanese CPI (IFS line 64) and 10 year government bond yield (Nikkei data service) in place of the UK variables. The Japanese data are plotted in Figures 56 through 61 in levels and first differences. The new series all appear stationary after differencing, and this is supported by ADF tests.[74]

A three lag VAR is sufficient to describe the data, though three large outliers in the US bond equation remain and require dummies (1980:04, 1984:12 and 1985:01). The first is again related to the Fed's switch to monetary targetting, and the latter two coincide with the sharp reversal of the US dollar after several years of appreciation. The two interest rate series still exhibit signs of non-normality (and borderline serial correlation) but lengthening the VAR does not rectify the problem and using the argument advanced above for the pound sterling model we proceed.

7.2 COINTEGRATION TESTS AND RESTRICTIONS ON LONG-RUN EQUILIBRIA

The cointegration analysis reported in Table 28 indicates the presence of at least one and possibly three cointegrating vectors assuming the model is correctly specified. If the DGP does not in fact contain a constant, there may even be four vectors. However, if we use the small sample-adjusted trace test critical values only

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[74] Tests statistics for levels and first differences are as follows: Japanese yen -0.655 (1) and -6.406 (2), Japanese CPI -2.862 (8) and -3.354 (5), and Japanese bond yields -0.818 (6) and -7.421 (5). The 5% test statistic is approximately -2.89 and the figures in parentheses give the number of lags added to ensure residual whiteness.

the first two vectors are significant. This vector carries signs consistent with PPP and appears stationary when plotted (see Figures 63 and 65). Since the vectors associated with smaller eigenvalues appear non-stationary we shall proceed under the assumption of just two cointegrating vectors.

Figure 56 Japanese yen per US dollar

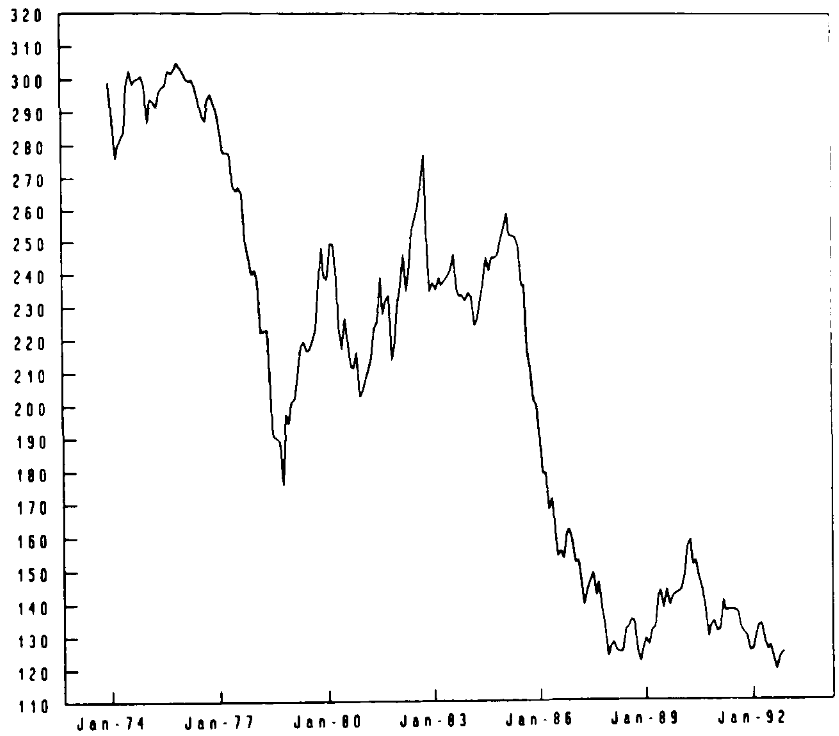


Figure 57 Japanese consumer price index

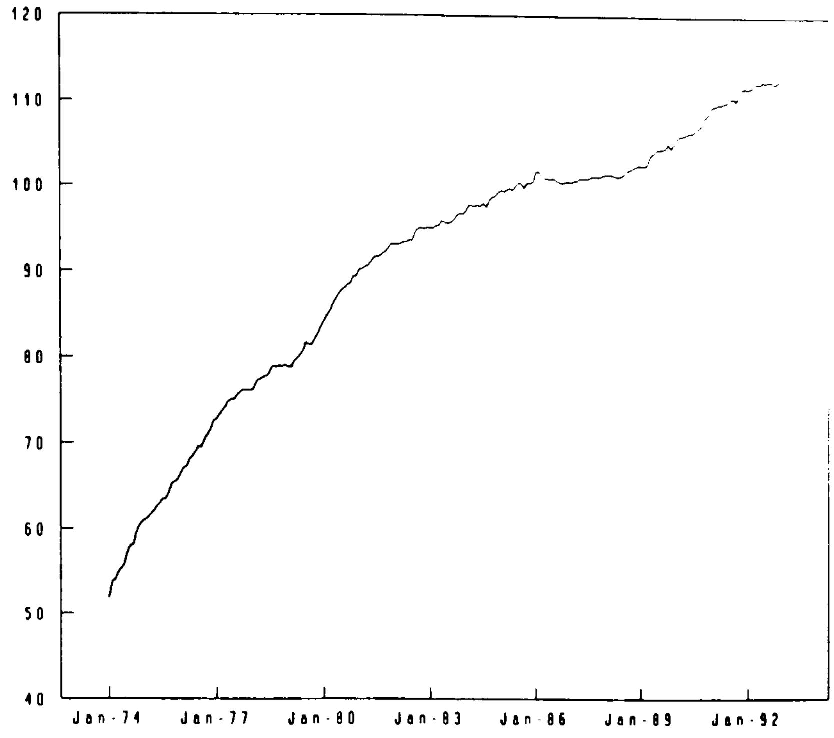


Figure 58 Japanese 8-10 year government bond yield

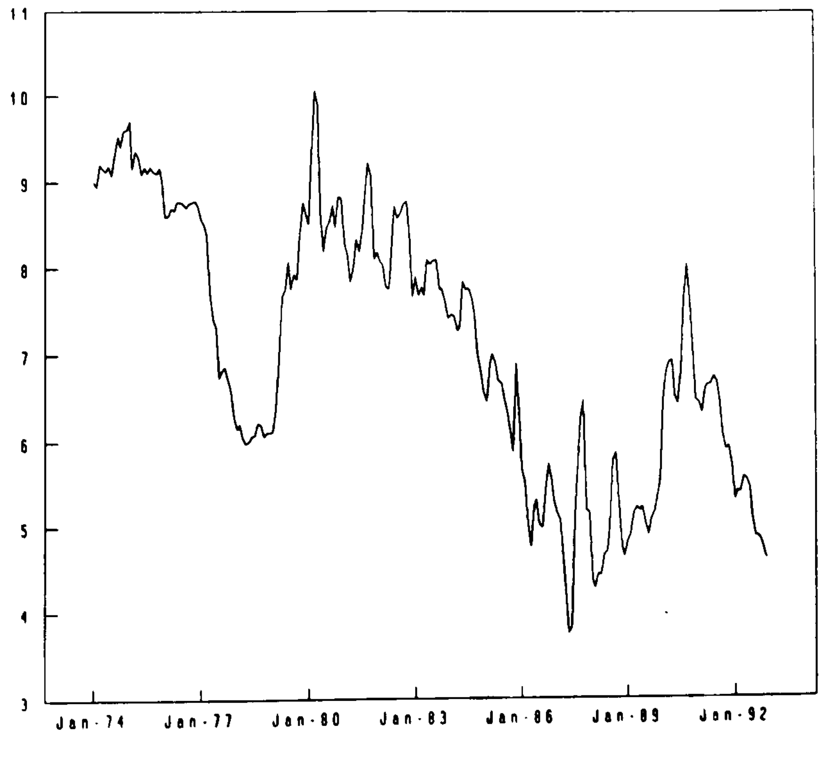


Figure 59 First difference of (log) yen exchange rate

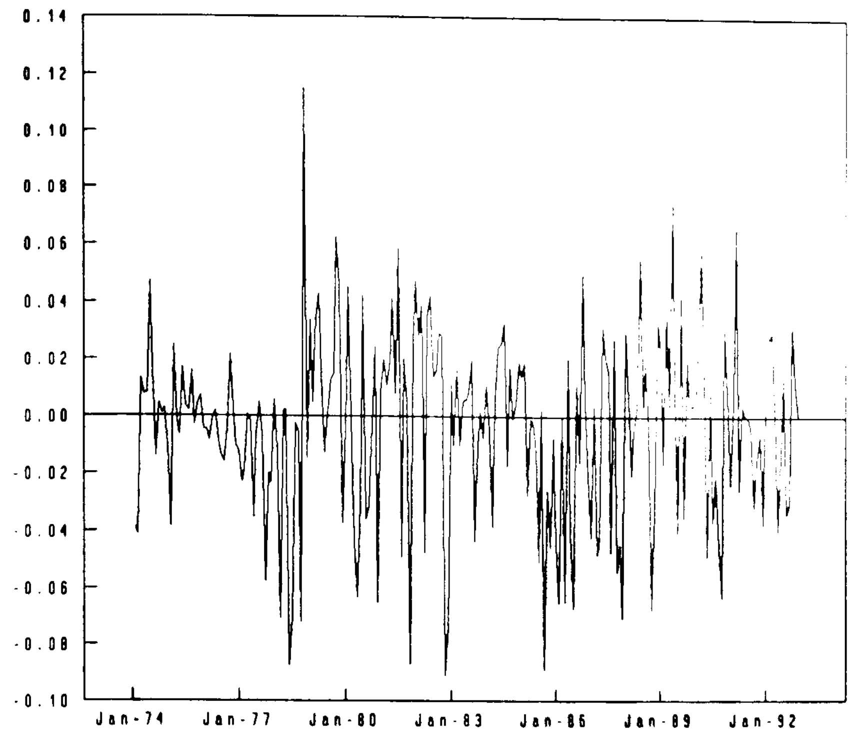


Figure 60 First difference of (log) Japanese CPI

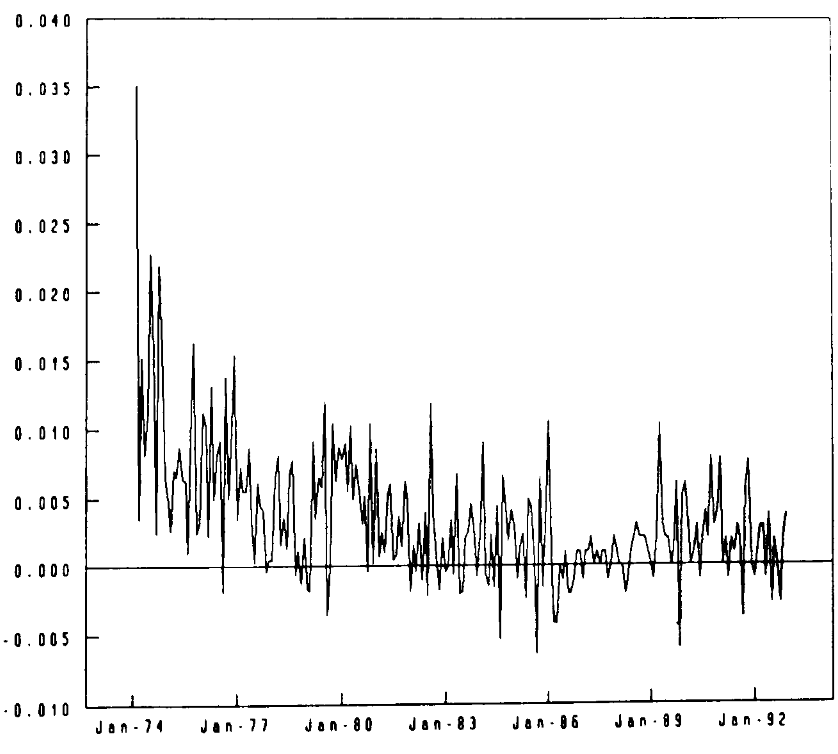


Figure 61 First difference of Japanese bond yield

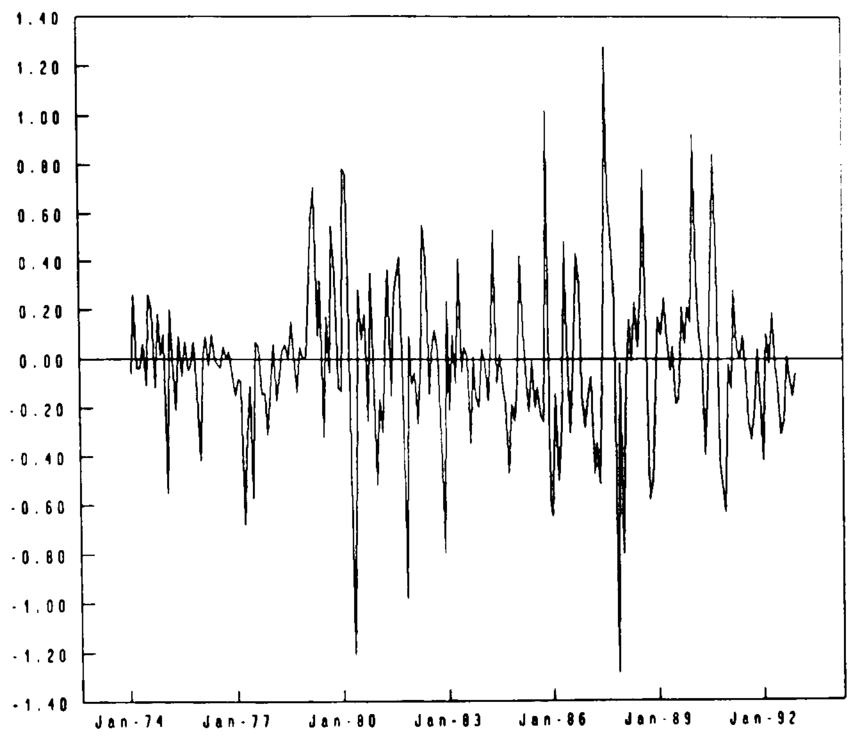


Table 28

Cointegration Analysis - Japanese Yen

	Eigenvalues	Test statistics: Maximal Eigenvalue	Test statistics: Trace	5% Critical values: Maximal Eigenvalue	5% Critical values: Trace
r ≤ 4	0.009	1.76	1.76	8.18	8.18
r ≤ 3	0.071	13.67	15.43	14.90	17.95
r ≤ 2	0.088	17.14	32.57*	21.07	31.52
r ≤ 1	0.114	22.59	55.16*	27.14	48.28
r = 0	0.302	66.84*	122.01*	33.32	70.60

	Vector 1	Vector 2	Vector 3	Vector 4	Vector 5
	Standardised eigenvectors (betas)				
s	1.000	1.000	1.000	1.000	1.000
p	-10.655	-1.518	12.215	21.088	0.924
p^*	6.124	1.329	-3.085	-27.805	-0.324
r	23.648	-14.622	51.940	-215.112	-3.927
r^*	-15.883	-0.777	-48.901	63.079	5.640
	Standardised loadings (alphas)				
s	0.003	-0.035	-0.014	-0.001	-0.004
p	0.004	-0.000	-0.000	0.000	0.000
p^*	-0.000	-0.004	-0.000	0.000	-0.000
r	-0.000	0.004	-0.001	0.000	-0.001
r^*	0.000	-0.003	0.000	0.000	-0.001

NOTES: *See Notes to Table 21.*

Figure 62 Residuals of first cointegrating vector

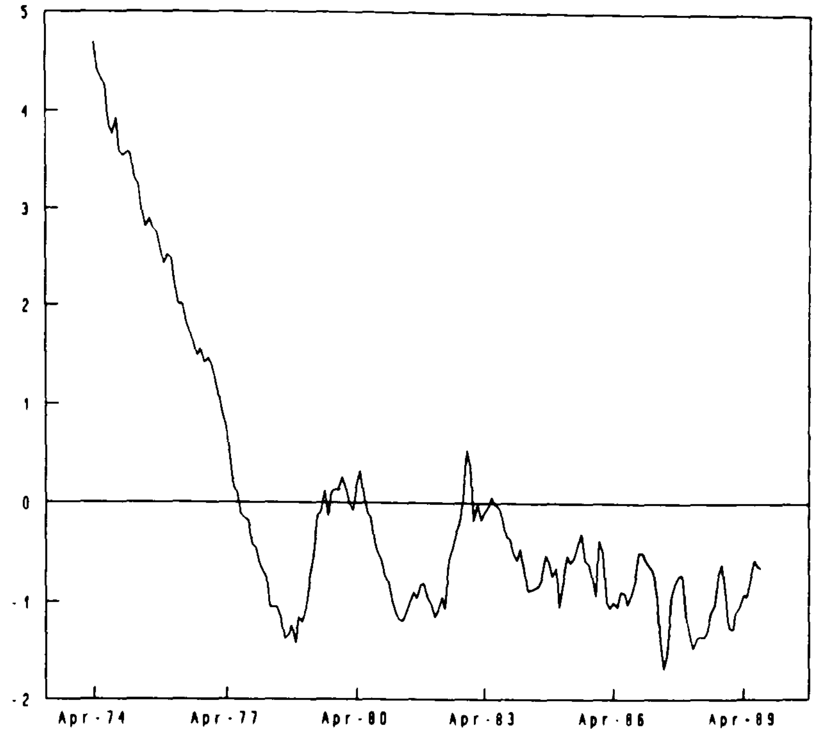


Figure 63 Residuals of second cointegrating vector

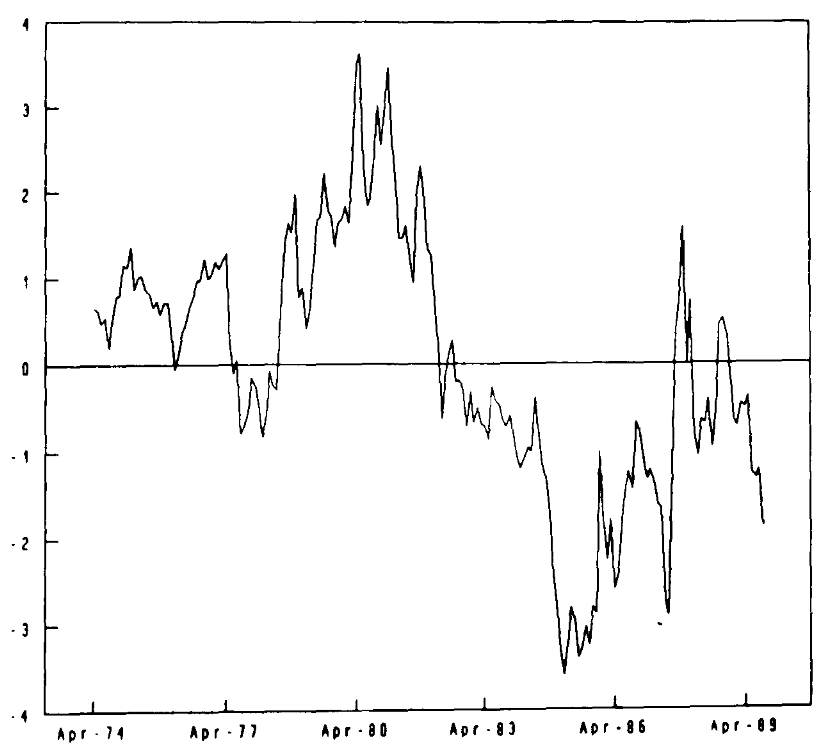


Figure 64 Corrected residuals of first cointegrating vector

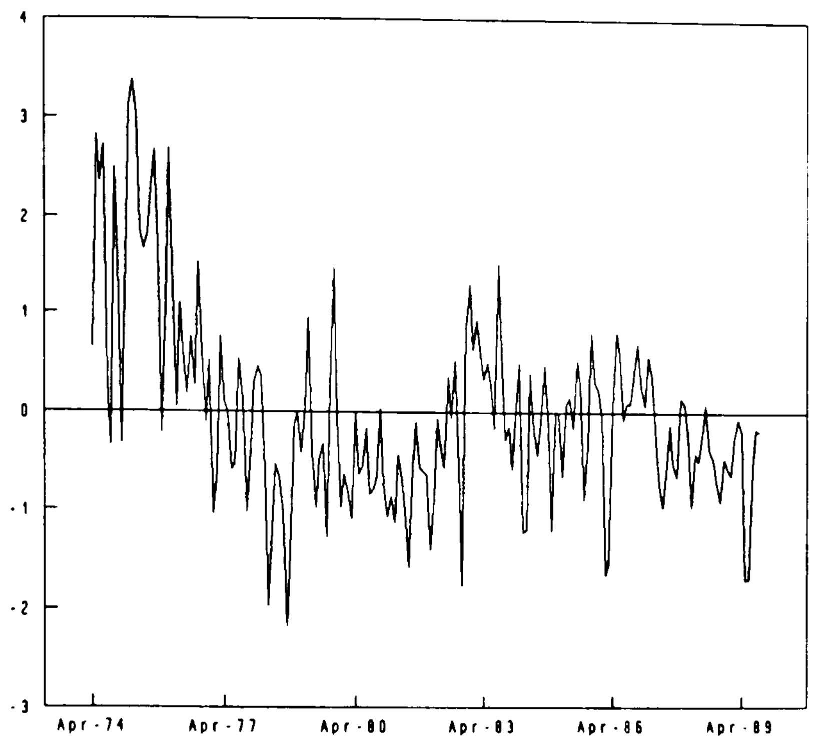
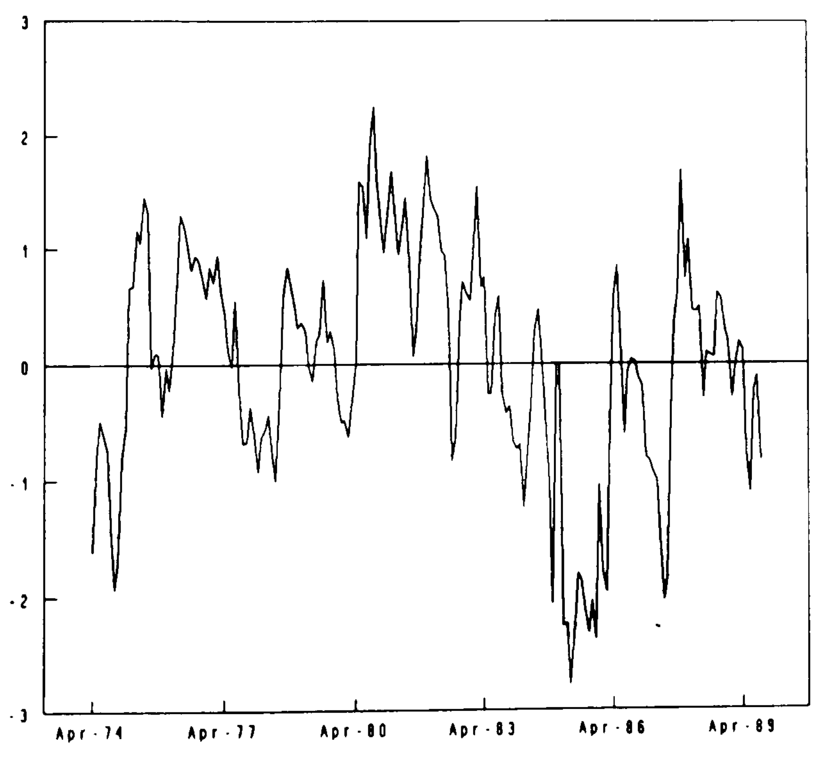


Figure 65 Corrected residuals of second cointegrating vector



The outcome of weak exogeneity tests are reported in Table 29. Interestingly, the exogeneity of the two price series cannot be rejected at the 15% level, while it can be for the exchange and interest rates at any reasonable level of marginal significance. The fact that the Japanese CPI series looks strongly endogenous indicates that it is domestic prices that are adjusting to disequilibrium rather than the exchange rate, which may be due to pricing to market behaviour by Japanese firms desperate to maintain market share in the face of a strengthening yen (see Athukorala and Menon (1994)).

Table 29

Restrictions on Cointegrating Vectors - Japanese Yen

	Weak exogeneity	
	Test Statistic	Marginal Significance
α_s	1.06	0.59
α_p	46.53	0.00
α_{p*}	4.26	0.12
α_r	1.59	0.45
α_{r*}	1.77	0.41
	Restrictions on beta matrix	
	Test Statistic	Marginal Significance
Hypothesis A	20.19	0.00
Hypothesis B	6.64	0.04
Hypothesis C	0.17	0.68
Hypothesis D	17.61	0.00

NOTES: *See Notes to Table 22.*

The tests of the four restrictions on the two beta vectors are reported in the lower section of Table 29. Again, we can reject each hypothesis with the exception of C. The PPP restrictions are imposed on just one vector and augmented by unconstrained interest rates. The restricted vectors are detailed in Table 30, and corrected residuals plotted in Figures 66 and 67. Once more we note the similarity of the second (unconstrained) vector to the PPP relationship.

Table 30
Restricted Cointegrating Vectors - Japanese Yen

	Standardised restricted vectors	
	β_1	β_2
s	1.000	1.000
p	-1.000	-5.225
p^*	1.000	3.248
r	-18.186	0.203
r^*	0.840	-6.521
	Standardised adjustment vectors	
	α_1	α_2
s	-0.031	0.003
p	-0.005	0.009
p^*	-0.003	-0.001
r	0.004	0.000
r^*	-0.003	0.000

7.3 THE PARSIMONIOUS VAR

In the same manner as for the pound sterling model we denote these two vectors by *ecm1* and *ecm2*. The VAR is transformed to stationarity by first differencing and the three dummies and two cointegrating vectors are included as additional $I(0)$ terms. This CVAR is then sequentially reduced to parsimony using F-tests. The significance tests of the remaining terms in the parsimonious VAR are given in Table 31.

Figure 66 Corrected residuals of first restricted vector

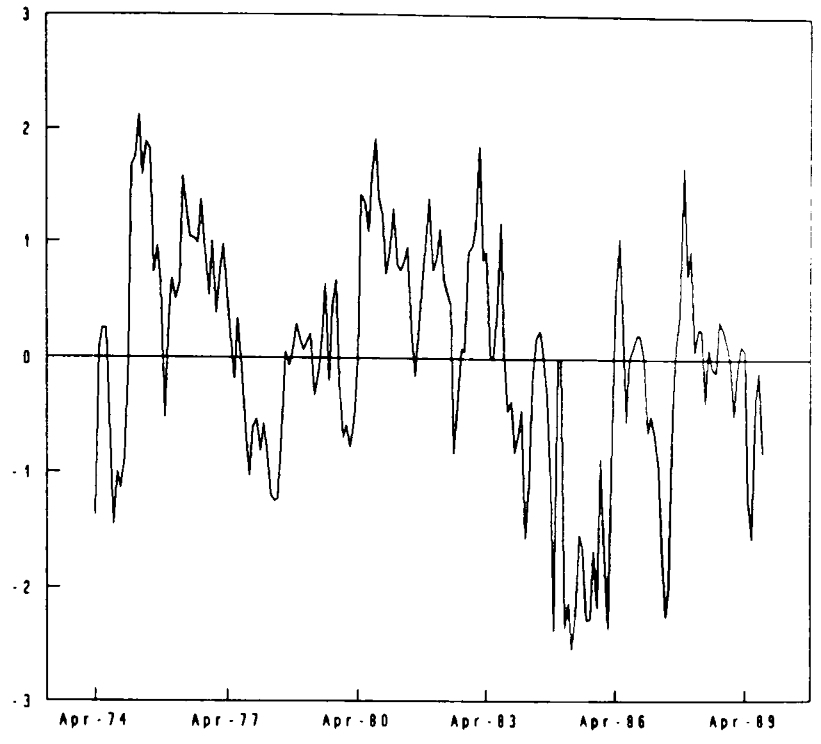


Figure 67 Corrected residuals of second restricted vector

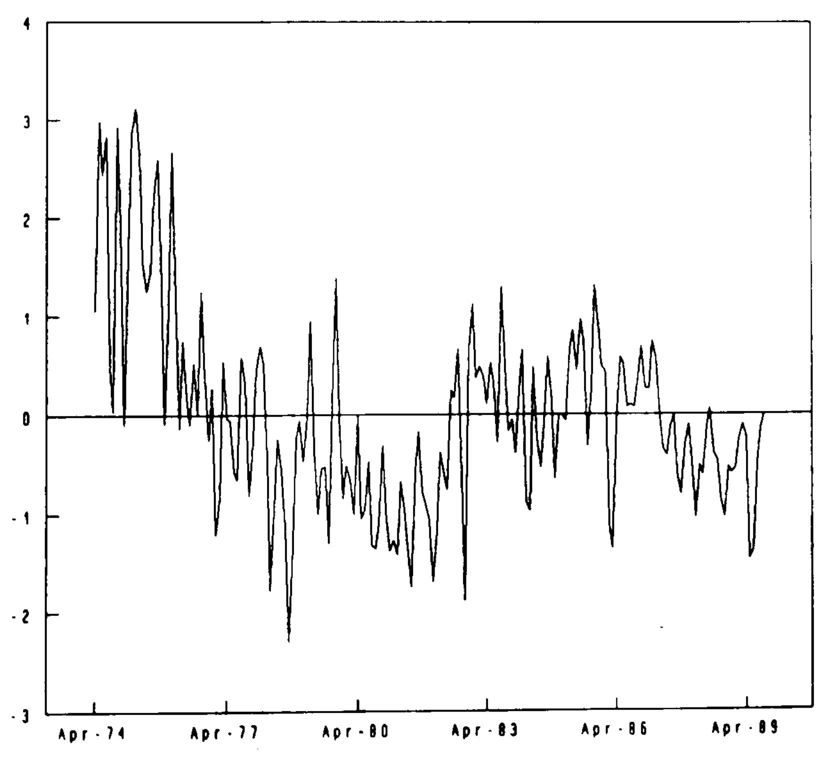


Table 31
F-Tests on Retained Regressors [*F* (5, 164)] - Japanese Yen

	$ecm1_{t-1}$	$ecm2_{t-2}$	Δs_{t-1}	Δp^*_{t-1}	Δr^*_{t-1}
F-Test	4.89	11.83	2.87	11.40	4.46
Marg. Sig.	0.000	0.000	0.016	0.000	0.001
	Δp^*_{t-2}	Δr^*_{t-2}	*dum80:04*	*dum84:12*	*dum85:01*
F-Test	2.73	2.72	3.52	3.15	3.04
Marg. Sig.	0.021	0.022	0.005	0.010	0.012

Table 32
Diagnostic Tests of the CVAR and PVAR - Japanese Yen

	CVAR			PVAR		
	Std. Dev.	Normality	S.C.	Std. Dev.	Normality	S.C.
Δs	0.03111	4.781	11.189	0.03187	4.635	7.027
Δp	0.00344	2.011	9.910	0.00352	2.385	18.188
Δp^*	0.00207	0.377	20.146	0.00212	0.467	21.903*
Δr	0.00293	8.739*	19.805	0.00299	17.748*	23.078*
Δr^*	0.00341	12.791*	22.142*	0.00352	18.779*	22.819*

NOTES: *See Notes to Table 25.*

The standard diagnostic tests for the CVAR and PVAR are reported in Table 32. Though there is evidence of twelfth-order serial correlation in three of the PVAR equations the actual test statistics have not deteriorated markedly from those of the CVAR, and the standard deviation of the equation residuals is practically unchanged. There is no evidence of fourth-order serial correlation in either the CVAR or PVAR for any equation (test statistics not reported). Encouragingly, the exchange rate equation is free from statistical problems.

The final step in the modelling exercise is to move to the structural equations. The final FIML estimates are given in Table 33. The equations are highly parsimonious, and in general accord with the weak exogeneity tests reported above. In particular, the exchange rate reacts solely to current changes in US interest rates (an increase in the US bond yield leading to a fall in the yen) and not to deviations from long-term equilibria. Both the Japanese and US price equations contain one of the *ecm* terms (as does the Japanese bond rate equation). The dummy variables are only significant in the US interest rate equation as would be expected. With the exception of Japanese prices, each equation contains a contemporaneous change term, confirming our hypothesis of simultaneity within the system.

The diagnostics of the SEMs are given in Table 34 together with those of the PVAR for comparison. Non-normality of the interest rate residuals remains, as does the high-order serial correlation.[75] There is little evidence of deterioration from PVAR to SEMs however, and in some respects there are marginal improvements. Again, the exchange rate equation passes the tests with ease. Most importantly, the encompassing test of the 32 over-identifying restrictions gives a test statistic of 29.24, well below the $\chi^2(32)$ 5% test statistic of 45.91. Despite some problems with the interest rate equations we conclude that the SEMs explain the data reasonably well, and in an intuitively understandable way.

The forecasting performance of the model equations are similar to those of the pound. The tests of parameter constancy ($\chi^2(195)/195 = 0.766$) and forecast error variance ($F(195,171) = 0.704$) are both comfortably below their respective critical values.

[75] There is also still no evidence of fourth-order serial correlation in the SEMs.

Table 33
SEM Equations - Japanese Yen

Equation	Variable	Coefficient	Std. Dev.	t-ratio
Δs_t	Δr^*_t	2.73900	1.00008	2.739
Δp_t	Δp^*_{t-2}	0.54671	0.07716	7.085
	$ecm2_{t-1}$	0.00737	0.00084	8.775
Δp^*_t	Δr_t	0.35311	0.16519	2.138
	Δp^*_{t-1}	0.50698	0.07436	6.818
	Δr^*_{t-2}	0.06458	0.03357	1.923
	$ecm1_{t-1}$	-0.00536	0.00141	3.804
Δr_t	Δp^*_t	0.34843	0.12255	2.843
	Δr^*_t	0.18954	0.08534	2.221
	Δs_{t-1}	0.01945	0.00576	3.374
	$ecm1_{t-1}$	0.00648	0.00167	3.884
Δr^*_t	Δp_t	-0.18779	0.09813	1.914
	Δp^*_t	0.49649	0.13386	3.709
	Δr^*_{t-1}	0.29330	0.06437	4.557
	Δr^*_{t-2}	-0.22171	0.06599	3.360
	dum80:04	-0.01472	0.00359	4.096
	dum84:12	0.01292	0.00346	3.738
	dum85:01	-0.01330	0.00355	3.742

Table 34
Diagnostic Tests of the PVAR and SEM - Japanese Yen

	PVAR			SEM		
	Std. Dev.	Normality	S.C.	Std. Dev.	Normality	S.C.
Δs	0.03187	4.635	7.027	0.03215	4.188	9.612
Δp	0.00352	2.385	18.188	0.00360	2.756	19.925
Δp^*	0.00212	0.467	21.903*	0.00212	0.004	22.011*
Δr	0.00299	17.748*	23.078*	0.00275	19.154*	22.455*
Δr^*	0.00352	18.779*	22.819*	0.00356	32.249*	22.611*

NOTES: *See Notes to Table 25.*

Once more we leave the full evaluation of the forecasts of this model until chapter 9. The following chapter performs the same modelling exercise for the Deutsche mark system, although with less pleasing statistical results.

CHAPTER 8

THE DEUTSCHE MARK EXCHANGE RATE MODEL

8.1 DATA DESCRIPTION AND THE BASIC VAR

The sterling- and yen-dollar models detailed above have proved reasonably successful in terms of diagnostic tests, interpretability of long- and short-term structures and limited forecast analysis. In this section we shall attempt to produce a similarly successful model for the Deutsche mark-dollar exchange rate.

Figure 68 Deutsche marks per US dollar

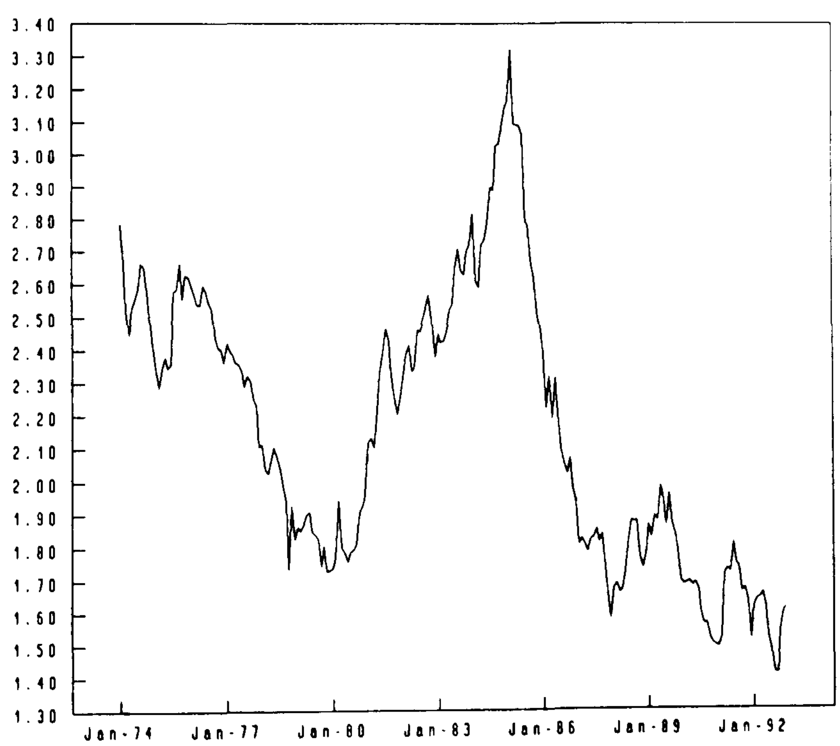


Figure 69 German consumer price index

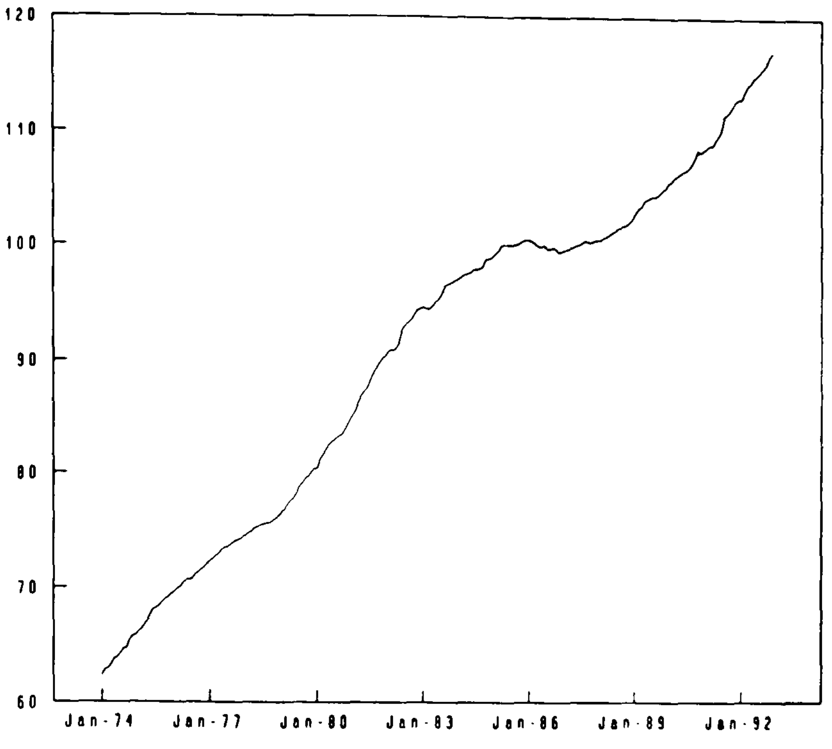


Figure 70 German long-term government bond yield

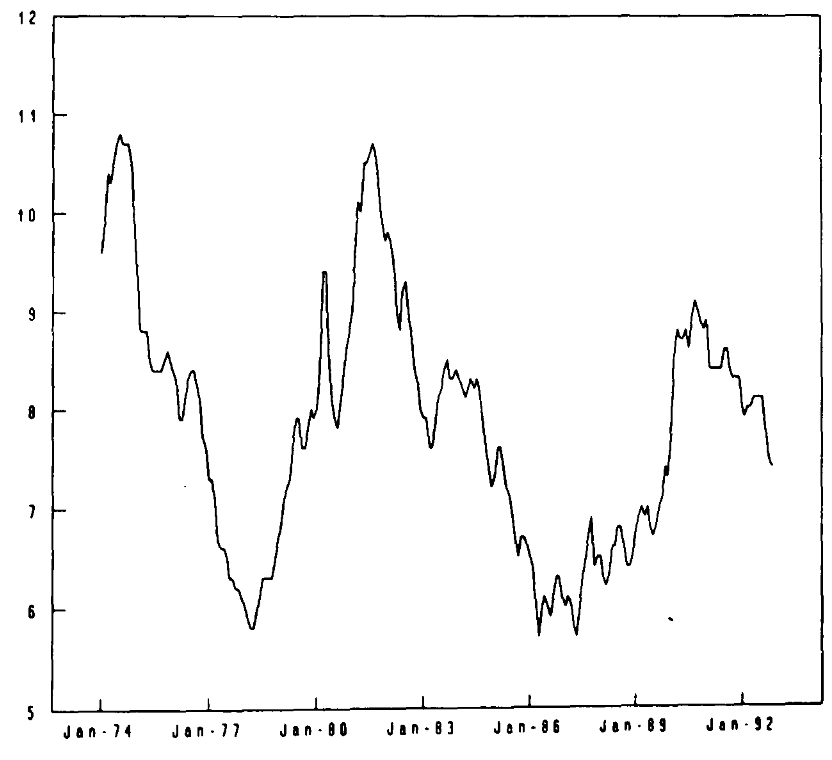


Figure 71 First difference of (log) Deutsche mark exchange rate

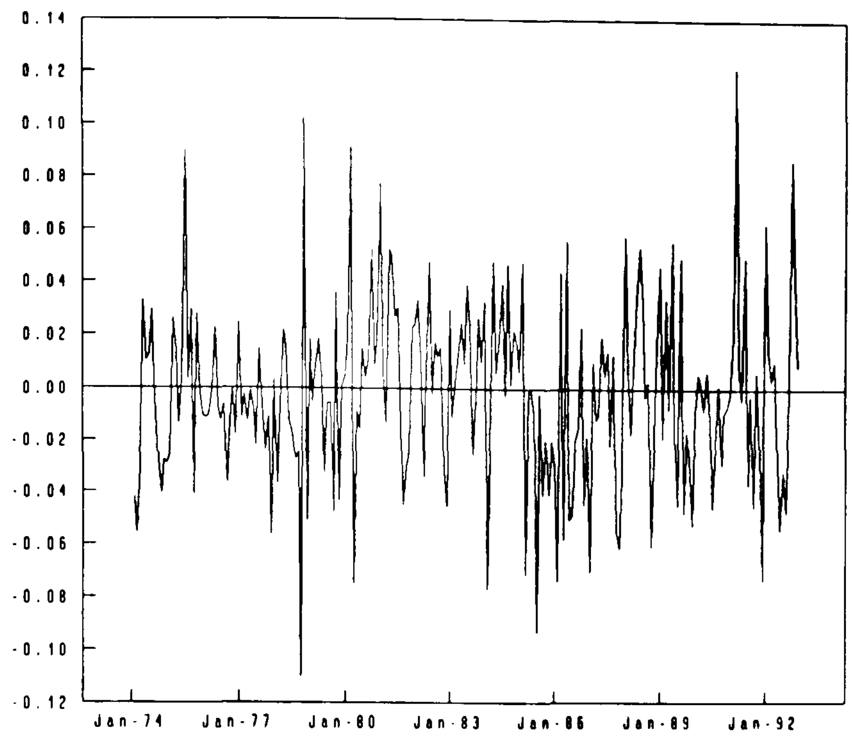


Figure 72 First difference of (log) German CPI

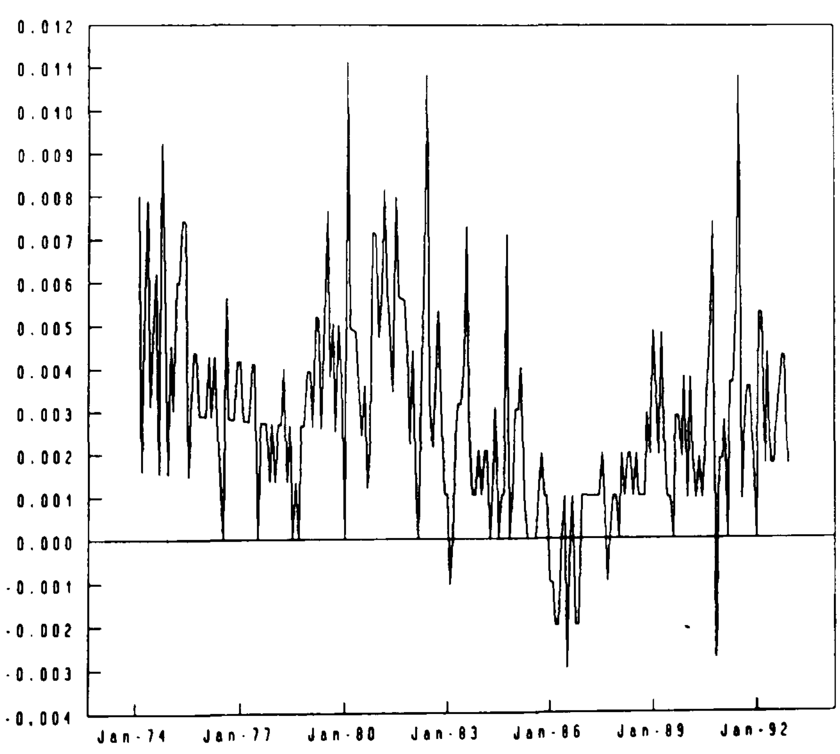
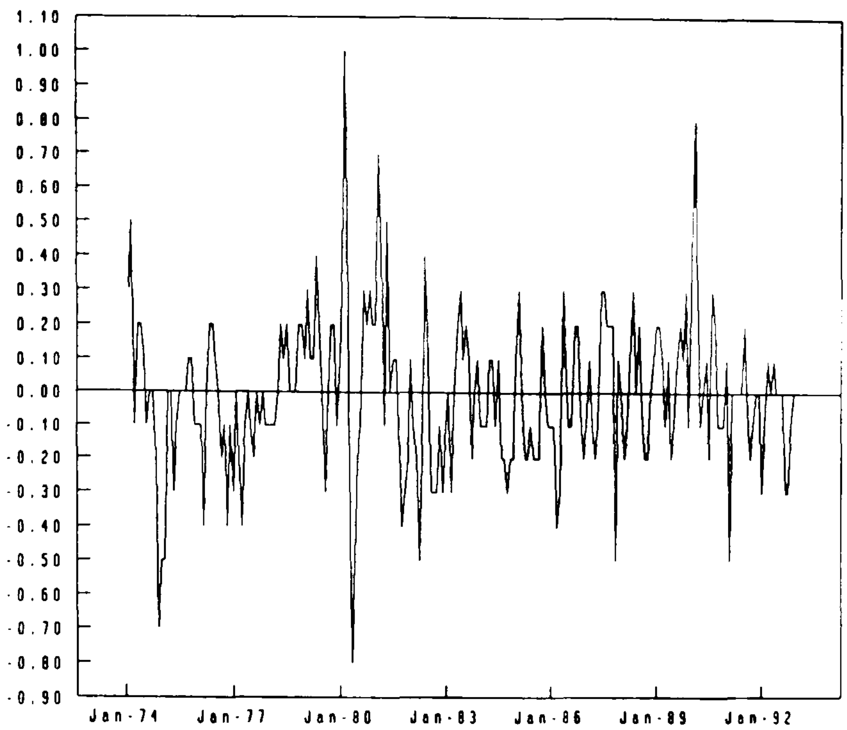


Figure 73 First difference of German bond yield



The spot rate data are again taken from IFS, line ae, the German CPI from IFS line 64, and the yield on 9-10 year government bonds from the Bundesbank data tapes.[76] Six dummy variables are needed to eliminate the noticeable outliers in the residuals of the three lag VAR (80:02, 80:04, 81:02, 81:11, 82:06 and 85:01), most of which are related to episodes dummied in the sterling and yen models.

8.2 COINTEGRATION TESTS AND RESTRICTIONS ON LONG-RUN EQUILIBRIA

Over the full period (1974:01 to 1989:09) we find evidence of just one cointegrating vector. The sign pattern is consistent with PPP but the coefficients on the two price terms are implausibly large. More worryingly, the associated alpha

[76] All three appear to be $I(1)$. The ADF test statistics for levels and first differences are as follows: Mark exchange rate -1.883 (7) and -8.261 (1), German CPI -1.642 (4) and -4.168 (2), and German bond yield -2.222 (2) and -8.266 (1). The 5% critical value is approximately -2.89 and the figures in parentheses give the number of lags added to ensure residual whiteness.

vector indicates that, if anything, the exchange rate adjusts so as to move *away* from equilibrium. This result is consistent with problems encountered in MacDonald and Marsh (1994*a*) in their study of non-augmented PPP, where error correction terms in the mark-dollar exchange rate models proved either insignificant or were incorrectly signed. Furthermore, all restrictions on the vector proved unacceptable. However, given the effects of the first oil shock to price indices, we decided to re-estimate the model over the slightly shorter period 1975:01 to 1989:09. These more successful cointegration results are presented in Table 35.

The more robust trace statistic indicates the presence of two cointegrating vectors, and the second is significant at the ten percent level according to the maximal eigenvalue test. Inference is unaltered if we assume the model is overparameterised. Residuals from these vectors are plotted in Figures 74 to 77. Since the second vector looks stationary we shall procede under the assumption of two cointegrating vectors. We note that the price coefficients in the first relationship bear signs consistent with PPP but that the magnitudes are rather large. The second vector appears inconsistent with (augmented) PPP.

Table 35
Cointegration Analysis - Deutsche mark

	Eigenvalues	Test statistics: Maximal Eigenvalue	Test statistics: Trace	5% Critical values: Maximal Eigenvalue	5% Critical values: Trace
r ≤ 4	0.014	2.43	2.43	8.18	8.18
r ≤ 3	0.045	7.97	10.39	14.90	17.95
r ≤ 2	0.089	16.31	26.70	21.07	31.52
r ≤ 1	0.136	25.36	52.06*	27.14	48.28
r = 0	0.227	44.84*	96.89*	33.32	70.60
	Vector 1	Vector 2	Vector 3	Vector 4	Vector 5
	Standardised eigenvectors (betas)				
s	1.000	1.000	1.000	1.000	1.000
p	-36.905	0.078	-9.192	-17.379	-7.589
p^*	17.131	0.935	4.838	9.379	3.590
r	2.936	31.011	-7.371	-9.004	-20.420
r^*	12.319	-14.614	-2.113	0.814	12.122
	Standardised loadings (alphas)				
s	0.004	-0.009	-0.109	0.026	0.002
p	0.002	0.001	0.002	0.001	0.000
p^*	0.001	-0.003	-0.001	-0.001	-0.000
r	-0.000	-0.002	0.002	0.002	-0.000
r^*	0.000	-0.000	-0.000	0.002	-0.002

NOTES: *See Notes to Table 21.*

Figure 74 Residuals of first cointegrating vector

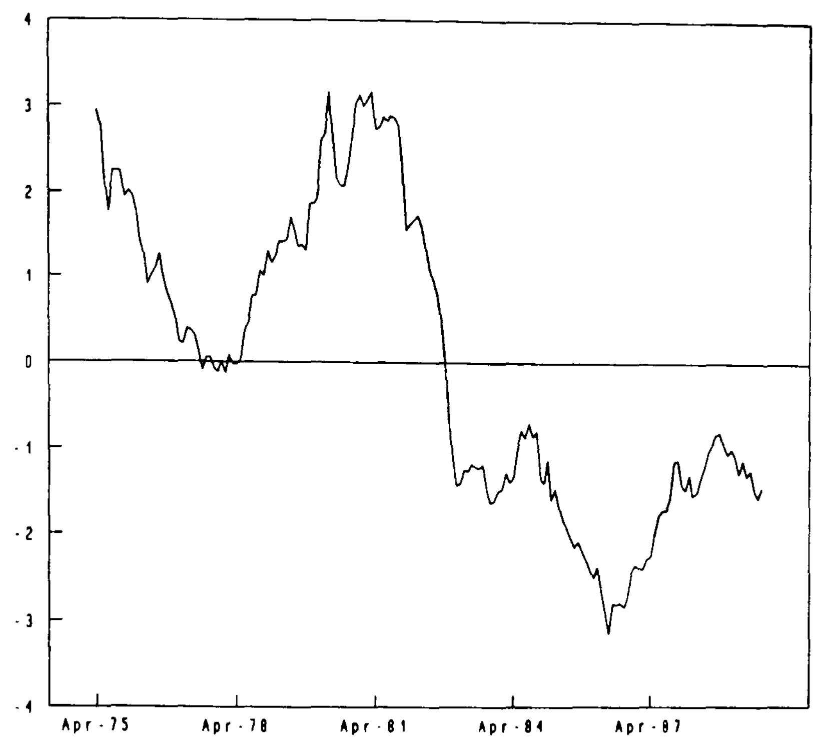


Figure 75 Residuals of second cointegrating vector

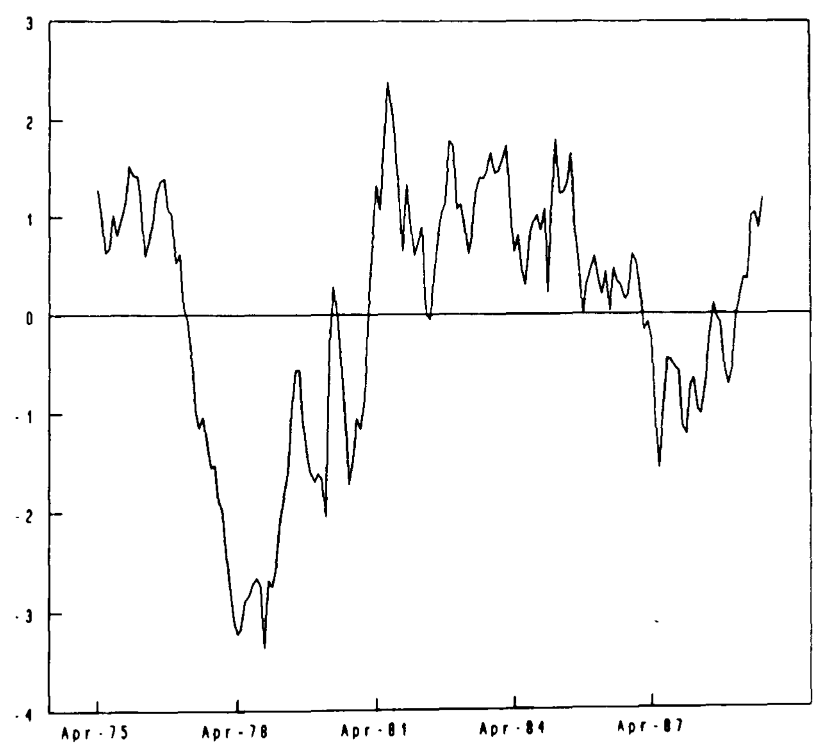


Figure 76 Corrected residuals of first cointegrating vector

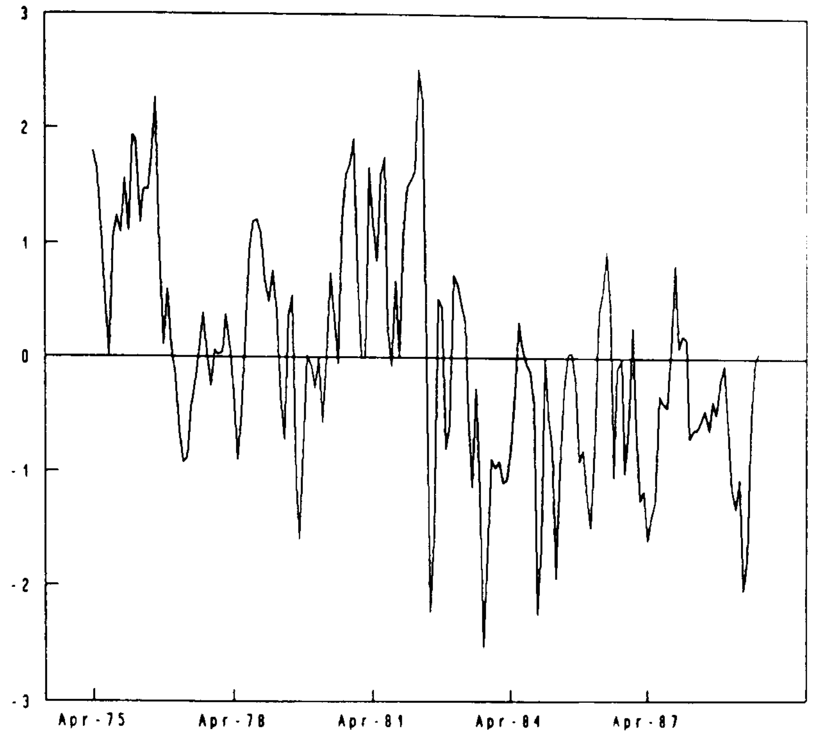


Figure 77 Corrected residuals of second cointegrating vector

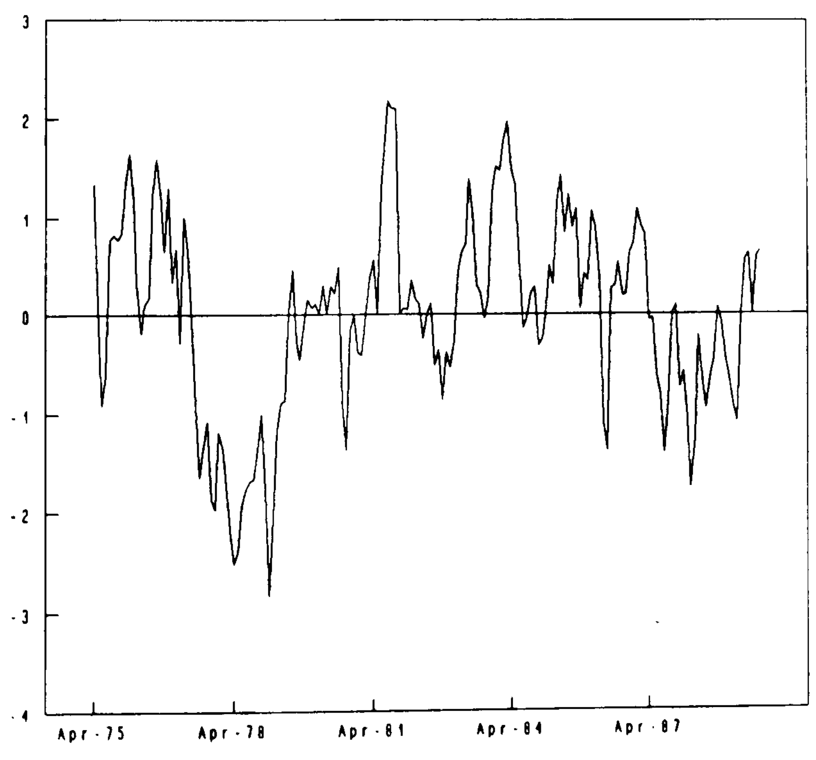


Table 36
Restrictions on Cointegrating Vectors - Deutsche mark

	Weak exogeneity	
	Test Statistic	Marginal Significance
α_s	0.77	0.68
α_p	24.42	0.00
α_{p*}	14.63	0.00
α_r	6.28	0.04
α_{r*}	0.58	0.75
	Restrictions on beta matrix	
	Test Statistic	Marginal Significance
Hypothesis A	11.88	0.01
Hypothesis B	0.88	0.35
Hypothesis C	4.06	0.13
Hypothesis D	11.88	0.02

NOTES: *See Notes to Table 22.*

Tests of restrictions on the two vectors are detailed in Table 36. Weak exogeneity is indicated for the exchange rate and US interest rate, and hypothesis C is the most restrictive set of constraints acceptable to the data. The constrained vectors are reported in Table 37, and the residuals of these relationships, corrected for short-run dynamics, are graphed in Figures 78 and 79.

Figure 78 Corrected residuals of first restricted vector

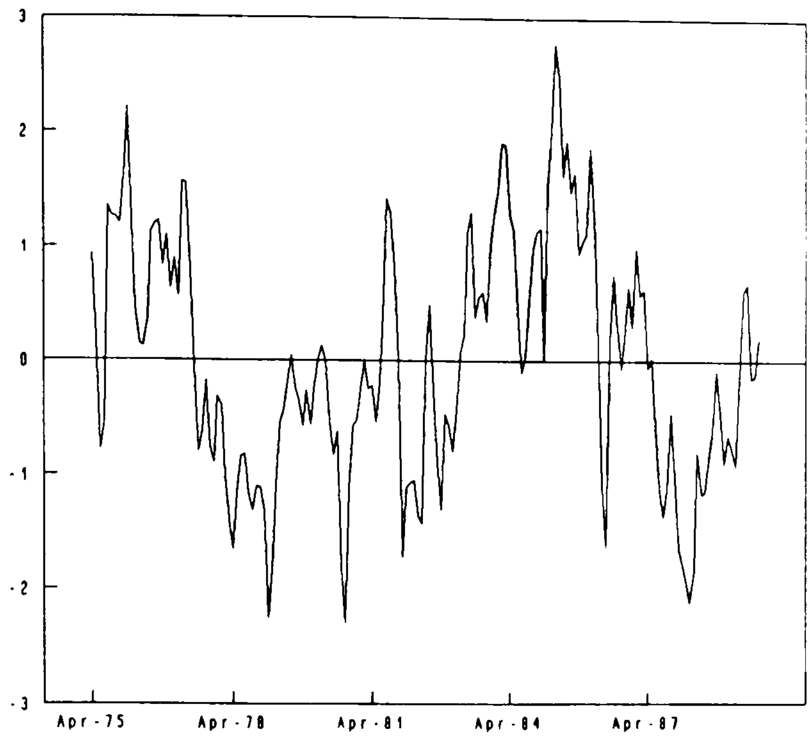


Figure 79 Corrected residuals of second constrained vector

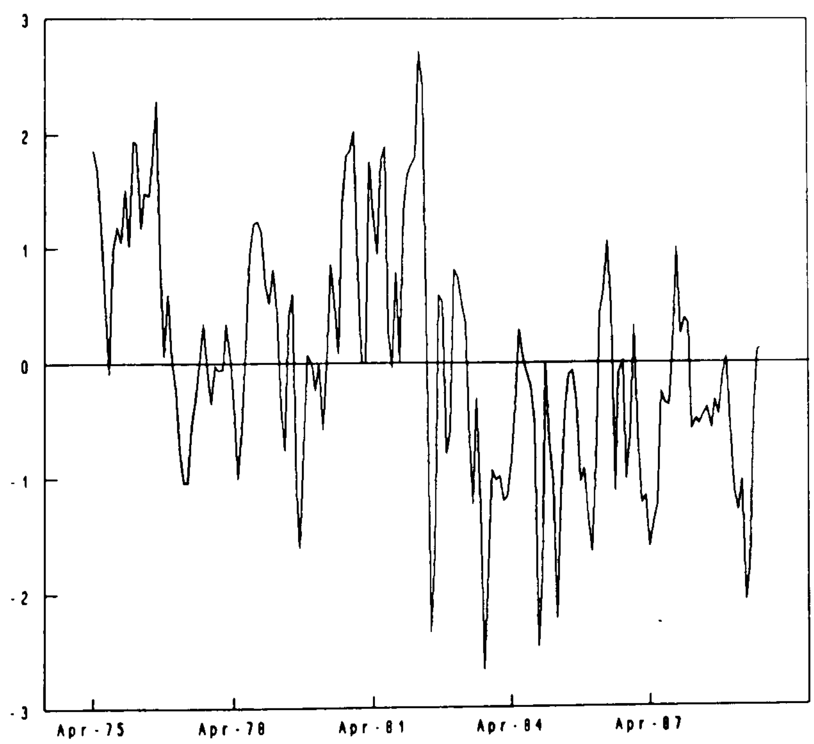


Table 37
Restricted Cointegrating Vectors - Deutsche mark

	Standardised restricted vectors	
	β_1	β_2
s	1.000	1.000
p	-1.000	-51.429
p^*	1.000	23.841
r	7.329	7.354
r^*	-7.329	17.772
	Standardised adjustment vectors	
	α_1	α_2
s	-0.049	0.001
p	0.002	0.001
p^*	-0.004	0.001
r	-0.003	-0.000
r^*	-0.002	0.000

Note that the adjustment coefficient for the exchange rate in the restricted cointegrating vector is large in absolute value and bears a negative sign, indicating that the exchange rate moves to restore equilibrium. This contrasts with the single significant vector estimated over the full sample.

8.3 THE PARSIMONIOUS VAR

Transforming the VAR to stationarity by first differencing and including the *ecm* terms and dummies as additional $I(0)$ variables maintains the long-run information inherent in the cointegrated system. This CVAR is reduced to parsimony by dropping the lagged terms that can be restricted to zero in standard F-tests. In fact only three terms can be excluded and the significance of those that remain are detailed in Table 38. All six dummies are significant, as are the *ecm* terms.

Table 38
F-Tests on Retained Regressors [F (5, 147)] - Deutsche mark

	$ecm1_{t-1}$	$ecm2_{t-1}$	Δs_{t-1}	Δp_{t-1}	Δp^*_{t-1}
F-Test	4.32	11.08	2.58	5.11	8.12
Marg. Sig.	0.001	0.000	0.029	0.000	0.000
	Δr_{t-1}	Δr^*_{t-1}	Δr_{t-2}	Δr^*_{t-2}	*dum80:02*
F-Test	2.36	4.03	2.85	2.27	5.02
Marg. Sig.	0.043	0.002	0.018	0.051	0.000
	dum80:04	*dum81:02*	*dum81:11*	*dum82:06*	*dum85:01*
F-Test	3.51	2.28	4.08	4.55	4.30
Marg. Sig.	0.005	0.050	0.002	0.001	0.001

Table 39
Diagnostic Tests of the CVAR and PVAR - Deutsche mark

	CVAR			PVAR		
	Std. Dev.	Normality	S.C.	Std. Dev.	Normality	S.C.
Δs	0.02876	1.160	11.194	0.02895	0.657	13.019
Δp	0.00144	7.888*	9.110	0.00146	7.943*	11.804
Δp^*	0.00192	1.552	15.054	0.00195	2.747	20.224
Δr	0.00161	7.989*	24.370*	0.00165	8.705*	17.772
Δr^*	0.00326	12.212*	17.590	0.00327	11.466*	18.933

NOTES: *See Notes to Table 25.*

Diagnostics on the CVAR and PVAR indicate non-normality in the bond and German price equations. Fourth-order serial correlation is not a problem in any vector. Since problems with the bond equations in particular are common to all three currencies it is worth emphasising that the variables entering the system were chosen to explain movements in the exchange rate. They were not designed to explain changes in interest rates and so it is not surprising that we have problems in fully capturing the dynamics of bond yields. An obvious extension that might improve the performance of the underlying VAR would be to add income terms to the system. We might even chose a system based on the monetary approach to the exchange rate (i.e. include the spot exchange rate, interest rates, money supplies and income levels) that has proven long-term validity (see MacDonald and Taylor (1994)). We shall leave this for future work, however, and persist with our small augmented PPP system.

8.4 THE STRUCTURAL ECONOMETRIC MODEL

The final SEM equations are listed above in Table 40. Similar comments apply to those estimated for the yen and pound sterling. The forty-six over-identifying restrictions cannot be rejected since the test statistic of 46.331 should be compared to a 5% critical value of 62.54. At least one error correction term is present in each equation, and the exchange rate reacts to disequilibrium embodied by the restricted *ecm*. There is a high degree of simultaneity, particularly via the US bond equation. The dummy variables have separated to their respective equations and are not significant elsewhere. The exchange rate equation points to noticeable short-term elasticity, with the Deutsche mark appreciating by 4% for each 1% increase in US prices and depreciating by over 5% for each 1% rise in German prices.

Table 40
SEM Equations - Deutsche mark

Equation	Variable	Coefficient	Std. Dev.	t-ratio
Δs_t	Δr^*_t	2.49386	0.99542	2.505
	Δs_{t-1}	-0.09213	0.05567	1.655
	Δp_{t-1}	5.26207	1.11396	4.724
	Δp^*_{t-1}	-4.06918	0.97354	4.180
	Δr^*_{t-2}	1.28446	0.47964	2.678
	$ecm1_{t-1}$	-0.04037	0.01828	2.208
Δp_t	Δp_{t-1}	0.20288	0.06202	3.271
	dum80:02	0.00769	0.00150	5.138
	dum82:06	0.00588	0.00144	4.070
	$ecm1_{t-1}$	0.00174	0.00085	2.056
	$ecm2_{t-1}$	0.00115	0.00015	7.928
Δp^*_t	Δp^*_{t-1}	0.42034	0.06145	6.840
	Δr_{t-2}	0.17679	0.06105	2.896
	$ecm1_{t-1}$	-0.00496	0.00120	4.118
	$ecm2_{t-1}$	0.00059	0.00017	3.472
Δr_t	Δs_{t-1}	0.01205	0.00380	3.172
	Δr_{t-1}	0.20180	0.06215	3.247
	Δr^*_{t-1}	0.14815	0.03274	4.525
	dum81:02	0.00473	0.00155	3.060
	$ecm1_{t-1}$	-0.00350	0.00102	3.421
	$ecm2_{t-1}$	-0.00034	0.00014	2.474
Δr^*_t	Δs_t	-0.15156	0.05086	2.980
	Δp_t	1.31131	0.42424	3.091
	Δp^*_t	-1.07499	0.45513	2.362
	Δr^*_{t-1}	0.40333	0.10428	3.868
	dum80:04	-0.01801	0.00499	3.609
	dum81:11	-0.02056	0.00490	4.199
	dum85:01	-0.02007	0.00517	3.878
	$ecm1_{t-1}$	-0.01605	0.00645	2.486

NOTES: See Notes to Table 26. The only weakly significant lagged change in the spot exchange rate is included since this removes a severe problem of serial correlation in the residuals of this equation.

Table 41
Diagnostic Tests of the PVAR and SEM - Deutsche mark

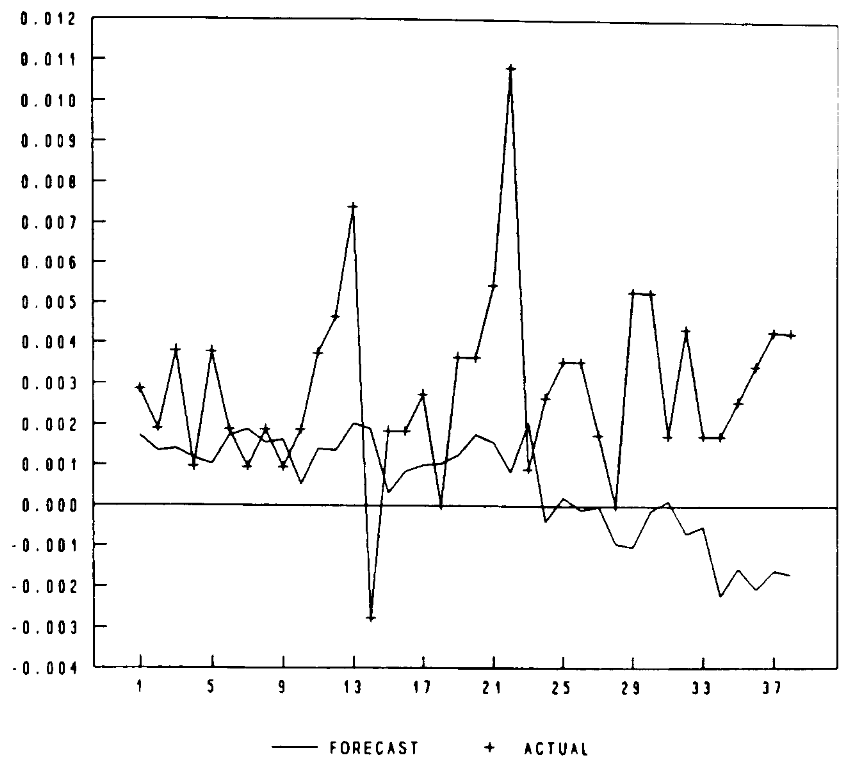
	PVAR			SEM		
	Std. Dev.	Normality	S.C.	Std. Dev.	Normality	S.C.
Δs	0.02895	0.657	13.019	0.02974	0.526	18.282
Δp	0.00146	7.943*	11.804	0.00150	13.637*	11.461
Δp^*	0.00195	2.747	20.224	0.00200	2.000	18.886
Δr	0.00165	8.705*	17.772	0.00175	13.005*	18.539
Δr^*	0.00327	11.466*	18.933	0.00686	6.035*	16.853

NOTES: *See Notes to Table 25.*

The diagnostics reported in Table 41 indicate no problems with serial correlation,[77] but non-normality persists in three of the equations. However, tests of the one-step-ahead forecasts reveal that the predictions of this model are poor. The $\chi^2(195)/195$ test of structural change between sample and forecast periods is a high 2.063, and the $F(195,157)$ test based on the forecast error variance returns a value of 1.861 significant at the one percent level. Considerable experimentation failed to produce an alternative model that did not have these faults. A major reason for this failure of the mark model is German reunification. Errors, particularly in the German price equation are large and feed through to each of the variables even in one-step-ahead forecasts due to the simultaneity of the system (see Figure 80). The immediate impact of reunification was to push German bond yields higher as inflation expectations rose and forecasts of the German budget deficit rocketed. Our model, which is backward-looking, first failed to foresee this rise in interest rates, and then interpreted it as a monetary tightening likely to have strong deflationary effects. Accordingly, the model-based forecasts of German inflation are much lower than actually occured.

[77] See notes to Table 40.

Figure 80 Actual and forecast changes in German CPI



These impacts of reunification ought to have been foreseen by professional forecasters who would have adjusted their predictions accordingly. A forecaster would therefore be expected to perform better than our simple model since his relevant information set is larger. Thus, the model predictions can be interpreted as a baseline case to which so-called residual adjustments would be made. However, to maintain comparability between currencies and to avoid all charges of bias in favour of our model, we shall continue to use the unadjusted forecasts. In the following chapter we evaluate the forecasts from all three econometric models using some of the techniques of chapter 3.

CHAPTER 9

SO JUST HOW GOOD ARE THESE FORECASTS?

9.1 DYNAMIC MODEL FORECASTS

We are now in a position to evaluate the forecasts produced from these three models using the methods of chapter 3. For each currency we shall compute measures of accuracy and profitability, and using the three currencies together we shall compute portfolio performance statistics. We now have two benchmarks against which performance can be judged - the random walk and the performance of our panel members. Over a three month horizon the former is still the most stringent, but when we are looking at the one year predictions we have not only the random walk to beat but also the best of our panellists.

In addition to the one month forecasts, our models are capable of generating fully dynamic multi-step-ahead predictions in which the forecast values of each variable are fed back into the reduced form equations to calculate projections for the subsequent period. Forecasts are made for a variety of horizons based on the data available up to the end of September 1989 (i.e. approximately corresponding to the forecasts made by our panellists on the first Monday of October 1989). New forecasts are then made using the data available up to the end of October 1989. This is repeated until we have forecasts based on the data up to the end of November 1992.[78] Note that the model is only estimated once, based on data available in October 1989. This means that this final set of forecasts are still based on the initial

[78] Here we assume that the value of each variable is known at the end of the month. This is not strictly true for the price series but very accurate forecasts based on preliminary data should be available. The financial prices are of course available in real time. It should also be noted that the forecasts produced by these models are not *ex ante* since they are made after the fact, even if only available data is included in the information set on which the models are conditioned. There is, however, no reason why these models cannot be used for true out-of-sample forecasting and we hope to produce a series of papers doing just that.

parameter estimates, and so does not fully take into account the information set available to forecasters.

Since the models detailed above were estimated with end-month data and the forecasts produced are for end-month values of the exchange rate, all of the evaluations considered in this chapter use similarly dated spot and forward rates. Thus, while the forecast period corresponds very closely to that over which we have evaluated the forecast panel, the results are not strictly comparable. To take an extreme example, the second set of forecasts from the panellists were made on 7th November 1989 for the spot rate on 7th February 1990 and 7th November 1990. The econometric models are forecasting the rate for 31st January 1990 and 31st October 1990, differences of seven days in both cases. A week is a long time in politics, and can be even more important in the foreign exchange market. Nevertheless, we feel that because of the benchmarking of our tests to the random walk, they will still provide a good indication of the performance of the model-based forecasts relative to those of our panel members.[79] The new spot and forward rate data used in the evaluation are detailed in the data appendix to this chapter.

9.2 THE MODEL FORECASTS VERSUS A RANDOM WALK

Table 42 gives the root mean squared error of the estimated model and associated random walk alternative for each currency over a range of forecast horizons. The third column of each section computes the ratio of model:random walk RMSEs such that a figure less than unity implies superior model forecasts. Figure 81 plots the ratio for each currency for horizons between one and twelve months. Over the one month horizon the random walk dominates across all three currencies. Over longer horizons, however, the relative accuracy of the models improves such that for each currency the ratio falls below unity. This happens relatively quickly for

[79] An alternative would be to interpolate the models' forecasts to provide predictions that correspond exactly to those provided by our panellists. However, we felt that interpolating the three and twelve month forecasts but leaving the others as end-month predictions would only confuse the reporting of results.

the pound sterling (ratio less than one at two month horizon) and Japanese yen (three month horizon) but is slower for the Deutsche mark. Over the long-run (twelve and twenty-four months) the ratio for all three currencies is 0.805 or less. The good performance of the Deutsche mark model is despite the Reunification problems noted above.

Figure 81 Relative root mean squared error performance

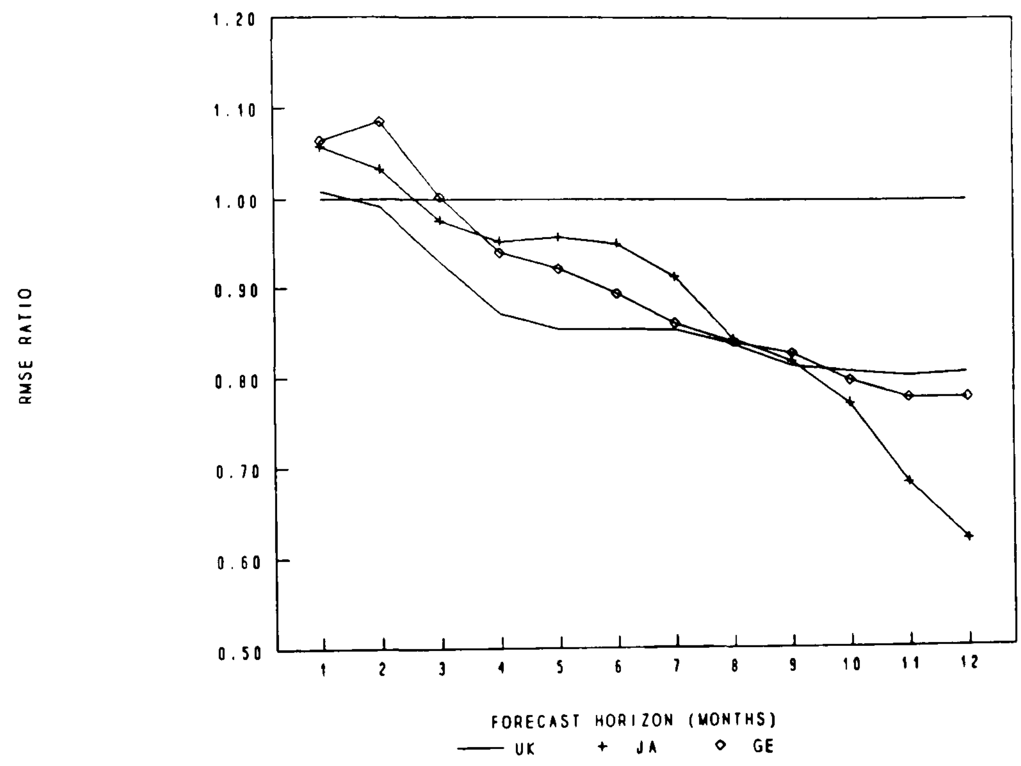


Table 42
Dynamic Forecast Performance - Root Mean Squared Errors

	Deutsche mark			Pound sterling			Japanese Yen		
Steps	R.W.	Model	Ratio	R.W.	Model	Ratio	R.W.	Model	Ratio
1	0.038	0.041	1.063	0.043	0.043	1.007	0.029	0.031	1.059
2	0.060	0.065	1.085	0.070	0.069	0.990	0.044	0.046	1.034
3	0.073	0.073	1.001	0.086	0.080	0.929	0.054	0.052	0.974
4	0.085	0.080	0.940	0.092	0.080	0.871	0.064	0.061	0.952
5	0.093	0.085	0.921	0.097	0.082	0.854	0.074	0.071	0.957
6	0.097	0.087	0.894	0.099	0.085	0.854	0.081	0.077	0.949
7	0.099	0.085	0.861	0.104	0.089	0.853	0.082	0.074	0.912
8	0.102	0.085	0.839	0.110	0.092	0.837	0.078	0.065	0.843
9	0.104	0.086	0.827	0.117	0.095	0.812	0.077	0.063	0.818
10	0.107	0.085	0.797	0.121	0.098	0.806	0.078	0.060	0.771
11	0.111	0.086	0.778	0.121	0.097	0.802	0.077	0.052	0.682
12	0.113	0.088	0.778	0.117	0.094	0.805	0.078	0.048	0.618
24	0.077	0.055	0.707	0.114	0.089	0.780	0.136	0.077	0.571

NOTES: *See text for details.*

Table 42 indicates that the systems approach to forecasting practised above can produce more accurate out-of-sample forecasts than a random walk model. The next step is to test for the statistical significance of this outperformance.[80]

The Williams-Kloot test was detailed in chapter 3, and is one of the tests that we shall apply to our forecasts. An alternative method has recently been suggested by Diebold and Mariano (1991). Repeating the notation of the Williams-Kloot test, denote the model and random walk forecasts of the outcome spot rate, A, by F_M and F_{RW} respectively. Defining $e^2_M = (F_M - A)^2$, $e^2_{RW} = (F_{RW} - A)^2$, and $d = e^2_M - e^2_{RW}$, the Diebold-Mariano test is a t-test of the null that the mean of d is zero, corrected for

[80] Tests of significance are not performed for forecasts in excess of the twelve month horizon due to a lack of independent observations.

serial correlation and heteroscedasticity where appropriate. Again, negative values of the test statistic indicate that the model is superior.

Both tests are carried out for each forecast horizon and are summarised in Table 43. The pound sterling model is superior at the ten percent level for all horizons greater than two months. For the yen, superiority is evident from the nine month horizon, and for the mark from the four month horizon.

Table 43
Significance of Forecast Performance

	Deutsche mark		Pound sterling		Japanese yen	
Steps	W-K test	D-M test	W-K test	D-M test	W-K test	D-M test
1	0.495	0.654	-0.659	-0.757	1.172	1.174
2	-1.077	1.149	-1.050	-0.892	-0.430	0.652
3	-0.652	-0.666	-1.921†	-2.310*	-0.375	-0.376
4	-2.010†	-1.941†	-2.916*	-3.228*	-0.509	-0.497
5	-2.720*	-2.563*	-2.955*	-2.718*	-0.431	-0.429
6	-3.028*	-2.505*	-2.786*	-2.168*	-0.436	-0.435
7	-3.562*	-2.918*	-3.351*	-2.097*	-0.732	-0.727
8	-3.670*	-2.490*	-4.114*	-2.140*	-1.537	-1.432
9	-3.917*	-2.051*	-4.148*	-2.025†	-2.054†	-1.958†
10	-4.026*	-1.841†	-3.698*	-1.841†	-3.258*	-3.170*
11	-3.742*	-1.802†	-3.544*	-1.813†	-4.828*	-4.257*
12	-3.076*	-1.518	-3.066*	-1.746†	-5.612*	-5.040*

NOTES: *An asterisk (dagger) denotes significance at the five (ten) percent level. See text for further details.*

These results contrast with all of the extant literature on forecasting the exchange rate.[81] No paper has demonstrated an ability to produce fully dynamic

[81] It is, of course, feasible that a similarly powerful forecasting model has been developed but is being used for trading in the foreign exchange market rather than be published.

forecasts that significantly outpredict a random walk over such a long test period for so many currencies. It is encouraging that the outperformance of the random walk begins at relatively short forecast horizons, at least for the pound and Deutsche mark. In terms of the quotation from Salemi (1983) given in chapter 3, our results suggest that the "longer" horizon, over which the exchange rate is related to fundamental variables, starts at three to six months. When the quote was first made, in the aftermath of the original Meese and Rogoff results, the longer horizon equated to one year or more.

Table 44

Dynamic Forecast Performance - Profits from Forward Speculation

		1 month	2 months	3 months	6 months	12 months
STG	Model	0.399	0.638	2.407	5.385	6.525
	R.W.	0.225	0.552	1.245	3.769	6.525
	Spread	0.174	0.086	1.162	1.616	0.000
JPY	Model	-0.056	0.266	1.475	3.065	6.866
	R.W.	1.064	1.056	1.108	1.062	0.318
	Spread	-1.119	-0.790	0.367	2.003	6.548
DEM	Model	0.669	-0.007	2.098	6.966	7.026
	R.W.	-0.131	-0.353	-0.257	2.408	3.761
	Spread	0.800	0.346	2.355	4.557	3.265

NOTES: The rows denoted Model give the average profit per trade based on the relevant model forecasts. The rows denoted R.W. give the average profits of the random walk model, while the rows marked Spread give the difference between the two profit levels.

As we noted in chapter 3, there are a variety of metrics by which forecasts can be evaluated. The accuracy measures considered above are important, popular and tough. They are not necessarily the most relevant, however, to an end-user of the forecasts. Table 44 give the results of applying the simple profitability test outlined in section 3.2 to our model forecasts. Recall that the test is designed to be indicative of the value a speculator may place on the predictions of our econometric models. The test is applied to the one, two, three, six and twelve month forecast horizons, where reliable forward rate quotations are obtainable. In all but two cases the model forecasts prove profitable to follow. Similarly, in only two cases are the forecasts less profitable than a strategy based on a prediction of no change. The significance of any outperformance by the model forecasts is, however, low (and unreported) due to the problems noted in chapter 3.

A more robust test of the value of these forecasts to a speculator can be made on the basis of the portfolio evaluations detailed in section 3.4, and it is to these that we now turn. For horizons upto six months, a variance-covariance matrix of returns is constructed based on the data described in section 3.4.1 and in the appendix.[82] Combined with the forecasts from the models, and using the two portfolio formation methods also detailed above, we can determine the profit resulting from simple but realistic investment strategies. As in chapter 3 we also calculate the profits from the random walk alternative and the excess profit of each portfolio, defined as the profit over and above that expected by a naive investor given the portfolio structure at each point in time. These are detailed in Table 45.

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82 We only evaluate the forecasts upto the six month horizon because of the lack of independent observations over longer forecast intervals.

Table 45
Dynamic Forecast Performance - Portfolio Profits

	Portfolio 1				Portfolio 2			
	Profit	Signif	Excess Profit	Signif	Profit	Signif	Excess Profit	Signif
1 month	63.45	0.107	47.25	0.239	33.45	0.193	23.36	0.383
R.W. 1	91.35	0.404	10.83	0.920	74.43	0.453	-8.42	0.931
2 months	32.41	0.515	26.57	0.601	32.07	0.154	24.38	0.296
R.W. 2	97.18	0.333	77.10	0.441	89.39	0.410	64.82	0.540
3 months	92.00	0.012	89.31	0.019	80.06	0.002	75.80	0.004
R.W. 3	110.87	0.230	109.85	0.235	103.09	0.329	98.98	0.339
6 months	110.45	0.000	111.84	0.000	96.87	0.018	100.16	0.018
R.W. 6	123.22	0.075	143.63	0.042	151.14	0.067	166.66	0.045

NOTES: *See text for details.*

Over the very short horizon (one or two months) both model and random walk return profits with either portfolio formation method. Those of the random walk are uniformly greater, but all profits are insignificantly different from zero. Over three and six month horizons, the average profits of the model-based portfolios approximate the target level of $100, and are significantly greater than zero for all four possible permutations. Again, profits from the random walk alternatives are larger than those from the model, but they are less significant, particularly over three months.

Adjusting the results to show profits over and above those that would be expected by a naive investor given the portfolio positions established has a substantial effect over short horizons, but these excess profits remain insignificant. Over longer horizons, the adjustment is less dramatic and only marginally influences the significance of any profits.

As we noted in chapter 3, the significance of average profits made from portfolio 2 (where leverage is endogenised) may not be an appropriate test. We also therefore examine the significance of the cumulated profits of these portfolios. Table 46 gives the results of such tests using the appropriate variance estimates (see section

3.4.1 for details of the procedures used). They are consistent with the results given in Table 45, and indicate that cumulative profits over the three and six month horizons are significantly greater than zero for both the model and random walk forecasts. Cumulated profits are marginally significant over the two month horizon using the theoretical variance, but a more general equation for the variance is statistically preferable and reduces the significance of profits. Over the longest horizon the theoretical value is again rejected, but this time for overstating the true variance of profits. Even taking the largest variance as the true value, the cumulated profits from the portfolios based on the model forecasts are highly significant. They compare favourably with those of the random walk model that are larger but less significant, indicating a much higher variation in profits.

Table 46
Significance of Cumulated Profits

		Portfolio Variance			
		Theoretical		Empirical	
	Sum Profits	t-stat	Signif.	t-stat	Signif.
1 mth	1,271	1.338	0.189	NA	NA
1 mth R.W.	2,829	0.874	0.388	NA	NA
2 mth	1,187	1.629	0.112	1.131	0.266
2 mth R.W.	3,307	1.481	0.147	1.055	0.298
3 mth	2,852	4.083	0.000	NA	NA
3 mth R.W.	3,711	2.144	0.039	NA	NA
6 mth	3,197	4.488	0.000	7.561	0.000
6 mth R.W.	4,988	3.629	0.001	4.013	0.000

NOTES: *See notes to Table 13.*

9.2 MODEL FORECASTS VERSUS PANEL MEMBERS

In terms of the academic contributions of our forecasting exercise, we feel that several advances have been made. A new modelling technique has been applied to foreign exchange data, resulting in well specified models that incorporate plausible long- and short-run relationships between five key variables. Most importantly, these models have been used to generate exchange rate forecasts capable of significantly outperforming the random walk benchmark over much shorter forecasting horizons than has hitherto been the case. By this criterion our modelling has been successful. However, another set of benchmarks exists against which our predictions should be evaluated - the forecasts of our panellists. This section compares the benchmarked performance of the model forecasts (i.e. ratios and spreads against a random walk) with those of the professional forecasters detailed in chapter 3. For the reasons noted above, the comparison of forecasts is not strictly valid. However, the benchmarking of performance against a random walk should minimise any inaccuracies.

How do the models do in terms of accuracy? Over three months, the RMSE ratio of the sterling and yen models is less than unity. The UK pound forecasts would have ranked second if added to the group of forecasters analyzed in chapter 3 behind forecaster G9 (whose ratio was 0.89). The yen model would have come out in first place. The Deutsche mark model RMSE ratio is very marginally greater than unity, placing it fifth. Recall that reunification took place in the middle of our forecast period and that whilst the panellists ought to have made allowance for this in their predictions, no such concessions were made in producing the model forecasts. That the model still ranks in the top five is testament to its resilience to change and lack of sample dependence, two of the goals of the structural econometric modelling technique used.

Over the longer horizon the comparison with our panellists becomes more stringent than with a random walk. It is therefore especially pleasing to find that the model forecasts still rank highly. For both the mark and sterling, the model comes out second to forecasters U30 and F7 respectively. Despite having a lower ratio than the other two currencies over this horizon, the yen fares slightly worse and is ranked tenth.

Using the simple profit spread as an alternative metric places the models a little lower: the sterling model ranks second and tenth over three and twelve months, the mark model seventh and tenth, and the yen model twenty-third and tenth. However, an important point that the profit comparisons show up is that the model is consistently profitable across currencies and horizon, whilst only two forecasters returned positive profit spreads for all three currencies over the three month horizon (B13 and B16), and only four over twelve months (F12, B28, U8 and U20). The consistent performance across currencies at the three month horizon is emphasised by the fact that the cumulated portfolio 2 profits of the models are comparable with the best of the forecasters (models - $2,852, G9 - $2,989) but much more significant (*t*-statistics of 4.083 and 2.634 under the applicable variance estimates respectively).

We conclude that not only do the econometric models forecast well when compared to a random walk, they also rank very highly when compared to our panel of professional forecasters.

DATA APPENDIX

The spot rate data used in the evaluation of the model forecasts are taken from the same source as the exchange rate data in chapters 6, 7 and 8. That is, they are all from the International Monetary Fund's *International Financial Statistics* publication. The IMF only provide three month forward rates comparable with this spot data. We unfortunately need one, two, three, six and twelve month forward rates. These were calculated as follows. Using the Barclays Bank International pages on Datastream (the same source used earlier in this thesis) we gather the required forward rates and the prevailing spot rates on the last day of each month. These are used to form the forward premiums offered on these days. These premiums are then combined with the IMF spot rates to form new forward rates. The three month forward rate so calculated can be compared with the original IMF forward rate. The existence of no large discrepancies indicates that the technique used has done no great violence to the truth.

In forming portfolios based on the models' predictions we need a variance-covariance matrix. As in chapter 3 these were obtained by taking non-overlapping actual spot and forward rates (forward rates calculated as just explained) from a historical data base. The one month portfolios obviously take each monthly observation, the two month portfolios use the February-April-June-August-October-December rotation, the three month portfolios use the rotation described in chapter 3, and the six month portfolios use the June-December rotation.

CHAPTER 10

CONCLUSIONS OF OUR INVESTIGATION INTO FORECASTERS' ABILITIES TO PREDICT MAJOR EXCHANGE RATES: 1989-1992

10.1 A RECAPITULATION OF EARLIER RESULTS

We had very little control over the type, frequency, quantity or quality of forecasts analysed in the first half of this thesis. We are aware of only one company willing to provide fully disaggregated forecasts of several exchange rates over a reasonable period of time from a high quality, international panel. We were therefore forced to take what was available. Fortunately, what we were given was very good, namely forecasts of the five key floating exchange rates from a panel that, given the quality of the companies surveyed, ought to contain some of the best currency forecasters in the world.

The two forecast horizons surveyed also proved to be ideal for the analysis. The longer, twelve month horizon is the minimum length over which worthwhile forecasts are thought to be possible based on previous research. The three month horizon is typical of what received wisdom considers to be the 'unforecastable' prediction intervals. It also happens to emerge as the minimum point over which our econometric models demonstrate significant predictive ability.

Since we have summarised our results at various stages throughout this thesis only a few brief comments are needed at this point. From an analysis of the predictions of a panel of almost two hundred economists and executives from the largest financial groups, industrial companies and forecasting agencies in the seven richest countries in the world we can state the following:

(i) Forecasters use commonly held information in different ways, and this contributes to the existence of systematic differences in forecaster ability - some forecasters are significantly more accurate than others;

(ii) Over the short horizon, even the best are no better than a random walk and the bulk are significantly worse. It looks as though there are several forecasters so bad that they make the merely poor look good by comparison;

(iii) In terms of the twelve month predictions, a sizeable sub-group are more accurate than a random walk, some significantly so. In contrast to the short forecast horizon, several forecasters are also significantly profitable to follow;

(iv) Combining forecasts in a variety of ways cannot greatly improve the accuracy of predictions over three months, but market participants as a whole appear to have some ability to predict major events such as the collapse of the sterling and lira links with the Deutsche mark in September 1992.

The additional information that professional forecasters may incorporate into their predictions does not improve their ability sufficiently for us to refute the accepted wisdom that the exchange rate behaves like an asset price over short horizons. This rather negative result can be contrasted with the findings of chapter 5, namely:

(v) A simple, small system of variables when estimated correctly is capable of producing fully dynamic exchange rate forecasts that are more accurate and profitable than a random walk over all but the shortest horizons;

(vi) The degree of accuracy is such that the forecasts are significantly more accurate than a random walk over intervals as short as three months.

Our synthesis of these results is that the long-run, defined as the period over which economic fundamentals have something relevant to say about the course of exchange rates, may be as short as three to four months. This is a marked improvement on previous work, which had implied that the long-run starts at one year.

We continue with a re-interpretation of our results focussing on some of the more positive aspects. We begin with the recognition that some of our panellists provide some very accurate and/or profitable predictions. In section 10.2.2 we also consider the implications of the full set of results within the framework of market efficiency considerations.

10.2 A DIFFERENT INTERPRETATION OF EARLIER RESULTS

10.2.1 FIRST CLASS FORECASTERS

We have attempted to consider as much of our panel of forecasters as possible, constrained only by some less than perfect response rates. The performance of each forecaster has been examined in some detail but the majority of our assertions have been based on the results of the panel as a whole. Thus, for instance, our comments as to the general inability of professional forecasters to predict exchange rates over the shorter horizon have masked the exceptional performance of nine panellists whose RMSE ratio is less than unity for at least one currency. Although none were significant at the five percent level, one in particular came close. Forecaster G9's Deutsche mark and sterling forecasts were significantly more accurate than the random walk at the ten and six percent level, respectively. G9's mark and sterling forecasts also produced significantly positive profits using our simple switching portfolio (the profit spread was also significant for the mark). As we noted in chapter 3, G9 was the only forecaster to produce significant profits when the three currency forecasts were combined to form simple portfolios.

No other forecaster came close to the performance of G9 at the shorter horizon, but several emerged with similar credit over twelve months. Forecasters F7, J7, B28 and G2 all produced long term forecasts significantly more accurate than the random walk at the five percent level for two of the three currencies, while B16 did so for all three. Again these accurate forecasters typically emerged as significantly profitable (although the star performer in this category was B28 rather than B16). It is also worth noting that G9 again proved to be an accurate and profitable forecaster over the longer horizon. Conversely, those with an ability to forecast long term displayed little ability to do so over shorter horizons. Indeed, F7 produced three month forecasts that were significantly worse than a random walk for all three currencies, despite outperforming over the twelve month horizon.

Without wishing to labour the point, we note that the econometric model forecasts compare very favourably with even the best of the panellists. The forecasts are more accurate then a random walk over both horizons with the sole exception of the mark at the three month horizon, significantly profitable to follow, and can combine to produce portfolio profits. This consistency of performance contrasts with the panel members. Even the best were unable to provide such accurate forecasts over both horizons for all three currencies.

10.2.2 EFFICIENT MARKETS HYPOTHESIS

Certain other aspects of the literature on the foreign exchange market have also been addressed in this thesis. Foremost amongst these is the question of market efficiency. As we noted in the introductory chapter, an efficient market would imply that the ability to make super-normal profits on the basis of forecasts is quickly arbitraged away. That is, forecasters are allowed to make profits for an unspecified but 'short' period of time. Two problems have to be faced in addressing this issue based on the results of this thesis. First, the appropriate method for determining trading strategies based on simple point forecasts has to be determined, and second, we must decide what constitutes a normal profit.

Based on our simple long/short switching trading strategy presented in section 3.2.2, the results indicate no ability to make any profits over the short horizon, let alone profits adjusted for expected returns or risk.[83] Over the longer forecast interval, between twenty and fifty percent of our panel produce statistically significant average profits. On the most naive model of risk neutrality and zero expected profits, these latter results contradict market efficiency.

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83 Although, it should be noted that the expected return need not be strictly positive (see equation (13) in the introduction.

The portfolio performances of the reduced panel of forecasters (section 3.4) is designed to include normal returns and also to compensate for the risk of the positions taken using Cornell's (1979) method. Only one forecaster out of twenty-two produces supernumerary profits significant at the five percent level over three months - a proportion that can be attributed entirely to chance. Portfolios based on the forecasts of the econometric models estimated in chapters 6 through 8, are capable of generating significant excess profits for horizons in excess of three months, but not below.

Our analysis of professionals' forecasts and those from our econometric models produce similar results. Profits are essentially zero over short horizons (approximately one to three months) but appear to be significantly greater than zero for longer horizons. However, these results may be entirely due to inefficiency in the forward market, where our positions were established, rather than the spot market. Goodhart, McMahon and Ngama (1992) argue along the Cambist line that the forward differential is determined solely by domestic money markets and contains no information about the expected path of exchange rates, due to the actions of covered parity arbitrageurs. Profits may then be being made because of persistent errors in the forward differential rather than persistent errors in the spot market. For example, suppose the spot rate does in fact evolve according to a random walk, and the expected rate in the next period is today's rate. If we assume initially that domestic and foreign interest rates are equal, the forward exchange rate also predicts that tomorrow's rate will equal today's. If the domestic interest rate then rises (for purely domestic reasons) the forward market discount would conflict with expectations and afford a profit opportunity.

An alternative though restrictive interpretation of the efficient markets hypothesis is that if all information is incorporated in the current exchange rate, investors are risk neutral and expect zero returns on average, no forecast ought to be more accurate than a random walk. Over the shortest horizons they are not. Only over a forecast horizon of several months has any forecasting ability been demonstrated by either the panellists or the econometric models. Our results can then be said to provide no evidence against the efficient markets hypothesis over the short-run of up to three months, but at least *prima facie* reason to doubt its validity over the longer term. Possibly less controvertially, we can say that the random walk still seems to be the most competitive forecasting model over short horizons, but can be significantly outperformed over longer forecast intervals based ona variety of metrics.

In the introductory chapter to the thesis we discussed the various grades of market efficiency used in the literature (i.e. weak, semi-strong and strong form efficiency). These grades are based on the information set on which forecasts are assumed to be conditioned. Based on our results (and since we have no idea of the information sets used by our panellists) we prefer an alternative hierarchy based instead on the time horizon over which information matters, along the lines of the quotation from Salemi (1983) given in chapter 3.

Over the 'long' term, economic fundamentals and possibly other information can help to predict the exchange rate. Hence, our econometric models and a significant group of our panellists can produce forecasts that are significantly more accurate than the random walk. Based on our results, this 'long' term may be from three months and upwards. One of the main contributions of this thesis has been to demonstrate that the long-run is substantially shorter than was previously imagined.

Over the 'short' term, no information seems able to improve upon the forecast from a random walk model. That is, all available information relevant to this time frame would appear to be contained in the spot rate. The 'short' term appears to include the one to three month horizons.

Although this time frame was not covered in this thesis, the actions of traders (rather than investors) would seem to indicate that there is also a 'very short' term over which information may again allow forecasts which are more accurate than those from the random walk model.

What policy implications can we draw from the work? This question hinges on the rationalisation of, on the one hand, the inability to predict short term movements in the exchange rate, with the clear evidence of a link between fundamentals and actual changes in exchange rates over the medium to long-run. Profitable opportunities appear to exist for long term investment in currencies which are not arbitraged away, even if short-run opportunities are.

Our results could be interpreted as confirmation of McKinnon's (1976) view that there is insufficient long term speculation in the foreign exchange market. Thus while the current spot price contains all avaliable information relevant to predicting the 'short' term change in prices, information is available which would improve 'long' term forecasts. Why are these long term profit opportunities not arbitraged away?

Several possible answers suggest themselves. First, the structure of the foreign exchange market might preclude such long term investment by pure speculators. Most banks will not even allow traders to hold positions overnight let alone for several months. This explanation is not unrelated to the second possibility, namely that the risk of taking on such long term exposure might demand such a large premium that even though speculators can predict the exchange rate, the returns from speculating are not large enough. Therefore, in an attempt to manage risk in a simple way, investment houses simply forbid their traders to take long term exposures. The perceived high degree of risk comes from the unforecastable short term movements in the exchange rate. Most investments are regularly 'marked-to-market' (i.e. the profit or loss of a position is calculated based on current market prices regardless of the intended time span of the investment) and very few companies or managers are willing to let short-run paper losses accumulate dramatically, even if their is a prospect of profit some time in the future. A key rule emphasised in popular guides to succesful trading is to 'run your profits but cut your losses.' Furthermore, financial instruments such as futures contracts are marked-to-market daily and margin calls are made (i.e. security in the form of cash or liquid assets is demanded by the clearing house). Such calls tie up liquidity and credit lines which cannot then be used to exploit other possibly more profitable opportunities.

Determining the solution to this problem is not the subject of this thesis but several proposals to reduce the impact of short term currency movements have been suggested elsewhere in the literature. These include Tobin's (1978) suggestion of putting "sand in the wheels of international finance" by taxing all foreign exchange transactions. The tax is supposed to be sufficiently small to be no deterent to trade and long term investment but large enough to stop flows of so-called hot money. Similarly, Liviatan (1980) has argued for a real interest equalisation tax, again designed to remove the incentive for short-term money flows. Thirdly, a dual exchange rate system could be introduced for all currencies whereby the commercial exchange rate is fixed (or at least tightly managed) by governments, while the exchange rate for capital account transactions floats.

The strengths and weaknesses of most of the major proposals are surveyed in Dornbusch and Frankel (1987). They are all subject to fundamental problems, usually in the form of world-wide enforceability. In the words of Dornbusch and Frankel, what is really needed is an investor with "sufficient liquidity, sufficient patience and sufficiently low risk-aversion to wait through the high short term volatility."

10.3 FURTHER RESEARCH

From the work presented in this thesis we can identify further that issues remain to be examined. We have shortened the horizon over which fundamentals can be shown to have a role in predicting exchange rates to around three months. However, the introductory chapter shows that most trades in the foreign exchange market are for much shorter periods than this. Furthermore, since most foreign exchange departments of major banks (though not, notably, some large corporations) claim to be profitable over and above returns made from exploiting the bid-ask spread, leading traders ought to be able to forecast very short-term currency movements. Even a one month interval may be too long a period. Instead, the day-to-day or even hour-to-hour forecast ability of professionals should be examined. Academic attempts to predict over such short intervals are rare and, typically, not successful (see Diebold *et al.* (1994)). The random walk model remains the dominant benchmark in the very short-run.

Reverting to the medium to long-run forecast horizon, other more traditional models of the exchange rate should be modelled with the latest econometric technology. As we mentioned in the previous chapter, the monetary approach to the exchange rate has found support as a long-run condition and an obvious step would be to reduce this relationship to a set of structural equations.

Finally, to test the robustness of the model presented in chapter 5, similar modelling exercises should be carried out for other exchange rates. We explain deviations from PPP either by persistent long-term capital flows or expected inflation differentials. Countries in approximate balance with similar inflation profiles ought, therefore, to yield simple, un-augmented PPP as the appropriate long-run relationship. This should be tested on, for example, the exchange rates between stable ERM currencies such as the Dutch guilder and Deutsche mark. The model could also be used to examine hyperinflationary currencies where PPP is thought to hold almost continuously.

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Table A1

Use of Panellist Forecasts

	Ito Tests (2.2) and Performance Evaluation (Chap 3)						Heterogeneity Tests (2.3)		Forecast Combination (Chap4)		
	DEM 3mth	STG 3mth	JPY 3mth	DEM 12mth	STG 12mth	JPY 12mth	3mth	12mth	DEM	STG	JPY
C1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
C2	✓	✓	✓	✓	✓	✓	✓	✓			
C3	✓	✓	✓	✓	✓	✓	✓	✓			
C4	✓	✓	✓	✓	✓	✓	✓	✓			
C5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
C11			✓								
C12	✓	✓	✓	✓	✓	✓	✓	✓			
C14	✓	✓	✓		✓						
C15	✓	✓	✓	✓	✓	✓	✓	✓			
C16	✓	✓	✓	✓	✓	✓		✓			
C17	✓		✓								
C18	✓	✓	✓	✓	✓	✓	✓	✓			
C19	✓	✓	✓	✓	✓	✓	✓	✓			
C20	✓	✓	✓								
F2	✓	✓	✓	✓		✓					
F4	✓	✓	✓	✓	✓	✓	✓	✓			
F5	✓	✓	✓	✓	✓	✓	✓	✓			
F7	✓	✓	✓	✓	✓	✓					
F8	✓	✓	✓	✓	✓	✓		✓			
F9	✓		✓	✓		✓					
F10	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
F11	✓			✓							
F12	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
F16	✓	✓	✓	✓	✓	✓	✓				
I1	✓	✓	✓	✓	✓	✓	✓	✓			
I2	✓	✓	✓	✓	✓	✓	✓	✓			
I5	✓	✓	✓	✓	✓	✓	✓	✓			
I6	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
I7	✓	✓	✓	✓	✓	✓	✓	✓			
I10	✓	✓	✓	✓	✓	✓		✓			
J1			✓			✓					✓
J2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

	Ito Tests (2.2) and Performance Evaluation (Chap 3)						Heterogeneity Tests (2.3)		Forecast Combination (Chap4)		
	DEM 3mth	STG 3mth	JPY 3mth	DEM 12mth	STG 12mth	JPY 12mth	3mth	12mth	DEM	STG	JPY
J3	✓		✓	✓		✓					✓
J4	✓		✓			✓					
J5			✓			✓					
J6	✓	✓	✓	✓	✓	✓					
J7	✓	✓	✓		✓	✓					✓
J9	✓	✓	✓	✓	✓	✓	✓	✓			
J10			✓								
J11	✓		✓			✓					✓
J12			✓			✓					
J13			✓			✓					
J14	✓	✓	✓				✓		✓		✓
J15			✓			✓					
J16	✓	✓	✓	✓	✓	✓	✓	✓			
J17		✓	✓								
J18	✓	✓	✓	✓	✓	✓					✓
J19			✓			✓					
J20	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
B1	✓	✓	✓	✓	✓	✓		✓			
B2	✓	✓	✓	✓	✓	✓	✓	✓			
B3	✓	✓	✓	✓	✓	✓					
B4	✓	✓	✓	✓	✓	✓	✓	✓			
B5				✓	✓	✓					
B7	✓	✓	✓	✓	✓	✓	✓	✓			
B8	✓	✓		✓	✓						
B9	✓	✓	✓				✓				
B10	✓										
B11	✓	✓	✓								
B12	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
B13	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
B14	✓	✓	✓	✓	✓	✓	✓	✓			
B15	✓	✓	✓	✓	✓	✓					
B16	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
B17	✓	✓	✓								
B18	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

	Ito Tests (2.2) and Performance Evaluation (Chap 3)						Heterogeneity Tests (2.3)		Forecast Combination (Chap4)		
	DEM 3mth	STG 3mth	JPY 3mth	DEM 12mth	STG 12mth	JPY 12mth	3mth	12mth	DEM	STG	JPY
B20	✓	✓	✓	✓	✓	✓					
B22	✓	✓	✓	✓	✓	✓	✓	✓			
B23	✓	✓	✓	✓	✓	✓	✓	✓	✓		
B25	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
B27	✓	✓	✓	✓	✓	✓	✓	✓			
B28	✓	✓	✓	✓	✓	✓	✓	✓			
B29	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
B30	✓	✓	✓	✓	✓	✓	✓	✓			
B31	✓	✓	✓	✓	✓	✓	✓	✓			
B32	✓	✓		✓	✓				✓	✓	
B35	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
B36		✓			✓						
U1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
U3	✓	✓	✓	✓		✓					
U5	✓	✓	✓	✓	✓	✓	✓	✓			
U6	✓	✓	✓	✓	✓	✓					
U7	✓		✓								
U8	✓	✓	✓	✓	✓	✓	✓	✓			
U10	✓	✓	✓								
U11	✓	✓	✓								
U12	✓		✓								
U13	✓	✓	✓	✓	✓	✓	✓	✓			
U15	✓	✓	✓	✓	✓	✓	✓	✓			
U17	✓	✓	✓								
U19	✓	✓	✓	✓	✓	✓	✓	✓			
U20	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
U24	✓	✓	✓	✓	✓	✓	✓	✓	✓		
U26	✓	✓	✓	✓	✓	✓					
U29	✓		✓			✓					
U30	✓		✓	✓		✓					
U31	✓	✓	✓								
G1	✓			✓							
G2	✓	✓	✓	✓	✓	✓	✓	✓			
G3	✓	✓	✓	✓	✓	✓	✓	✓			

	Ito Tests (2.2) and Performance Evaluation (Chap 3)						Heterogeneity Tests (2.3)		Forecast Combination (Chap4)		
	DEM 3mth	STG 3mth	JPY 3mth	DEM 12mth	STG 12mth	JPY 12mth	3mth	12mth	DEM	STG	JPY
G4	✓	✓	✓	✓	✓	✓	✓	✓	✓		
G5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
G7	✓			✓							
G8	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
G9	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
G10	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
G11	✓	✓	✓	✓	✓	✓	✓	✓			
G12	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
G13	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
G14	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
G15	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
G16	✓										
G17	✓			✓							
G18	✓	✓	✓	✓							
G19	✓	✓	✓	✓	✓	✓	✓	✓			
G20	✓	✓	✓	✓	✓	✓	✓	✓			
G22	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
G23	✓			✓					✓		

NOTES: A ✓ in a column indicates that the forecaster's predictions were used in the relevant tests. The criteria for inclusion in each test were as follows: Ito-type tests of information interpretation: min. 20 forecasts for both three and twelve month horizons; Fixed effects and Prentice nonparametric tests of performance heterogeneity: min. 29 forecasts for each of the three currencies over three months, min. 23 over twelve months; Performance evaluation (RMSEs, profit, rationality and directional tests): min. 20 forecasts for both three and twelve month horizons; Forecast combination methods: min. 35 forecasts (only three month forecasts examined). The exact number of responses made for each forecaster/currency/horizon combination is given in table A2, for those forecasters who provided at least 20 predictions for any currency.

Table A2

Individual Forecaster Accuracy - RMSE

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio
C1	35	*1.156*	35	*1.133*	35	*1.241*	27	1.123	27	1.018	27	0.741
C2	30	1.277	30	1.186	30	*1.383*	23	0.953	23	1.002	23	**0.622**
C3	34	1.127	34	1.094	34	*1.190*	26	0.952	26	1.047	26	0.662
C4	31	1.100	31	1.114	31	*1.201*	24	0.938	24	1.259	24	1.122
C5	36	*1.208*	36	1.089	36	*1.250*	27	1.135	27	1.067	27	1.056
C11					25	1.177						
C12	34	1.105	34	*1.252*	34	1.297	25	1.153	26	1.130	26	1.000
C14	21	1.098	21	*1.576*	20	*1.987*			20	1.008		
C15	32	1.171	31	1.074	32	1.179	25	1.117	25	0.940	25	1.251
C16	28	*1.274*	28	*1.218*	28	*1.240*	24	1.187	24	0.959	24	0.959
C17	20	0.991			20	1.208						
C18	31	1.205	32	1.096	32	*1.228*	26	1.106	26	1.097	26	**0.638**
C19	32	*1.272*	32	*1.280*	33	*1.286*	25	*1.678*	25	1.476	26	*1.679*
C20	21	1.115	20	1.049	22	*1.681*						
F2	36	*1.151*	21	1.020	31	*1.265*	27	*1.351*			22	1.195
F4	34	*1.193*	33	1.132	34	*1.289*	26	1.084	26	1.054	26	**0.607**
F5	32	1.211	32	*1.295*	32	*1.327*	25	*1.617*	25	*1.756*	25	1.214
F7	30	*1.425*	28	*1.257*	28	*1.466*	21	1.054	20	**0.730**	20	**0.649**
F8	31	*1.231*	27	*1.135*	28	1.209	23	*1.375*	23	1.161	23	0.900
F9	31	*1.261*			31	1.167	24	*1.352*			23	0.691
F10	36	*1.233*	36	*1.192*	36	*1.265*	26	*1.287*	26	*1.248*	26	0.849
F11	31	*1.219*					25	1.126				
F12	35	1.089	35	1.033	35	1.120	26	0.943	27	0.935	27	**0.447**
F16	31	1.208	31	1.096	31	*1.334*	22	*1.320*	22	1.278	22	1.190
I1	32	*1.272*	32	*1.151*	32	*1.312*	25	*1.296*	25	*1.409*	25	0.931
I2	33	*1.171*	33	*1.214*	33	*1.258*	25	0.992	25	1.120	25	**0.744**

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio
I5	34	*1.181*	34	*1.210*	34	1.111	26	1.129	25	1.060	25	1.094
I6	36	*1.207*	33	1.084	36	*1.370*	27	0.944	24	1.132	27	0.965
I7	34	*1.202*	34	1.104	34	1.066	25	0.904	26	0.931	26	**0.555**
I10	27	1.081	27	*1.177*	27	*1.234*	25	1.108	26	1.137	26	1.155
J1					36	*1.436*					27	0.901
J2	35	*1.108*	35	*1.075*	35	*1.132*	26	1.054	26	1.046	26	**0.674**
J3	33	*1.206*			36	*1.177*	24	1.269			27	*1.358*
J4	20	1.020			29	*1.277*					22	0.744
J5					23	1.288					20	*1.546*
J6	33	*1.177*	27	1.066	33	*1.341*	26	0.929	20	1.110	26	1.074
J7	25	*1.321*	24	1.119	35	1.167			20	**0.822**	27	**0.683**
J9	34	1.128	34	1.028	34	*1.373*	24	0.997	25	0.996	25	0.770
J10					22	*1.224*						
J11	28	*1.235*			35	*1.181*					26	**0.488**
J12					28	*1.275*					22	**0.898**
J13					32	1.085					26	1.103
J14	36	*1.315*	34	1.057	36	*1.477*						
J15					31	1.146					26	0.798
J16	31	1.033	30	1.049	31	1.139	24	1.159	24	*1.253*	24	*1.391*
J17			21	1.108	28	1.216						
J18	31	1.041	26	*1.121*	35	*1.170*	22	**0.810**	20	1.420	26	0.800
J19					25	1.248					21	1.048
J20	36	*1.178*	36	*1.130*	36	*1.302*	27	1.084	27	1.030	27	0.853
B1	27	*1.339*	29	*1.216*	29	*1.458*	26	1.273	26	1.008	26	1.176
B2	32	1.107	33	1.142	33	1.189	25	1.162	25	*1.267*	25	**0.666**
B3	20	1.098	20	1.178	20	1.067	20	*1.300*	20	*1.401*	20	1.121
B4	30	*1.416*	31	*1.307*	30	*1.306*	24	0.956	25	0.951	24	1.184
B5							21	0.941	22	1.177	22	0.909
B7	30	1.119	30	1.065	30	*1.240*	24	*1.420*	25	*1.616*	25	*1.650*
B8	29	*1.217*	29	1.198			24	1.096	22	1.136		
B9	31	1.079	31	1.119	31	*1.187*						

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio
B10	20	*1.255*										
B11	21	1.126	22	1.009	21	1.194						
B12	35	*1.341*	35	1.171	35	*1.515*	26	1.147	26	*1.231*	26	1.219
B13	35	1.021	35	1.030	35	1.174	26	1.140	26	1.050	26	0.789
B14	32	*1.229*	32	1.058	32	*1.369*	24	1.083	24	*1.155*	24	0.867
B15	24	*1.234*	24	*1.204*	21	1.148	24	*1.205*	24	*1.339*	21	*1.752*
B16	36	1.058	36	0.998	36	1.099	26	**0.900**	27	**0.900**	27	**0.539**
B17	26	*1.225*	26	*1.102*	26	1.136						
B18	35	*1.376*	35	*1.245*	35	*1.347*	26	1.239	26	1.324	26	**0.393**
B20	29	1.191	29	1.143	26	*1.611*	24	*1.396*	25	*1.331*	22	*1.534*
B22	34	*1.351*	34	1.128	34	*1.526*	25	1.075	25	1.053	25	0.959
B23	35	*1.222*	34	*1.154*	33	*1.254*	25	1.206	26	*1.111*	25	**0.571**
B25	35	1.181	36	1.090	33	1.205	25	1.095	26	1.080	26	0.937
B27	33	*1.347*	33	*1.237*	33	*1.441*	26	1.137	26	1.010	26	**0.411**
B28	31	1.112	32	1.017	32	1.299	24	**0.865**	24	0.906	23	**0.541**
B29	36	1.055	36	1.180	35	*1.298*	27	0.887	27	1.063	26	*1.543*
B30	34	1.135	34	*1.198*	34	0.991	25	1.026	26	1.342	26	**0.646**
B31	32	*1.290*	32	1.244	31	1.120	26	1.181	26	*1.282*	25	1.263
B32	35	1.176	36	1.054			25	1.139	26	1.165		
B35	36	*1.359*	36	1.125	36	*1.568*	26	0.910	27	0.963	27	1.006
B36			34	1.038					25	1.077		
U1	36	1.090	35	1.004	35	0.989	26	1.088	27	1.183	27	*1.195*
U3	33	1.249	28	1.015	32	1.564	25	1.439			25	*1.963*
U5	32	1.085	33	*1.086*	33	1.079	25	1.068	25	1.021	25	1.092
U6	26	1.086	26	*1.120*	26	*1.202*	22	*1.411*	23	*1.539*	23	*1.683*
U7	20	*1.317*			20	*1.358*						
U8	34	1.078	34	0.994	34	*1.304*	24	0.944	25	0.906	25	0.958
U10	22	*1.118*	22	*1.097*	22	1.268						
U11	25	1.070	25	1.046	25	*1.393*						
U12	24	1.026			24	*1.241*						
U13	32	1.170	33	1.086	33	1.216	24	1.027	25	1.043	25	0.813

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio
U15	33	*1.199*	32	1.130	33	*1.476*	24	*1.567*	24	1.546	25	*1.759*
U17	21	1.083	21	1.113	21	*1.412*						
U19	33	*1.291*	33	*1.210*	33	*1.432*	24	*1.187*	24	1.147	24	**0.768**
U20	36	0.983	35	0.957	35	1.165	27	0.843	27	0.997	27	0.808
U24	35	0.971	34	1.057	34	1.075	26	0.964	27	1.137	27	**0.528**
U26	29	*1.217*	28	*1.491*	29	1.342	22	*1.504*	22	*1.547*	23	1.634
U29	26	*1.491*			27	*1.494*					20	0.820
U30	27	1.115			27	1.227	22	0.765			21	1.044
U31	24	*1.212*	25	1.027	26	*1.282*						
G1	34	1.291					25	*1.226*				
G2	33	1.125	33	1.143	33	1.166	25	**0.793**	25	*1.257*	25	**0.715**
G3	33	*1.185*	31	*1.171*	31	*1.248*	24	1.057	23	1.136	23	0.971
G4	35	*1.390*	33	*1.381*	32	*1.430*	26	*1.452*	24	*1.750*	23	*1.401*
G5	36	*1.163*	36	1.066	36	1.154	26	1.040	27	*1.253*	27	**0.719**
G7	26	1.026					26	1.237				
G8	36	*1.325*	36	1.140	36	*1.452*	27	1.068	27	1.028	27	**0.725**
G9	35	0.945	35	0.890	35	1.155	26	0.879	26	1.085	26	**0.729**
G10	36	*1.229*	35	*1.141*	36	*1.426*	26	1.059	26	0.913	27	0.733
G11	34	1.163	33	1.091	34	*1.479*	25	0.997	24	1.312	25	1.175
G12	35	*1.293*	35	*1.219*	34	*1.358*	27	1.216	27	1.069	26	*1.647*
G13	36	*1.385*	36	*1.258*	36	*1.327*	27	1.255	27	1.128	27	0.934
G14	36	1.128	36	1.144	36	*1.283*	27	*1.219*	27	*1.479*	27	0.823
G15	36	*1.246*	36	1.145	36	*1.362*	25	*1.241*	26	1.248	26	0.940
G16	24	*1.277*										
G17	32	1.081					23	0.935				
G18	35	*1.201*	27	0.953	27	1.138	25	0.899				
G19	33	*1.122*	33	1.065	33	1.183	24	1.132	24	1.025	24	0.840

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio	No.	Ratio
G20	33	*1.195*	33	1.030	33	1.207	25	1.093	25	1.039	25	0.797
G22	36	*1.258*	36	1.108	35	*1.405*	27	0.974	27	1.005	26	0.750
G23	36	*1.209*					25	1.115				

NOTES: For each currency/maturity combination, the first column gives the number of responses made by a forecaster, and the second column gives the ratio of forecaster RMSE to random walk RMSE, the latter being calculated only over the months for which responses were given. A ratio significantly below unity at the five percent level is represented by bold type, and a ratio significantly greater than unity at the five percent level by italic type.

Table A3

Individual Forecaster Profitability

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Profit	**Spread**	**Profit**	**Spread**	**Profit**	**Spread**	**Profit**	**Spread**	**Profit**	**Spread**	**Profit**	**Spread**
C1	(1.269)	(1.024)	(0.725)	*(3.179)*	(0.331)	(0.624)	2.041	(1.266)	**5.999**	(2.635)	2.712	2.548
C2	0.852	1.484	1.476	0.000	0.239	(0.889)	**7.363**	3.674	**8.810**	0.000	**6.403**	5.446
C3	0.838	0.642	(0.201)	*(2.973)*	(0.297)	(0.662)	3.398	0.402	**4.211**	(4.327)	**5.854**	6.055
C4	(0.358)	(0.746)	(0.432)	(3.387)	(0.619)	(0.656)	**5.749**	1.320	0.816	(7.070)	(0.890)	(1.561)
C5	(2.069)	(2.034)	1.182	(0.953)	*(1.857)*	(2.257)	(1.153)	(4.460)	**5.324**	(3.309)	(0.164)	(0.328)
C11					(0.366)	(0.096)						
C12	1.495	1.090	(0.127)	*(3.180)*	0.774	0.408	(1.685)	(5.400)	4.529	(4.646)	2.192	2.122
C14	0.808	2.594	(0.390)	(1.745)	(2.408)	(1.406)			1.910	(2.670)		
C15	(1.350)	(1.339)	2.206	(0.776)	(1.173)	(1.830)	1.426	(2.073)	5.828	(3.259)	1.461	1.721
C16	0.173	(1.445)	(1.175)	*(3.608)*	(0.009)	(1.128)	(0.492)	*(3.862)*	**5.942**	(2.812)	2.318	2.457
C17	1.051	1.685			(0.900)	(1.439)						
C18	*(2.241)*	(2.000)	0.585	(1.645)	(1.017)	(0.877)	1.266	(1.106)	**7.321**	(0.774)	**6.363**	6.614
C19	(0.720)	(0.826)	0.333	(2.919)	*(2.449)*	(2.607)	(5.480)	(7.467)	(5.601)	(13.006)	*(6.171)*	*(5.920)*
C20	0.551	1.907	(1.226)	(2.000)	(0.323)	(0.610)						
F2	(0.951)	(0.916)	1.097	(2.274)	(1.246)	(2.462)	(3.756)	(7.063)			(1.807)	(2.998)
F4	(1.771)	(1.931)	(0.246)	(2.792)	(1.012)	(1.453)	1.039	(2.450)	**5.758**	(2.627)	**5.367**	4.687
F5	(1.471)	(1.492)	(1.775)	(4.871)	(0.218)	(0.356)	(4.881)	(7.069)	(7.483)	(14.966)	*(1.946)*	(2.037)
F7	*(3.909)*	*(4.555)*	*(4.064)*	*(6.464)*	0.264	0.678	(0.017)	(3.632)	**5.403**	1.716	**5.828**	3.833
F8	*(2.653)*	(2.605)	(1.913)	*(4.127)*	0.694	0.926	(3.763)	(4.759)	**3.459**	(4.243)	**3.249**	3.888
F9	(2.282)	(1.708)			0.140	(0.360)	(2.375)	(4.697)			**5.164**	5.189
F10	*(3.335)*	(3.300)	*(3.073)*	*(5.208)*	*(1.982)*	(2.382)	*(5.548)*	(8.521)	(1.905)	*(9.896)*	3.367	3.014
F11	*(2.658)*	(2.073)					(0.047)	(1.909)				
F12	1.663	1.438	**3.809**	1.088	(0.039)	(0.469)	4.753	1.703	**9.098**	0.465	**6.681**	6.517
F16	(1.518)	(1.850)	(0.056)	(2.129)	0.181	(0.160)	*(5.657)*	(8.597)	0.741	(8.108)	2.550	2.034
I1	(0.978)	(1.540)	(0.041)	*(3.067)*	0.130	0.091	4.226	0.360	2.233	*(5.186)*	**4.790**	4.475
I2	(1.893)	(1.735)	(0.683)	(2.988)	(1.085)	(1.526)	**4.093**	0.742	**7.263**	(1.792)	**4.548**	4.057
I5	*(3.521)*	(3.631)	*(2.915)*	*(5.347)*	(0.520)	(0.862)	2.865	(0.401)	**7.852**	(0.988)	(0.176)	0.018
I6	(0.757)	(0.722)	(0.156)	(1.988)	(0.154)	(0.553)	**4.964**	1.657	**3.380**	(2.805)	1.794	1.630
I7	(0.455)	(0.717)	**2.917**	0.184	1.259	1.102	3.913	1.221	**6.584**	(1.406)	**6.926**	6.573
I10	(0.428)	0.735	(1.260)	*(4.569)*	(0.748)	(0.757)	(0.117)	(3.522)	7.799	(1.316)	(1.773)	(1.761)
J1					(0.941)	(1.341)					**5.549**	5.386

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Profit	Spread	Profit	Spread	Profit	Spread	Profit	Spread	Profit	Spread	Profit	Spread
J2	(0.371)	(0.533)	(0.028)	(1.828)	(1.514)	(2.100)	2.284	(1.241)	7.044	(1.624)	**5.805**	5.284
J3	(1.367)	(1.473)			*(1.542)*	(1.942)	1.425	(2.867)			*(4.062)*	(4.226)
J4	1.512	0.755			(0.179)	(0.130)					**6.819**	7.706
J5					1.606	1.449					0.228	0.425
J6	(0.749)	(0.362)	(1.876)	(4.435)	*(3.142)*	*(3.289)*	4.589	1.421	**9.725**	(1.146)	(0.612)	(0.574)
J7	(1.542)	(1.625)	(0.260)	*(2.325)*	1.447	1.017			**8.065**	0.390	**6.475**	6.311
J9	0.338	0.636	0.245	*(1.815)*	(0.774)	(1.017)	**3.540**	1.676	**8.753**	0.000	**4.342**	4.819
J10					(1.012)	(0.523)						
J11	(2.348)	(2.987)			1.152	0.865					**6.479**	6.634
J12					(1.326)	(1.896)					1.605	2.591
J13					0.242	0.431					(1.168)	(1.562)
J14	(0.989)	(0.954)	0.426	(0.988)	*(1.511)*	(1.911)						
J15					0.361	0.656					**4.715**	4.362
J16	**2.903**	**2.452**	**2.971**	(1.053)	(0.189)	(0.361)	3.372	(0.083)	(1.239)	*(11.442)*	*(3.257)*	(2.852)
J17			(1.066)	(1.620)	0.199	(0.541)						
J18	0.245	1.343	*(3.594)*	*(5.142)*	(0.020)	(0.358)	**6.537**	**6.451**	(1.670)	(10.401)	7.016	**7.049**
J19					1.621	2.428					1.473	(0.763)
J20	(0.282)	(0.247)	0.648	(1.487)	(0.116)	(0.516)	(0.270)	(3.577)	5.639	(2.994)	2.848	2.685
B1	*(3.403)*	(4.732)	(1.558)	(2.107)	(1.362)	(2.419)	(1.364)	(5.170)	4.333	(4.779)	1.103	0.617
B2	2.160	2.637	1.371	(0.718)	1.600	1.127	0.280	(3.846)	**3.257**	(6.479)	**6.699**	**6.589**
B3	1.139	1.950	(1.175)	*(5.515)*	(0.098)	(0.124)	*(5.962)*	(9.235)	*(7.142)*	*(18.283)*	2.309	3.244
B4	(1.647)	(1.515)	(0.635)	*(3.617)*	(0.055)	(0.193)	**6.565**	3.898	**9.550**	1.088	(0.016)	(0.515)
B5							6.022	(0.111)	1.120	(7.723)	**3.889**	3.340
B7	(1.125)	0.465	1.205	(0.635)	(0.569)	(0.545)	*(8.428)*	*(11.772)*	*(9.311)*	*(19.275)*	(2.590)	(2.630)
B8	*(3.594)*	(3.810)	(1.893)	(4.229)			3.779	2.251	2.291	(4.130)		
B9	(0.426)	(0.205)	*(3.135)*	*(5.629)*	(1.438)	(1.563)						
B10	(1.517)	2.078										
B11	(0.328)	0.467	2.154	(1.531)	(0.384)	(0.682)						
B12	(1.912)	(2.200)	0.831	(1.106)	0.029	(0.328)	1.271	(3.097)	1.233	(6.517)	1.642	1.079
B13	1.126	0.838	2.158	0.222	1.067	0.710	0.602	(3.766)	**5.995**	(1.755)	**6.048**	5.485
B14	*(2.455)*	(2.267)	(0.394)	(1.921)	(1.464)	(1.469)	0.980	(1.517)	4.717	(2.028)	**4.303**	3.125
B15	(0.924)	0.630	(0.306)	*(3.629)*	(1.492)	(1.453)	(1.028)	(3.148)	(3.132)	(11.533)	*(6.095)*	*(5.310)*
B16	1.526	1.561	4.740	2.605	1.108	0.709	**5.439**	2.389	7.955	(0.679)	**5.927**	5.763
B17	(2.093)	(2.285)	(0.590)	*(2.539)*	0.375	(0.087)						
B18	*(2.310)*	(2.472)	*(2.860)*	*(4.660)*	(1.063)	(1.649)	(2.416)	(5.941)	(2.253)	(10.922)	**6.869**	6.349

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Profit	**Spread**	**Profit**	**Spread**	**Profit**	**Spread**	**Profit**	**Spread**	**Profit**	**Spread**	**Profit**	**Spread**
B20	1.233	1.787	0.352	(2.484)	*(3.023)*	(3.577)	*(6.606)*	(9.863)	3.429	(6.385)	*(3.203)*	(2.476)
B22	*(2.849)*	(3.181)	0.421	(2.102)	(1.312)	(1.828)	0.569	*(3.463)*	**8.420**	(1.282)	3.289	3.362
B23	*(2.820)*	(2.799)	*(2.389)*	*(4.458)*	(1.670)	(1.882)	(0.746)	(3.640)	4.135	(5.152)	**6.479**	6.734
B25	(1.367)	(1.655)	0.315	(1.820)	0.398	0.450	0.625	(3.517)	5.391	(2.359)	2.636	2.072
B27	(0.931)	(0.759)	(0.189)	*(2.614)*	(1.689)	(1.957)	5.911	3.359	**7.958**	(0.141)	**5.408**	5.677
B28	(1.787)	(1.418)	2.116	(0.331)	0.760	0.838	**7.542**	**5.534**	**9.639**	**1.805**	**5.746**	5.502
B29	(1.069)	(1.034)	1.016	(1.119)	(1.085)	(1.634)	**7.424**	**4.117**	**5.327**	(3.306)	*(4.386)*	(5.067)
B30	(1.301)	(0.610)	(2.554)	(4.357)	1.437	0.921	1.101	(2.398)	*(3.101)*	*(12.233)*	**4.995**	5.042
B31	1.408	1.020	**3.259**	(0.816)	1.667	1.261	0.457	(2.809)	(0.934)	(9.829)	0.162	(0.219)
B32	*(2.821)*	(3.236)	0.383	(1.752)			0.709	(2.697)	**4.999**	(4.288)		
B35	(1.235)	(1.200)	1.454	(0.681)	0.049	(0.351)	5.509	2.459	**7.030**	(1.604)	2.499	2.335
B36			0.202	(2.563)					4.070	*(5.398)*		
U1	(2.037)	(2.002)	1.288	(0.649)	0.242	(0.116)	(3.232)	(6.282)	1.341	*(7.293)*	*(4.371)*	(4.535)
U3	*(2.829)*	(2.818)	1.301	(1.065)	*(2.917)*	*(3.242)*	(4.069)	(6.948)			*(4.880)*	(5.087)
U5	0.853	0.750	(0.137)	*(2.658)*	0.261	(0.233)	2.183	*(1.608)*	**6.682**	(0.147)	(1.549)	(2.368)
U6	(0.405)	(0.475)	1.423	(2.082)	(0.381)	(0.119)	*(8.899)*	*(13.551)*	*(9.073)*	*(17.624)*	(2.539)	(2.662)
U7	(1.655)	(1.593)			(1.530)	*(2.320)*						
U8	(0.327)	0.187	0.908	(0.851)	(0.885)	(1.616)	3.839	1.182	**9.491**	0.933	1.378	1.357
U10	(1.711)	*(3.644)*	*(4.418)*	*(5.074)*	(0.131)	(1.254)						
U11	(1.783)	*(3.347)*	(2.810)	(2.759)	(0.643)	(1.673)						
U12	0.162	0.328			(1.238)	(0.557)						
U13	(0.928)	(0.148)	1.474	(0.557)	(0.464)	(0.602)	1.396	(1.332)	**3.894**	(4.451)	**3.339**	3.760
U15	*(2.551)*	(2.966)	(2.114)	(4.227)	*(2.144)*	(2.437)	(5.971)	(9.299)	*(7.038)*	*(14.076)*	*(4.540)*	(4.898)
U17	(0.892)	1.649	(0.307)	(1.191)	(1.141)	(1.652)						
U19	*(2.482)*	(2.810)	(1.085)	(2.689)	(0.955)	(1.808)	0.612	(3.133)	4.232	*(4.853)*	**3.802**	3.298
U20	1.078	1.113	**2.368**	0.452	(0.448)	(0.997)	**6.165**	2.857	**10.667**	**2.033**	2.229	2.065
U24	1.421	1.421	0.409	(1.559)	1.567	1.046	6.409	3.359	1.325	(7.308)	**6.952**	**6.788**
U26	(0.773)	0.459	*(4.199)*	*(6.418)*	0.859	1.056	*(6.110)*	(5.998)	(7.356)	(14.847)	0.444	1.971
U29	(2.468)	(3.194)			1.766	1.720					**5.394**	5.934
U30	**2.686**	2.763			(0.177)	(0.705)	**5.531**	1.193			2.468	2.717
U31	*(3.133)*	*(4.527)*	1.068	(0.121)	(0.457)	(0.556)						
G1	*(2.705)*	(2.967)					*(4.513)*	(7.874)				
G2	0.629	0.408	0.793	(2.060)	1.129	0.840	**7.639**	**5.284**	(2.098)	*(10.393)*	**5.931**	**6.589**
G3	*(2.752)*	(2.902)	(0.988)	(3.358)	(0.912)	(1.546)	3.582	(0.197)	6.919	(1.349)	1.513	1.670
G4	*(2.713)*	(2.692)	(2.088)	(4.272)	(0.773)	(0.922)	(4.713)	(7.881)	*(3.550)*	*(13.241)*	(1.500)	(0.833)

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Profit	Spread	Profit	Spread	Profit	Spread	Profit	Spread	Profit	Spread	Profit	Spread
G5	(0.990)	(0.955)	(2.128)	*(4.262)*	(0.866)	(1.266)	4.350	1.300	2.474	*(6.160)*	2.903	2.739
G7	1.720	2.493					(0.165)	(4.533)				
G8	*(3.640)*	(3.605)	(0.541)	(2.676)	*(2.851)*	*(3.250)*	**3.247**	(0.060)	**6.384**	(2.250)	**4.174**	4.010
G9	**3.260**	**3.469**	**5.520**	3.538	(0.934)	(1.765)	4.764	1.044	**7.618**	(1.477)	**3.752**	3.292
G10	(0.778)	(0.743)	0.299	*(1.682)*	*(2.712)*	*(3.112)*	1.975	(1.076)	**10.116**	1.021	**4.672**	4.508
G11	(0.426)	(0.387)	(0.796)	(2.234)	(1.304)	(1.780)	2.517	(0.208)	(4.388)	(12.000)	**4.141**	3.703
G12	(1.220)	(1.087)	0.406	(1.628)	0.216	0.011	(1.449)	(4.756)	4.674	(3.960)	(0.473)	(0.593)
G13	(2.234)	(2.199)	0.064	(2.071)	0.038	(0.362)	(0.225)	(3.533)	5.432	(3.202)	3.461	3.297
G14	0.315	0.350	(0.471)	(2.606)	(0.980)	(1.379)	(4.254)	(7.562)	*(4.968)*	*(13.602)*	2.746	2.582
G15	(1.145)	(1.110)	1.211	(0.924)	(1.391)	*(1.791)*	*(3.551)*	*(6.548)*	(0.087)	(8.982)	2.506	2.490
G16	*(4.881)*	(4.743)										
G17	(0.971)	(1.361)					**4.539**	0.421				
G18	(1.204)	(1.012)	0.793	(1.350)	1.292	0.687	**5.875**	**3.495**				
G19	(1.072)	(0.494)	0.155	(1.747)	0.183	0.163	0.045	(1.283)	5.962	(1.700)	**4.209**	5.013
G20	*(2.894)*	(2.600)	1.056	(1.541)	(0.113)	(0.174)	(1.857)	(3.924)	5.789	(2.219)	**4.962**	5.435
G22	(2.583)	(2.548)	(0.998)	(3.132)	(0.976)	(1.232)	2.721	(0.587)	**9.138**	0.505	**4.232**	4.112
G23	(1.052)	(1.017)					2.617	(0.380)				

NOTES: The figure in the first column of each currency/maturity combination gives the per trade profit made on the basis of the forecasts according to the simple switching strategy outlined in section 3.2.2. The second column gives the spread, or difference, between the per trade profit of the forecaster and the per trade profit of the random walk, such that a positive number indicates that the forecaster returns higher profits. Profits and spreads significantly greater than (less than) zero at the five percent level are printed in bold (italic) type. The number of forecasts made correspond to the numbers in table A3 above.

Table A4

Individual Forecaster Rationality Tests

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig
C1	58.854	0.000	21.476	0.000	34.486	0.000	39.588	0.000	**3.206**	0.201	44.515	0.000
	49.723	0.000	15.802	0.000	32.721	0.000	16.878	0.000	**0.346**	0.556	13.807	0.000
	0.653	0.721	0.640	0.726	1.854	0.396	3.793	0.150	**2.868**	0.238	6.032	0.049
C2	17.803	0.000	18.327	0.000	62.669	0.000	**2.766**	0.251	1.477	0.478	14.845	0.001
	17.220	0.000	11.058	0.001	38.605	0.000	**1.795**	0.180	1.213	0.271	8.587	0.003
	2.304	0.316	2.680	0.262	6.471	0.039	**1.200**	0.549	11.466	0.003	26.415	0.000
C3	16.820	0.000	13.217	0.001	23.344	0.000	11.386	0.003	15.279	0.000	333.183	0.000
	12.291	0.000	10.846	0.001	22.752	0.000	10.537	0.001	5.313	0.021	67.821	0.000
	2.005	0.367	1.936	0.380	0.494	0.781	3.097	0.213	13.491	0.001	37.548	0.000
C4	18.349	0.000	5.276	0.071	19.696	0.000	8.864	0.012	12.866	0.002	77.700	0.000
	12.064	0.001	4.050	0.044	11.010	0.001	8.412	0.004	12.859	0.000	53.145	0.000
	0.770	0.680	3.525	0.172	2.869	0.238	5.993	0.050	6.955	0.031	42.052	0.000
C5	13.807	0.001	4.727	0.094	26.517	0.000	**4.318**	0.115	10.288	0.006	181.496	0.000
	5.598	0.018	2.658	0.103	14.155	0.000	**3.150**	0.076	10.231	0.001	11.071	0.001
	4.203	0.122	6.236	0.044	8.059	0.018	**5.762**	0.056	7.347	0.025	280.869	0.000
C11					15.877	0.000						
					14.845	0.000						
					0.374	0.829						
C12	10.277	0.006	24.085	0.000	21.358	0.000	7.206	0.027	8.032	0.018	106.725	0.000
	8.499	0.004	16.477	0.000	21.176	0.000	2.357	0.125	0.001	0.975	58.315	0.000
	0.346	0.841	2.595	0.273	5.492	0.064	15.948	0.000	7.800	0.020	29.649	0.000
C14	5.954	0.051	17.715	0.000	34.458	0.000			11.532	0.003		
	5.938	0.015	4.107	0.043	9.223	0.002			0.010	0.919		
	0.380	0.827	15.470	0.000	36.909	0.000			12.531	0.002		
C15	13.334	0.001	3.140	0.208	26.305	0.000	12.795	0.002	**3.427**	0.180	203.104	0.000
	7.558	0.006	2.005	0.157	9.634	0.002	11.456	0.001	**0.041**	0.839	63.991	0.000
	3.877	0.144	7.488	0.024	8.850	0.012	6.232	0.044	**3.187**	0.203	6.687	0.035
C16	25.897	0.000	95.326	0.000	25.246	0.000	85.901	0.000	**1.371**	0.504	194.757	0.000
	10.792	0.001	18.683	0.000	22.456	0.000	63.219	0.000	**0.056**	0.813	54.344	0.000
	4.837	0.089	12.776	0.002	1.208	0.547	0.675	0.714	**2.444**	0.295	207.675	0.000
C17	**3.819**	0.148			16.002	0.000						
	0.227	0.633			14.838	0.000						
	4.961	0.084			9.311	0.010						
C18	14.149	0.001	9.102	0.011	36.370	0.000	20.517	0.000	11.225	0.004	395.715	0.000
	13.900	0.000	9.084	0.003	28.180	0.000	17.431	0.000	4.460	0.035	394.063	0.000
	0.077	0.962	0.358	0.836	0.470	0.791	0.092	0.955	9.817	0.007	5.667	0.059

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig
C19	23.749	0.000	22.773	0.000	15.631	0.000	36.521	0.000	29.258	0.000	210.609	0.000
	7.302	0.007	7.989	0.005	12.880	0.000	0.051	0.822	1.236	0.266	137.093	0.000
	8.190	0.017	9.258	0.010	9.965	0.007	36.787	0.000	35.473	0.000	229.666	0.000
C20	6.767	0.034	**3.255**	0.196	92.390	0.000						
	6.025	0.014	**2.330**	0.127	83.189	0.000						
	0.780	0.677	**1.158**	0.561	13.588	0.001						
F2	17.166	0.000	7.896	0.019	42.329	0.000	11.026	0.004			189.846	0.000
	6.103	0.013	0.038	0.845	30.931	0.000	0.000	0.997			52.536	0.000
	4.356	0.113	21.253	0.000	6.303	0.043	25.602	0.000			22.992	0.000
F4	15.520	0.000	7.362	0.025	47.269	0.000	9.138	0.010	11.779	0.003	108.054	0.000
	9.507	0.002	6.736	0.009	36.318	0.000	2.706	0.100	2.749	0.097	47.040	0.000
	2.811	0.245	6.363	0.042	2.512	0.285	27.871	0.000	27.810	0.000	45.510	0.000
F5	10.511	0.005	20.530	0.000	118.308	0.000	21.468	0.000	52.886	0.000	123.010	0.000
	5.834	0.016	18.678	0.000	84.537	0.000	2.868	0.090	1.444	0.230	122.955	0.000
	3.709	0.157	4.017	0.134	1.386	0.500	17.967	0.000	24.408	0.000	41.304	0.000
F7	82.801	0.000	76.009	0.000	167.439	0.000	7.142	0.028	42.647	0.000	95.074	0.000
	79.058	0.000	31.006	0.000	94.323	0.000	6.472	0.011	18.926	0.000	21.475	0.000
	0.061	0.970	2.311	0.315	0.610	0.737	73.860	0.000	7.033	0.030	61.098	0.000
F8	42.218	0.000	40.728	0.000	26.401	0.000	29.435	0.000	**3.938**	0.140	301.649	0.000
	16.179	0.000	11.241	0.001	24.883	0.000	24.323	0.000	**0.075**	0.785	19.174	0.000
	2.414	0.299	1.912	0.384	0.173	0.917	3.753	0.153	**4.436**	0.109	456.088	0.000
F9	16.461	0.000			9.344	0.009	93.401	0.000			34.737	0.000
	13.512	0.000			9.245	0.002	21.661	0.000			13.770	0.000
	0.669	0.716			4.034	0.133	10.641	0.005			3.602	0.165
F10	64.926	0.000	29.901	0.000	32.335	0.000	307.443	0.000	57.257	0.000	334.253	0.000
	53.791	0.000	18.636	0.000	32.305	0.000	88.004	0.000	23.725	0.000	73.369	0.000
	1.496	0.473	3.291	0.193	1.912	0.384	2.780	0.249	1.714	0.424	5.354	0.069
F11	28.922	0.000					11.236	0.004				
	28.701	0.000					11.126	0.001				
	1.552	0.460					2.404	0.301				
F12	11.372	0.003	**1.494**	0.474	5.678	0.058	**2.024**	0.364	**0.717**	0.699	15.180	0.001
	6.628	0.010	**1.410**	0.235	5.678	0.017	**0.000**	0.990	**0.003**	0.959	8.420	0.004
	0.357	0.836	**0.275**	0.872	5.152	0.076	**3.324**	0.190	**1.352**	0.509	9.742	0.008
F16	9.477	0.009	**2.979**	0.225	21.695	0.000	36.102	0.000	29.789	0.000	122.172	0.000
	3.808	0.051	**2.032**	0.154	18.568	0.000	13.677	0.000	3.252	0.071	38.825	0.000
	3.924	0.141	**5.557**	0.062	5.272	0.072	10.857	0.004	7.169	0.028	9.685	0.008
I1	30.395	0.000	14.851	0.001	73.628	0.000	92.308	0.000	273.653	0.000	101.396	0.000
	24.506	0.000	12.618	0.000	67.375	0.000	88.498	0.000	65.915	0.000	87.366	0.000
	0.487	0.784	0.358	0.836	0.523	0.770	1.011	0.603	0.102	0.950	20.147	0.000
I2	12.737	0.002	27.550	0.000	32.042	0.000	**2.038**	0.361	18.395	0.000	113.716	0.000
	7.656	0.006	21.084	0.000	28.338	0.000	**1.648**	0.199	18.244	0.000	10.121	0.001
	1.036	0.596	2.307	0.316	4.082	0.130	**3.826**	0.148	17.493	0.000	178.442	0.000

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig
I5	17.989	0.000	60.799	0.000	12.868	0.002	5.143	0.076	7.096	0.029	110.127	0.000
	6.313	0.012	15.081	0.000	10.697	0.001	0.837	0.360	0.019	0.891	17.494	0.000
	3.277	0.194	6.467	0.039	5.438	0.066	11.295	0.004	5.113	0.078	96.061	0.000
I6	16.771	0.000	**3.942**	0.139	118.080	0.000	3.602	0.165	6.209	0.045	192.009	0.000
	13.964	0.000	**3.824**	0.051	62.456	0.000	0.572	0.450	4.732	0.030	70.011	0.000
	1.966	0.374	**2.884**	0.237	3.358	0.187	10.965	0.004	8.485	0.014	22.006	0.000
I7	23.610	0.000	5.387	0.068	18.460	0.000	**0.259**	0.878	**0.810**	0.667	35.854	0.000
	18.667	0.000	5.387	0.020	18.443	0.000	**0.177**	0.674	**0.288**	0.592	0.199	0.655
	0.393	0.822	0.768	0.681	0.136	0.934	**0.263**	0.877	**5.328**	0.070	162.448	0.000
I10	13.249	0.001	38.046	0.000	34.465	0.000	6.827	0.033	6.344	0.042	409.169	0.000
	12.060	0.001	13.886	0.000	22.329	0.000	4.168	0.041	5.821	0.016	114.843	0.000
	1.916	0.384	1.803	0.406	3.106	0.212	5.224	0.073	1.832	0.400	90.481	0.000
J1					61.023	0.000					97.486	0.000
					35.621	0.000					97.261	0.000
					11.493	0.003					49.730	0.000
J2	15.696	0.000	10.133	0.006	25.447	0.000	75.622	0.000	30.874	0.000	138.772	0.000
	11.260	0.001	8.614	0.003	21.407	0.000	12.390	0.000	2.595	0.107	11.011	0.001
	1.017	0.601	1.506	0.471	0.884	0.643	2.970	0.226	0.592	0.744	6.707	0.035
J3	19.986	0.000			17.427	0.000	18.023	0.000			114.167	0.000
	7.829	0.005			11.728	0.001	7.707	0.006			70.990	0.000
	2.063	0.357			4.567	0.102	11.224	0.004			200.306	0.000
J4	17.434	0.000			40.727	0.000					94.627	0.000
	9.308	0.002			20.138	0.000					10.193	0.001
	10.296	0.006			0.424	0.809					20.293	0.000
J5					23.301	0.000					257.697	0.000
					5.633	0.018					257.671	0.000
					14.161	0.001					12.014	0.002
J6	16.283	0.000	2.990	0.224	65.089	0.000	**0.744**	0.689	**4.713**	0.095	129.663	0.000
	16.036	0.000	0.625	0.429	61.381	0.000	**0.744**	0.388	**0.232**	0.630	126.776	0.000
	1.612	0.447	8.654	0.013	6.275	0.043	**1.150**	0.563	**4.627**	0.099	47.575	0.000
J7	43.358	0.000	12.015	0.002	23.144	0.000			76.921	0.000	72.332	0.000
	43.257	0.000	11.949	0.001	10.226	0.001			10.688	0.001	43.692	0.000
	0.179	0.914	1.489	0.475	1.265	0.531			0.751	0.687	12.244	0.002
J9	15.795	0.000	6.357	0.042	43.055	0.000	**2.350**	0.309	**1.442**	0.486	45.651	0.000
	8.523	0.004	5.444	0.020	38.822	0.000	**0.727**	0.394	**0.553**	0.457	12.267	0.000
	0.600	0.741	0.847	0.655	1.145	0.564	**2.265**	0.322	**1.051**	0.591	31.210	0.000
J10					17.761	0.000						
					17.541	0.000						
					0.462	0.794						
J11	15.382	0.000			23.695	0.000					9.635	0.008
	12.668	0.000			14.623	0.000					1.979	0.159
	0.842	0.656			0.318	0.853					21.958	0.000

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig
J12					22.521	0.000					57.593	0.000
					22.518	0.000					4.087	0.043
					0.652	0.722					76.337	0.000
J13					15.025	0.001					621.736	0.000
					12.030	0.001					18.590	0.000
					3.082	0.214					138.632	0.000
J14	24.899	0.000	4.239	0.120	80.599	0.000						
	24.554	0.000	0.478	0.489	31.283	0.000						
	4.814	0.090	8.823	0.012	12.997	0.002						
J15					33.652	0.000					75.340	0.000
					24.917	0.000					37.698	0.000
					0.924	0.630					46.272	0.000
J16	5.587	0.061	5.044	0.080	7.388	0.025	36.936	0.000	40.778	0.000	251.933	0.000
	2.898	0.089	2.579	0.108	6.945	0.008	13.736	0.000	31.907	0.000	103.113	0.000
	7.320	0.026	3.781	0.151	1.056	0.590	1.970	0.373	3.153	0.207	152.646	0.000
J17			11.547	0.003	40.605	0.000						
			11.055	0.001	22.500	0.000						
			9.939	0.007	1.858	0.395						
J18	13.098	0.001	39.357	0.000	34.667	0.000	4.960	0.084	42.127	0.000	227.750	0.000
	12.450	0.000	37.216	0.000	22.392	0.000	2.986	0.084	23.369	0.000	227.173	0.000
	0.865	0.649	0.036	0.982	0.892	0.640	0.323	0.851	39.584	0.000	2.692	0.260
J19					46.414	0.000					402.869	0.000
					26.891	0.000					188.432	0.000
					0.324	0.851					22.083	0.000
J20	23.902	0.000	27.742	0.000	41.529	0.000	6.672	0.036	3.093	0.213	77.393	0.000
	18.561	0.000	26.107	0.000	36.244	0.000	1.149	0.284	0.014	0.907	10.561	0.001
	0.388	0.824	1.614	0.446	3.663	0.160	7.770	0.021	4.358	0.113	79.499	0.000
B1	22.399	0.000	15.982	0.000	86.102	0.000	64.479	0.000	10.051	0.007	237.179	0.000
	21.376	0.000	12.627	0.000	86.085	0.000	32.354	0.000	3.703	0.054	103.991	0.000
	1.529	0.465	4.175	0.124	5.956	0.051	14.716	0.001	6.368	0.041	9.015	0.011
B2	10.322	0.006	11.109	0.004	18.263	0.000	15.767	0.000	74.639	0.000	154.699	0.000
	6.287	0.012	9.020	0.003	18.188	0.000	12.706	0.000	74.203	0.000	76.551	0.000
	0.483	0.785	2.531	0.282	3.428	0.180	0.853	0.653	0.635	0.728	90.360	0.000
B3	6.183	0.045	14.987	0.001	3.709	0.157	41.845	0.000	44.618	0.000	280.670	0.000
	1.462	0.227	0.521	0.470	3.614	0.057	41.832	0.000	0.376	0.540	59.364	0.000
	7.560	0.023	12.713	0.002	9.632	0.008	5.639	0.060	13.774	0.001	257.354	0.000
B4	43.935	0.000	22.830	0.000	17.176	0.000	2.175	0.337	0.262	0.877	363.501	0.000
	32.041	0.000	20.921	0.000	12.008	0.001	2.172	0.141	0.163	0.687	37.806	0.000
	0.096	0.953	1.136	0.567	4.064	0.131	0.983	0.612	0.170	0.919	44.897	0.000
B5							5.085	0.079	3.566	0.168	198.379	0.000
							0.445	0.505	3.531	0.060	92.023	0.000
							6.769	0.034	8.170	0.017	177.376	0.000

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig
B7	5.478	0.065	**3.182**	0.204	36.449	0.000	42.192	0.000	32.133	0.000	158.022	0.000
	4.857	0.028	**3.178**	0.075	29.170	0.000	38.485	0.000	32.082	0.000	65.211	0.000
	2.486	0.289	**2.968**	0.227	1.376	0.503	7.307	0.026	11.909	0.003	392.875	0.000
B8	10.930	0.004	9.879	0.007			25.597	0.000	**2.753**	0.253		
	6.274	0.012	8.344	0.004			19.239	0.000	**1.128**	0.288		
	1.911	0.385	1.904	0.386			5.329	0.070	**2.609**	0.271		
B9	**3.533**	0.171	10.504	0.005	30.610	0.000						
	1.795	0.180	10.305	0.001	27.815	0.000						
	2.122	0.346	2.401	0.301	3.619	0.164						
B10	29.781	0.000										
	16.970	0.000										
	0.583	0.747										
B11	6.621	0.036	**3.792**	0.150	7.910	0.019						
	6.242	0.012	**1.486**	0.223	7.711	0.005						
	3.834	0.147	**2.116**	0.347	3.337	0.189						
B12	23.392	0.000	14.363	0.001	59.016	0.000	19.312	0.000	146.956	0.000	231.699	0.000
	22.720	0.000	12.673	0.000	43.280	0.000	14.357	0.000	135.627	0.000	113.405	0.000
	2.528	0.282	2.141	0.343	3.741	0.154	7.966	0.019	1.890	0.389	11.191	0.004
B13	5.887	0.053	**2.140**	0.343	30.006	0.000	12.550	0.002	7.233	0.027	191.506	0.000
	5.761	0.016	**1.161**	0.281	20.527	0.000	12.362	0.000	0.145	0.703	97.295	0.000
	0.000	1.000	**0.374**	0.830	0.384	0.825	9.870	0.007	2.649	0.266	1.240	0.538
B14	14.236	0.001	**2.868**	0.238	60.078	0.000	5.384	0.068	14.531	0.001	136.772	0.000
	7.892	0.005	**2.601**	0.107	55.054	0.000	4.353	0.037	13.586	0.000	100.115	0.000
	2.219	0.330	**1.128**	0.569	0.236	0.889	8.417	0.015	0.804	0.669	3.460	0.177
B15	25.499	0.000	62.190	0.000	10.218	0.006	14.678	0.001	10.452	0.005	283.224	0.000
	13.905	0.000	11.302	0.001	4.280	0.039	9.508	0.002	6.493	0.011	42.946	0.000
	5.341	0.069	2.230	0.328	5.564	0.062	2.188	0.335	2.616	0.270	220.748	0.000
B16	7.483	0.024	**0.415**	0.813	5.612	0.060	**5.193**	0.075	4.501	0.105	20.546	0.000
	3.623	0.057	**0.267**	0.605	5.262	0.022	**2.939**	0.086	4.418	0.036	16.992	0.000
	2.111	0.348	**2.672**	0.263	4.128	0.127	**3.123**	0.210	1.361	0.506	0.595	0.743
B17	10.652	0.005	14.083	0.001	7.891	0.019						
	7.814	0.005	8.164	0.004	6.670	0.010						
	2.535	0.282	1.475	0.478	3.165	0.205						
B18	88.760	0.000	51.377	0.000	44.104	0.000	12.332	0.002	13.982	0.001	5.899	0.052
	59.882	0.000	26.950	0.000	36.541	0.000	0.392	0.531	0.253	0.615	0.108	0.743
	2.005	0.367	3.427	0.180	0.731	0.694	21.976	0.000	17.610	0.000	10.377	0.006
B20	16.056	0.000	14.449	0.001	111.058	0.000	309.729	0.000	124.714	0.000	902.639	0.000
	14.058	0.000	8.492	0.004	78.721	0.000	99.951	0.000	32.311	0.000	77.402	0.000
	0.078	0.962	2.353	0.308	8.288	0.016	9.718	0.008	3.100	0.212	220.420	0.000
B22	39.057	0.000	6.853	0.033	79.999	0.000	81.426	0.000	4.556	0.102	123.515	0.000
	30.282	0.000	6.538	0.011	50.348	0.000	44.342	0.000	0.020	0.889	97.446	0.000
	0.845	0.655	5.202	0.074	1.145	0.564	7.708	0.021	8.106	0.017	8.462	0.015

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig
B23	64.259	0.000	34.274	0.000	32.522	0.000	175.006	0.000	108.726	0.000	116.861	0.000
	26.101	0.000	23.672	0.000	31.376	0.000	100.341	0.000	6.925	0.009	50.580	0.000
	0.724	0.696	1.287	0.525	0.324	0.851	2.290	0.318	1.412	0.494	80.628	0.000
B25	8.945	0.011	5.662	0.059	21.497	0.000	4.099	0.129	11.391	0.003	44.371	0.000
	8.563	0.003	5.638	0.018	20.478	0.000	2.743	0.098	0.042	0.838	25.391	0.000
	0.689	0.708	0.840	0.657	2.260	0.323	7.307	0.026	10.510	0.005	81.520	0.000
B27	135.355	0.000	40.912	0.000	101.035	0.000	35.659	0.000	5.403	0.067	19.050	0.000
	103.006	0.000	29.923	0.000	98.763	0.000	21.484	0.000	4.723	0.030	3.656	0.056
	0.012	0.994	0.405	0.817	0.442	0.802	0.433	0.805	0.528	0.768	15.882	0.000
B28	5.084	0.079	1.046	0.593	37.719	0.000	2.111	0.348	12.795	0.002	113.716	0.000
	2.393	0.122	0.326	0.568	26.098	0.000	0.883	0.347	12.793	0.000	20.316	0.000
	1.035	0.596	2.316	0.314	4.705	0.095	2.480	0.289	2.179	0.336	12.367	0.002
B29	5.925	0.052	7.702	0.021	12.855	0.002	131.330	0.000	7.014	0.030	338.590	0.000
	4.891	0.027	6.921	0.009	11.756	0.001	39.359	0.000	0.165	0.685	105.086	0.000
	4.053	0.132	0.701	0.704	6.644	0.036	11.513	0.003	2.293	0.318	380.174	0.000
B30	8.341	0.015	28.085	0.000	1.861	0.394	4.435	0.109	20.422	0.000	43.397	0.000
	5.369	0.020	11.984	0.001	1.601	0.206	0.332	0.565	1.918	0.166	40.833	0.000
	5.356	0.069	5.837	0.054	1.232	0.540	13.515	0.001	13.423	0.001	16.868	0.000
B31	32.970	0.000	29.404	0.000	6.769	0.034	9.466	0.009	16.374	0.000	400.972	0.000
	26.964	0.000	27.530	0.000	5.811	0.016	8.109	0.004	16.289	0.000	396.290	0.000
	1.619	0.445	1.286	0.526	4.342	0.114	0.332	0.847	2.609	0.271	41.492	0.000
B32	8.899	0.012	2.506	0.286			4.638	0.098	13.685	0.001		
	2.239	0.135	1.524	0.217			0.531	0.466	0.000	0.994		
	7.143	0.028	4.610	0.100			10.286	0.006	6.044	0.049		
B35	18.162	0.000	3.417	0.181	36.101	0.000	0.929	0.628	15.308	0.000	169.655	0.000
	8.100	0.004	2.453	0.117	30.299	0.000	0.032	0.859	0.672	0.412	160.311	0.000
	4.097	0.129	1.144	0.565	10.032	0.007	8.425	0.015	3.969	0.137	90.705	0.000
B36			2.117	0.347					7.586	0.023		
			0.801	0.371					1.106	0.293		
			8.102	0.017					2.682	0.262		
U1	7.538	0.023	3.463	0.177	2.891	0.236	5.229	0.073	21.345	0.000	593.570	0.000
	2.511	0.113	0.162	0.688	1.265	0.261	0.179	0.673	20.586	0.000	6.447	0.011
	3.885	0.143	6.374	0.041	6.607	0.037	5.849	0.054	9.776	0.008	1032.833	0.000
U3	11.411	0.003	4.247	0.120	43.732	0.000	25.432	0.000			616.510	0.000
	5.950	0.015	0.008	0.931	27.635	0.000	0.056	0.813			14.542	0.000
	8.651	0.013	4.537	0.103	15.650	0.000	32.312	0.000			974.688	0.000
U5	12.306	0.002	13.043	0.001	7.577	0.023	64.856	0.000	8.988	0.011	193.354	0.000
	12.048	0.001	9.227	0.002	7.505	0.006	56.378	0.000	4.100	0.043	0.635	0.425
	0.621	0.733	2.143	0.342	2.777	0.249	4.967	0.083	0.923	0.630	243.952	0.000
U6	7.681	0.021	13.816	0.001	30.755	0.000	49.798	0.000	25.514	0.000	106.585	0.000
	5.325	0.021	8.785	0.003	19.602	0.000	39.581	0.000	24.853	0.000	70.566	0.000
	1.140	0.565	4.814	0.090	1.165	0.558	28.267	0.000	10.231	0.006	396.426	0.000

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig
U7	16.657	0.000			24.918	0.000						
	11.925	0.001			23.332	0.000						
	3.674	0.159			1.384	0.501						
U8	7.315	0.026	**1.146**	0.564	18.384	0.000	**1.185**	0.553	7.468	0.024	201.146	0.000
	7.113	0.008	**0.522**	0.470	17.903	0.000	**0.043**	0.835	6.000	0.014	2.690	0.101
	0.294	0.863	**0.882**	0.643	6.614	0.037	**1.905**	0.386	2.053	0.358	192.017	0.000
U10	9.130	0.010	9.023	0.011	13.237	0.001						
	8.072	0.004	8.572	0.003	11.602	0.001						
	1.275	0.529	10.166	0.006	4.003	0.135						
U11	**3.811**	0.149	6.282	0.043	112.587	0.000						
	3.570	0.059	3.560	0.059	112.057	0.000						
	1.144	0.564	4.159	0.125	0.759	0.684						
U12	7.048	0.029			27.607	0.000						
	1.071	0.301			9.563	0.002						
	4.987	0.083			5.113	0.078						
U13	16.660	0.000	**3.197**	0.202	15.017	0.001	3.939	0.140	16.321	0.000	183.134	0.000
	9.028	0.003	**2.504**	0.114	14.470	0.000	0.033	0.855	8.743	0.003	41.358	0.000
	4.809	0.090	**4.149**	0.126	3.392	0.183	7.775	0.020	5.977	0.050	194.349	0.000
U15	18.420	0.000	5.422	0.066	70.005	0.000	269.509	0.000	22.367	0.000	519.011	0.000
	14.366	0.000	0.618	0.432	36.177	0.000	155.116	0.000	0.657	0.418	63.892	0.000
	2.544	0.280	19.244	0.000	8.397	0.015	21.469	0.000	32.898	0.000	985.029	0.000
U17	9.517	0.009	10.738	0.005	45.031	0.000						
	3.717	0.054	6.411	0.011	11.481	0.001						
	2.596	0.273	1.989	0.370	7.932	0.019						
U19	11.613	0.003	12.431	0.002	66.614	0.000	109.782	0.000	6.128	0.047	39.263	0.000
	11.153	0.001	11.668	0.001	48.100	0.000	108.703	0.000	3.494	0.062	39.220	0.000
	0.224	0.894	1.496	0.473	0.474	0.789	1.864	0.394	1.703	0.427	14.022	0.001
U20	**1.057**	0.589	**0.742**	0.690	21.895	0.000	**2.445**	0.294	10.003	0.007	38.264	0.000
	0.793	0.373	**0.055**	0.815	16.740	0.000	**0.481**	0.488	10.000	0.002	30.183	0.000
	0.272	0.873	**5.408**	0.067	7.242	0.027	**5.918**	0.052	3.837	0.147	34.116	0.000
U24	**0.414**	0.813	5.794	0.055	9.466	0.009	**1.383**	0.501	**3.302**	0.192	18.675	0.000
	0.372	0.542	4.264	0.039	9.465	0.002	**1.272**	0.259	**1.348**	0.246	7.592	0.006
	0.449	0.799	4.000	0.135	1.894	0.388	**0.910**	0.634	**5.105**	0.078	1.226	0.542
U26	40.667	0.000	75.849	0.000	38.637	0.000	27.313	0.000	57.257	0.000	798.593	0.000
	35.796	0.000	32.170	0.000	27.693	0.000	21.741	0.000	46.214	0.000	187.819	0.000
	0.749	0.688	2.616	0.270	2.337	0.311	3.482	0.175	39.666	0.000	8.697	0.013
U29	52.743	0.000			51.533	0.000					72.969	0.000
	44.305	0.000			41.785	0.000					54.096	0.000
	0.843	0.656			2.818	0.244					3.396	0.183
U30	6.053	0.048			9.832	0.007	**0.868**	0.648			213.620	0.000
	5.945	0.015			9.550	0.002	**0.736**	0.391			88.308	0.000
	1.633	0.442			1.885	0.390	**1.942**	0.379			22.446	0.000

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig
U31	23.342	0.000	**3.619**	0.164	43.179	0.000						
	20.208	0.000	**2.609**	0.106	35.353	0.000						
	1.522	0.467	**0.977**	0.614	0.460	0.795						
G1	23.152	0.000					120.587	0.000				
	3.110	0.078					20.758	0.000				
	12.572	0.002					13.091	0.001				
G2	16.034	0.000	6.180	0.046	27.335	0.000	**1.820**	0.403	35.110	0.000	124.874	0.000
	8.996	0.003	6.126	0.013	15.813	0.000	**0.790**	0.374	25.700	0.000	69.550	0.000
	1.552	0.460	0.235	0.889	1.576	0.455	**0.679**	0.712	3.070	0.215	1.655	0.437
G3	16.548	0.000	33.708	0.000	46.584	0.000	26.158	0.000	14.126	0.001	750.982	0.000
	15.352	0.000	33.661	0.000	33.598	0.000	5.784	0.016	10.793	0.001	556.412	0.000
	0.479	0.787	5.643	0.060	1.102	0.576	6.400	0.041	1.536	0.464	22.438	0.000
G4	34.685	0.000	43.902	0.000	131.971	0.000	38.241	0.000	214.376	0.000	914.680	0.000
	25.820	0.000	30.534	0.000	116.584	0.000	13.883	0.000	13.205	0.000	162.808	0.000
	2.112	0.348	6.519	0.038	0.528	0.768	8.900	0.012	12.551	0.002	168.017	0.000
G5	19.309	0.000	**3.286**	0.193	13.068	0.001	5.828	0.054	44.996	0.000	33.864	0.000
	15.889	0.000	**2.860**	0.091	11.205	0.001	5.024	0.025	44.957	0.000	22.184	0.000
	0.369	0.832	**4.465**	0.107	4.443	0.108	2.009	0.366	1.549	0.461	25.600	0.000
G7	**2.442**	0.295					15.951	0.000				
	2.367	0.124					10.056	0.002				
	1.247	0.536					24.952	0.000				
G8	20.019	0.000	6.007	0.050	80.746	0.000	7.793	0.020	7.030	0.030	92.368	0.000
	10.148	0.001	4.559	0.033	75.418	0.000	5.188	0.023	2.922	0.087	58.870	0.000
	3.084	0.214	2.806	0.246	4.317	0.115	4.516	0.105	5.750	0.056	18.873	0.000
G9	**0.320**	0.852	**5.213**	0.074	18.634	0.000	**0.608**	0.738	**2.758**	0.252	39.496	0.000
	0.094	0.760	**3.136**	0.077	18.600	0.000	**0.429**	0.513	**2.727**	0.099	20.767	0.000
	0.361	0.835	**4.556**	0.103	2.577	0.276	**0.500**	0.779	**1.275**	0.529	30.384	0.000
G10	26.200	0.000	22.945	0.000	106.822	0.000	13.550	0.001	**0.327**	0.849	285.870	0.000
	26.194	0.000	19.479	0.000	102.678	0.000	10.715	0.001	**0.030**	0.862	131.168	0.000
	0.259	0.879	0.753	0.686	1.434	0.488	1.505	0.471	**1.029**	0.598	3.400	0.183
G11	11.320	0.003	15.006	0.001	25.920	0.000	**3.167**	0.205	17.077	0.000	60.265	0.000
	11.166	0.001	13.843	0.000	23.571	0.000	**3.060**	0.080	13.125	0.000	50.343	0.000
	0.148	0.929	0.003	0.998	2.424	0.298	**2.116**	0.347	8.584	0.014	17.361	0.000
G12	82.897	0.000	38.758	0.000	86.444	0.000	28.271	0.000	26.537	0.000	669.140	0.000
	69.998	0.000	38.504	0.000	83.803	0.000	27.775	0.000	2.288	0.130	466.740	0.000
	0.432	0.806	2.457	0.293	0.007	0.996	4.760	0.093	7.910	0.019	21.669	0.000
G13	17.947	0.000	14.160	0.001	35.935	0.000	12.444	0.002	6.913	0.032	51.591	0.000
	14.301	0.000	14.157	0.000	35.935	0.000	6.939	0.008	0.173	0.678	33.417	0.000
	1.797	0.407	0.525	0.769	0.883	0.643	15.247	0.000	5.385	0.068	2.675	0.263
G14	8.149	0.017	10.737	0.005	21.640	0.000	20.427	0.000	83.575	0.000	27.521	0.000
	3.928	0.047	10.220	0.001	16.743	0.000	8.877	0.003	44.480	0.000	24.170	0.000
	2.543	0.280	4.196	0.123	7.991	0.018	9.303	0.010	9.014	0.011	6.805	0.033

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig	Test Stat	Mgn Sig
G15	19.754	0.000	19.228	0.000	161.564	0.000	36.777	0.000	5.272	0.072	66.227	0.000
	13.178	0.000	17.127	0.000	144.923	0.000	22.243	0.000	1.452	0.228	32.045	0.000
	2.273	0.321	3.040	0.219	3.110	0.211	10.223	0.006	6.314	0.043	7.846	0.020
G16	34.409	0.000										
	27.956	0.000										
	0.805	0.669										
G17	5.797	0.055					**4.498**	0.106				
	4.126	0.042					**3.489**	0.062				
	1.257	0.533					**5.686**	0.058				
G18	11.166	0.004	0.196	0.907	17.530	0.000	**0.261**	0.877				
	9.621	0.002	0.015	0.903	15.572	0.000	**0.013**	0.911				
	0.537	0.765	6.158	0.046	2.060	0.357	**0.234**	0.890				
G19	11.991	0.002	**4.687**	0.096	17.905	0.000	26.243	0.000	**4.906**	0.086	44.242	0.000
	4.306	0.038	**2.441**	0.118	17.543	0.000	6.051	0.014	**0.706**	0.401	14.140	0.000
	2.308	0.315	**5.189**	0.075	0.777	0.678	3.062	0.216	**0.680**	0.712	34.524	0.000
G20	11.245	0.004	**1.992**	0.369	16.411	0.000	14.470	0.001	**2.413**	0.299	43.516	0.000
	3.970	0.046	**1.191**	0.275	14.821	0.000	13.580	0.000	**2.200**	0.138	2.457	0.117
	2.202	0.332	**0.996**	0.608	2.220	0.330	2.193	0.334	**1.639**	0.441	213.655	0.000
G22	13.250	0.001	**3.244**	0.198	31.105	0.000	2.411	0.300	**5.872**	0.053	69.137	0.000
	8.248	0.004	**2.720**	0.099	28.287	0.000	0.178	0.673	**0.947**	0.330	52.782	0.000
	2.690	0.261	**4.143**	0.126	4.346	0.114	6.801	0.033	**3.517**	0.172	10.036	0.007
G23	14.598	0.001					3.910	0.142				
	8.542	0.003					2.970	0.085				
	2.963	0.227					16.343	0.000				

NOTES: The first column of figures for each forecaster/currency/maturity combination gives the value of three test statistics. These are, respectively, the test that $\alpha=0/\beta=1$ in equation (30), that $\beta=1$ in equation (30), and that $\Phi_0=\Phi_1=0$ in equation (31). These are distributed χ^2 with two, one and two degrees of freedom respectively. The second column of figures for each combination gives the marginal significance associated with each test statistic. A bold typeface indicates that all three tests cannot be rejected at the five percent level, and that the forecaster is deemed to be rational for that currency/maturity combination.

Table A5
Individual Directional AbilityTests

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig
C1	-0.034	0.005	-0.032	0.041	-0.015	0.079	-0.033	0.225	0.057	0.021	-0.002	0.710
	-0.034	0.005	-0.039	0.025	-0.014	0.168	-0.030	0.266	0.050	0.160	-0.001	0.865
	-0.143	0.000	0.028	0.174	-0.048	0.031	-0.042	0.092	0.062	0.004	0.017	0.229
C2	-0.008	0.719	0.009	0.762	-0.001	0.957	NA	NA	0.064	0.011	NA	NA
	0.008	0.732	-0.008	0.801	-0.011	0.336	NA	NA	0.074	0.018	0.021	0.033
	-0.027	0.331	-0.004	0.904	0.004	0.776	0.048	0.297	0.021	0.487	0.019	0.145
C3	0.010	0.339	0.008	0.507	-0.011	0.144	0.026	0.260	-0.002	0.859	0.007	0.053
	0.001	0.931	0.004	0.780	-0.013	0.220	0.034	0.067	0.009	0.407	-0.001	0.803
	-0.013	0.579	-0.002	0.920	-0.011	0.520	0.063	0.000	0.032	0.257	0.006	0.479
C4	-0.013	0.369	-0.005	0.800	-0.006	0.585	0.020	0.271	0.037	0.022	0.005	0.416
	-0.011	0.410	0.008	0.605	-0.007	0.626	0.021	0.252	0.039	0.036	0.004	0.528
	-0.023	0.507	-0.082	0.002	-0.039	0.002	0.048	0.007	0.021	0.475	0.009	0.261
C5	0.002	0.856	0.009	0.623	-0.014	0.231	0.018	0.299	0.073	0.001	0.020	0.006
	-0.004	0.851	0.029	0.164	-0.022	0.086	0.024	0.159	0.067	0.012	0.020	0.016
	-0.048	0.207	-0.035	0.197	-0.027	0.047	0.047	0.010	0.118	0.000	0.038	0.001
C11					-0.012	0.288						
					-0.022	0.069						
					-0.011	0.606						
C12	-0.012	0.414	-0.038	0.018	0.001	0.949	0.011	0.687	0.065	0.001	0.012	0.206
	-0.015	0.435	-0.047	0.017	0.002	0.867	0.017	0.614	0.099	0.000	0.012	0.154
	-0.003	0.938	-0.046	0.055	-0.018	0.333	-0.003	0.957	0.058	0.413	0.018	0.152
C14	0.017	0.314	0.003	0.798	-0.052	0.000			0.071	0.001		
	0.013	0.404	0.010	0.449	-0.028	0.437			0.055	0.000		
	0.019	0.410	0.034	0.289	-0.003	0.921			0.072	0.008		
C15	-0.005	0.687	0.005	0.679	-0.011	0.413	-0.020	0.364	0.074	0.002	0.007	0.226
	-0.005	0.721	0.013	0.388	-0.005	0.769	-0.021	0.327	0.069	0.014	0.006	0.318
	0.012	0.541	0.040	0.400	0.030	0.000	0.007	0.837	0.081	0.033	0.008	0.365
C16	0.001	0.946	-0.016	0.441	0.002	0.870	-0.078	0.001	0.016	0.520	0.001	0.873
	0.008	0.639	-0.029	0.145	0.006	0.592	-0.070	0.001	0.022	0.348	0.003	0.630
	-0.019	0.648	-0.016	0.507	0.017	0.191	-0.041	0.136	0.064	0.001	0.028	0.057
C17	-0.006	0.647			-0.018	0.244						
	0.001	0.957			-0.016	0.430						
	0.059	0.353			0.000	0.994						
C18	-0.021	0.076	-0.018	0.248	-0.016	0.106	-0.038	0.000	-0.016	0.648	0.007	0.161
	-0.020	0.103	-0.012	0.397	-0.027	0.047	-0.024	0.004	-0.003	0.927	0.007	0.161
	0.002	0.945	-0.010	0.667	-0.003	0.847	-0.052	0.053	0.034	0.269	0.020	0.000

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig
C19	0.014	0.304	0.018	0.141	-0.021	0.063	NA	NA	NA	NA	-0.013	0.005
	0.021	0.194	0.029	0.224	-0.025	0.072	NA	NA	NA	NA	-0.003	0.427
	-0.010	0.748	0.010	0.672	-0.026	0.401	0.116	0.001	0.111	0.015	0.001	0.754
C20	0.019	0.222	0.008	0.675	-0.007	0.599						
	0.007	0.654	0.008	0.795	-0.008	0.617						
	0.016	0.631	0.051	0.446	-0.028	0.052						
F2	0.008	0.567	0.024	0.187	-0.013	0.113	NA	NA			0.006	0.275
	0.003	0.869	0.036	0.109	-0.022	0.018	0.028	0.486			0.008	0.073
	-0.031	0.192	0.065	0.078	-0.023	0.251	0.072	0.204			0.004	0.455
F4	-0.007	0.498	-0.016	0.204	-0.011	0.302	**0.082**	0.000	0.052	0.165	**0.023**	0.007
	-0.015	0.290	-0.014	0.304	-0.024	0.017	**0.088**	0.000	0.125	0.002	**0.023**	0.007
	0.001	0.982	0.000	0.997	-0.025	0.459	**0.098**	0.006	0.137	0.000	**0.038**	0.000
F5	0.002	0.898	-0.002	0.877	-0.018	0.104	0.018	0.382			-0.014	0.042
	-0.004	0.839	-0.002	0.884	-0.023	0.087	0.018	0.382			-0.012	0.079
	-0.015	0.713	-0.045	0.092	-0.048	0.001	0.048	0.141			-0.016	0.081
F7	-0.040	0.008	-0.044	0.037	-0.010	0.236	-0.004	0.750	**0.063**	0.002	0.005	0.429
	-0.050	0.001	-0.052	0.014	-0.017	0.022	0.006	0.695	**0.074**	0.000	0.012	0.318
	-0.084	0.023	-0.119	0.000	-0.017	0.064	0.043	0.066	**0.136**	0.000	0.036	0.033
F8	-0.028	0.048	0.009	0.574	0.004	0.725	-0.051	0.014	NA	NA	0.003	0.700
	-0.020	0.253	-0.007	0.739	-0.007	0.597	-0.065	0.011	0.157	0.002	0.008	0.430
	0.003	0.904	-0.023	0.369	-0.059	0.007	-0.109	0.001	0.060	0.141	0.027	0.039
F9	-0.022	0.142			-0.004	0.680	-0.015	0.439			0.007	0.414
	-0.024	0.205			-0.006	0.634	-0.015	0.493			0.005	0.614
	-0.066	0.040			0.040	0.054	-0.061	0.006			0.014	0.183
F10	-0.038	0.004	-0.039	0.020	-0.023	0.003	-0.045	0.028	-0.038	0.003	0.001	0.944
	-0.045	0.001	-0.065	0.001	-0.021	0.046	-0.067	0.000	-0.043	0.057	0.003	0.677
	-0.049	0.016	-0.019	0.042	-0.046	0.028	-0.077	0.000	-0.082	0.123	0.015	0.187
F11	-0.025	0.020					0.034	0.064				
	-0.029	0.028					0.033	0.129				
	-0.058	0.095					0.022	0.242				
F12	-0.007	0.594	0.002	0.898	-0.022	0.007	**0.057**	0.000	0.048	0.014	**0.030**	0.000
	-0.006	0.695	0.006	0.709	-0.013	0.261	**0.060**	0.000	0.064	0.001	**0.031**	0.000
	0.012	0.809	-0.021	0.741	0.026	0.283	**0.070**	0.000	0.007	0.909	**0.033**	0.002
F16	-0.006	0.723	-0.009	0.718	0.002	0.861	-0.024	0.397	0.038	0.280	0.004	0.696
	-0.001	0.969	-0.005	0.873	-0.005	0.680	-0.003	0.949	0.020	0.489	0.007	0.528
	-0.024	0.523	0.014	0.698	-0.003	0.845	-0.063	0.035	-0.020	0.594	0.011	0.440
I1	-0.017	0.284	-0.002	0.915	-0.005	0.497	-0.017	0.363	-0.041	0.016	0.007	0.171
	-0.022	0.258	-0.008	0.652	-0.008	0.327	-0.033	0.186	-0.043	0.012	0.005	0.485
	-0.083	0.063	-0.028	0.210	-0.049	0.004	-0.042	0.276	-0.101	0.000	0.006	0.573
I2	-0.013	0.399	-0.018	0.302	-0.012	0.155	0.034	0.086	**0.069**	0.003	**0.019**	0.003
	-0.014	0.409	-0.017	0.390	-0.021	0.042	0.042	0.048	**0.069**	0.003	**0.025**	0.004
	-0.001	0.965	-0.016	0.614	0.012	0.341	0.023	0.394	**0.145**	0.000	**0.029**	0.002

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig
I5	-0.012	0.342	-0.035	0.085	-0.012	0.248	0.030	0.082	**0.075**	0.000	0.012	0.076
	-0.023	0.380	-0.043	0.091	-0.001	0.914	0.030	0.082	**0.089**	0.000	0.007	0.413
	-0.017	0.651	-0.036	0.236	-0.019	0.185	0.051	0.179	**0.138**	0.000	0.019	0.099
I6	0.001	0.887	-0.001	0.958	-0.007	0.436	**0.044**	0.000	**0.039**	0.042	0.010	0.218
	0.003	0.797	-0.007	0.719	-0.016	0.079	**0.051**	0.000	**0.046**	0.007	0.008	0.381
	-0.029	0.272	0.053	0.188	-0.002	0.905	**0.076**	0.001	**0.045**	0.057	0.005	0.349
I7	-0.008	0.531	-0.006	0.710	0.007	0.449	0.019	0.314	0.027	0.059	0.029	0.002
	-0.010	0.621	0.006	0.776	0.002	0.828	0.019	0.484	0.029	0.156	**0.034**	0.001
	-0.003	0.901	0.015	0.698	-0.022	0.001	0.113	0.006	0.086	0.013	**0.049**	0.000
I10	-0.006	0.657	-0.017	0.184	-0.005	0.702	0.020	0.380	0.008	0.590	-0.002	0.854
	-0.005	0.692	-0.017	0.305	-0.028	0.042	0.020	0.335	0.004	0.847	0.001	0.931
	0.032	0.000	-0.064	0.003	-0.025	0.000	0.004	0.918	-0.011	0.760	-0.010	0.107
J1					-0.011	0.315					0.008	0.092
					-0.007	0.545					0.008	0.092
					-0.024	0.245					0.015	0.190
J2	-0.014	0.323	-0.021	0.162	-0.027	0.019	-0.029	0.109	0.012	0.696	-0.004	0.560
	-0.021	0.132	-0.028	0.115	-0.021	0.034	-0.029	0.109	-0.007	0.830	0.000	0.994
	-0.075	0.107	NA	NA	-0.021	0.114	0.012	0.774	-0.034	0.470	-0.007	0.566
J3	-0.017	0.415			-0.011	0.281	0.032	0.184			-0.002	0.463
	-0.017	0.472			-0.015	0.206	0.040	0.143			-0.002	0.463
	-0.013	0.600			-0.015	0.262	0.009	0.748			0.008	0.351
J4	-0.002	0.788			-0.020	0.209					0.028	0.015
	-0.014	0.184			-0.018	0.371					0.032	0.008
	NA	NA			-0.006	0.778					0.004	0.760
J5					**0.033**	0.016					0.003	0.606
					0.024	0.072					-0.001	0.921
					0.026	0.082					0.002	0.693
J6	0.010	0.468	0.004	0.826	-0.026	0.015	0.013	0.400	-0.027	0.238	-0.002	0.733
	0.007	0.648	0.017	0.476	-0.027	0.019	0.015	0.346	-0.027	0.315	-0.001	0.899
	-0.041	0.108	0.065	0.027	-0.035	0.000	0.031	0.279	0.130	0.025	0.002	0.859
J7	-0.018	0.138	-0.001	0.955	0.008	0.546			**0.069**	0.001	0.023	0.207
	-0.029	0.060	0.002	0.911	-0.004	0.814			**0.063**	0.000	0.021	0.229
	-0.008	0.749	-0.026	0.542	0.010	0.630			**0.153**	0.000	0.019	0.057
J9	-0.010	0.398	0.015	0.353	-0.017	0.124	0.020	0.037	0.007	0.478	0.015	0.198
	-0.009	0.622	-0.015	0.216	-0.023	0.096	0.028	0.083	0.016	0.083	0.017	0.172
	-0.022	0.605	NA	NA	-0.055	0.015	0.018	0.791	NA	NA	0.032	0.073
J10					-0.015	0.207						
					-0.020	0.119						
					-0.013	0.566						
J11	-0.022	0.251			0.006	0.644					**0.030**	0.034
	-0.019	0.319			-0.005	0.755					**0.053**	0.008
	-0.020	0.451			-0.008	0.646					**0.037**	0.042

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig
J12					-0.021	0.044					0.018	0.077
					-0.042	0.003					0.017	0.077
					-0.015	0.330					-0.013	0.412
J13					0.003	0.774					0.006	0.308
					0.008	0.453					0.009	0.119
					0.029	0.000					0.003	0.553
J14	0.012	0.387	0.007	0.559	-0.010	0.483						
	0.016	0.317	0.019	0.225	-0.024	0.071						
	-0.020	0.382	0.029	0.511	-0.011	0.428						
J15					-0.003	0.744					0.016	0.043
					0.001	0.884					0.017	0.036
					0.017	0.266					0.022	0.047
J16	0.007	0.592	-0.005	0.668	-0.002	0.843	0.014	0.311	-0.065	0.011	-0.006	0.325
	0.007	0.695	-0.005	0.748	0.000	0.998	0.014	0.311	-0.074	0.013	-0.001	0.839
	0.022	0.159	NA	NA	-0.036	0.018	-0.023	0.407	-0.092	0.007	-0.015	0.081
J17			-0.013	0.611	-0.002	0.829						
			-0.020	0.431	-0.002	0.892						
			-0.070	0.128	-0.063	0.037						
J18	-0.017	0.211	-0.016	0.442	-0.019	0.195	0.065	0.000	-0.067	0.011	NA	NA
	-0.006	0.661	-0.041	0.023	-0.021	0.149	0.068	0.000	-0.068	0.016	NA	NA
	NA	NA	-0.077	0.009	-0.026	0.100	0.065	0.000	-0.060	0.038	0.000	0.987
J19					0.012	0.294					0.020	0.000
					0.007	0.495					0.022	0.000
					-0.007	0.642					0.026	0.000
J20	-0.008	0.556	-0.005	0.731	-0.010	0.268	0.010	0.409	0.058	0.000	0.013	0.182
	-0.009	0.551	-0.015	0.303	-0.007	0.565	0.018	0.444	0.076	0.000	0.015	0.127
	-0.052	0.022	-0.037	0.001	-0.042	0.069	0.000	0.995	0.016	0.738	0.024	0.124
B1	-0.026	0.161	-0.010	0.619	-0.012	0.271	-0.002	0.929	0.025	0.421	0.007	0.233
	-0.027	0.149	-0.009	0.686	-0.009	0.508	-0.004	0.877	0.037	0.197	0.007	0.233
	-0.030	0.262	-0.025	0.343	-0.026	0.003	-0.029	0.154	0.051	0.089	0.009	0.099
B2	0.013	0.534	-0.001	0.934	-0.007	0.466	-0.034	0.259	-0.055	0.068	0.018	0.002
	0.005	0.854	-0.004	0.833	-0.002	0.850	-0.026	0.460	-0.063	0.034	0.024	0.000
	-0.016	0.419	-0.002	0.922	0.012	0.492	-0.056	0.096	-0.105	0.000	0.007	0.242
B3	0.016	0.257	NA	NA	0.009	0.226	-0.045	0.014	NA	NA	0.017	0.008
	0.021	0.308	0.042	0.089	0.022	0.067	-0.067	0.002	NA	NA	0.015	0.019
	0.018	0.342	0.022	0.492	0.060	0.007	-0.034	0.185	-0.130	0.002	0.016	0.020
B4	-0.021	0.161	-0.012	0.338	-0.003	0.802	0.054	0.001	0.051	0.000	0.002	0.792
	-0.023	0.124	-0.016	0.226	0.000	0.988	0.065	0.001	0.040	0.144	0.002	0.792
	-0.034	0.117	-0.021	0.330	0.019	0.464	0.013	0.741	0.047	0.291	0.013	0.160
B5							0.050	0.000	0.035	0.184	0.023	0.003
							0.055	0.000	0.034	0.246	0.022	0.011
							0.068	0.008	0.034	0.185	0.037	0.005

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig
B7	-0.013	0.429	-0.012	0.554	-0.010	0.377	-0.061	0.000	-0.077	0.001	-0.005	0.677
	-0.017	0.414	-0.009	0.724	-0.010	0.419	-0.058	0.000	-0.082	0.001	-0.006	0.593
	-0.108	0.000	-0.037	0.197	0.005	0.694	-0.094	0.001	-0.105	0.001	-0.004	0.736
B8	-0.031	0.121	-0.029	0.138			-0.003	0.855	-0.057	0.010		
	-0.033	0.126	-0.028	0.199			0.008	0.499	-0.083	0.009		
	0.005	0.909	0.005	0.897			-0.008	0.633	0.006	0.913		
B9	0.020	0.096	-0.006	0.723	-0.013	0.198						
	-0.003	0.851	0.001	0.941	-0.015	0.185						
	0.011	0.729	-0.022	0.321	-0.014	0.035						
B10	-0.008	0.597										
	0.007	0.646										
	0.048	0.294										
B11	-0.001	0.951	0.022	0.087	-0.010	0.412						
	-0.002	0.913	0.025	0.108	-0.004	0.762						
	0.033	0.247	0.063	0.127	0.050	0.038						
B12	-0.015	0.284	-0.004	0.823	-0.001	0.932	-0.033	0.042	-0.060	0.001	0.001	0.857
	-0.015	0.334	-0.009	0.654	-0.002	0.859	-0.033	0.042	-0.070	0.000	0.003	0.625
	-0.026	0.205	-0.040	0.031	-0.016	0.431	-0.010	0.677	-0.031	0.575	0.003	0.694
B13	0.004	0.695	0.008	0.633	0.003	0.745	-0.005	0.766	0.037	0.057	0.012	0.026
	0.001	0.915	0.005	0.841	0.006	0.623	0.002	0.928	0.029	0.032	0.012	0.026
	0.016	0.579	-0.040	0.433	0.002	0.931	-0.018	0.513	0.099	0.027	0.002	0.724
B14	-0.005	0.730	-0.001	0.943	-0.015	0.128	0.001	0.968	-0.021	0.355	0.000	0.970
	-0.008	0.664	0.003	0.886	-0.021	0.044	0.006	0.832	-0.041	0.123	0.000	0.970
	0.001	0.988	0.025	0.415	-0.006	0.483	0.011	0.647	-0.033	0.237	0.005	0.755
B15	0.004	0.801	-0.004	0.730	-0.002	0.865	-0.016	0.105	0.007	0.804	0.003	0.863
	-0.010	0.627	0.008	0.566	-0.003	0.841	0.004	0.748	0.022	0.645	0.003	0.863
	-0.062	0.027	0.025	0.323	0.025	0.266	-0.010	0.833	-0.015	0.791	0.010	0.465
B16	0.010	0.318	0.018	0.181	0.006	0.560	0.010	0.404	0.065	0.000	0.006	0.351
	0.002	0.857	0.028	0.154	-0.002	0.899	0.046	0.001	0.073	0.000	0.013	0.247
	-0.040	0.033	-0.054	0.012	-0.027	0.285	0.155	0.000	0.129	0.003	0.021	0.054
B17	-0.013	0.412	0.005	0.733	0.007	0.550						
	-0.013	0.494	-0.006	0.739	0.010	0.512						
	-0.033	0.544	-0.002	0.967	0.006	0.824						
B18	-0.017	0.157	-0.027	0.084	-0.014	0.206	0.003	0.943	NA	NA	NA	NA
	-0.015	0.216	-0.030	0.052	-0.013	0.426	0.024	0.636	NA	NA	0.046	0.000
	-0.068	0.000	-0.078	0.051	-0.039	0.013	0.077	0.039	0.105	0.014	0.046	0.000
B20	0.009	0.534	0.013	0.531	-0.028	0.005	-0.043	0.002	-0.029	0.245	0.012	0.008
	0.006	0.684	0.013	0.531	-0.027	0.007	-0.060	0.001	-0.036	0.088	0.013	0.016
	-0.004	0.799	0.012	0.535	-0.039	0.004	-0.070	0.000	-0.037	0.069	0.012	0.171
B22	-0.024	0.093	-0.005	0.734	-0.012	0.251	-0.019	0.372	-0.003	0.824	0.004	0.453
	-0.027	0.098	0.004	0.820	-0.008	0.523	-0.020	0.400	0.017	0.380	0.008	0.166
	-0.033	0.040	-0.024	0.446	-0.023	0.125	-0.044	0.016	0.124	0.085	0.014	0.140

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig
B23	-0.025	0.097	-0.017	0.179	-0.020	0.040	-0.057	0.002	-0.009	0.650	**0.024**	0.009
	-0.031	0.019	-0.026	0.098	-0.019	0.122	-0.052	0.002	-0.016	0.523	**0.028**	0.000
	-0.066	0.033	-0.022	0.128	-0.054	0.031	-0.071	0.000	-0.027	0.473	**0.021**	0.054
B25	-0.005	0.667	0.005	0.791	0.002	0.827	-0.002	0.928	NA	NA	0.016	0.076
	-0.009	0.533	0.001	0.952	-0.002	0.826	0.001	0.973	0.091	0.013	0.016	0.169
	-0.032	0.499	-0.068	0.105	-0.003	0.888	-0.017	0.725	0.082	0.128	0.019	0.232
B27	-0.025	0.048	-0.015	0.377	-0.022	0.022	0.038	0.055	0.012	0.593	0.011	0.126
	-0.024	0.020	-0.012	0.492	-0.028	0.003	0.034	0.144	0.028	0.273	0.031	0.012
	-0.040	0.007	-0.011	0.611	-0.020	0.027	-0.098	0.047	0.007	0.743	0.058	0.000
B28	-0.013	0.456	-0.004	0.849	0.006	0.600	0.016	0.379	**0.041**	0.006	0.019	0.144
	-0.022	0.378	0.000	0.995	0.001	0.949	0.047	0.003	**0.048**	0.001	0.023	0.085
	0.023	0.575	0.059	0.302	-0.011	0.371	0.078	0.025	**0.138**	0.000	0.038	0.021
B29	-0.002	0.849	-0.013	0.475	-0.010	0.421	**0.087**	0.000	0.042	0.145	0.005	0.253
	-0.001	0.912	-0.011	0.623	-0.012	0.421	**0.088**	0.000	0.040	0.202	0.005	0.150
	0.043	0.120	-0.112	0.062	-0.030	0.292	**0.144**	0.000	0.005	0.933	0.010	0.074
B30	0.009	0.532	-0.013	0.558	0.016	0.034	0.012	0.558	-0.007	0.710	**0.017**	0.044
	0.016	0.202	0.001	0.977	0.013	0.250	0.030	0.166	0.032	0.119	**0.021**	0.039
	-0.001	0.965	0.002	0.938	0.058	0.000	0.067	0.075	0.002	0.913	**0.013**	0.072
B31	0.002	0.915	-0.005	0.663	0.014	0.305	-0.047	0.110	-0.046	0.102	-0.008	0.270
	-0.011	0.521	-0.002	0.907	0.007	0.655	-0.050	0.076	-0.047	0.162	-0.003	0.609
	-0.014	0.514	-0.019	0.383	0.040	0.081	-0.027	0.603	-0.093	0.016	-0.008	0.192
B32	-0.023	0.101	-0.017	0.304			0.028	0.114	**0.092**	0.000		
	-0.016	0.335	-0.032	0.138			0.012	0.558	**0.092**	0.000		
	0.055	0.328	0.092	0.000			0.047	0.348	**0.105**	0.017		
B35	-0.003	0.852	0.001	0.937	-0.002	0.881	0.032	0.239	**0.060**	0.005	**0.018**	0.002
	-0.007	0.706	-0.001	0.974	-0.003	0.817	0.032	0.239	**0.068**	0.011	**0.018**	0.002
	-0.021	0.493	0.008	0.838	0.003	0.884	0.056	0.166	**0.084**	0.004	**0.026**	0.000
B36			0.003	0.876					0.032	0.320		
			0.000	0.984					0.024	0.505		
			0.073	0.048					-0.004	0.922		
U1	-0.033	0.080	NA	NA	0.006	0.520	-0.020	0.322	NA	NA	**0.028**	0.000
	-0.030	0.228	0.054	0.284	0.021	0.039	0.023	0.514	NA	NA	**0.032**	0.000
	NA	NA	0.085	0.353	NA	NA	0.030	0.578	0.115	0.002	**0.066**	0.000
U3	-0.009	0.524	0.014	0.287	-0.024	0.055	**0.067**	0.002			**0.028**	0.000
	-0.005	0.730	0.033	0.075	-0.030	0.008	**0.067**	0.002			**0.036**	0.000
	-0.001	0.977	0.031	0.593	0.004	0.776	**0.086**	0.097			**0.043**	0.001
U5	-0.008	0.366	-0.030	0.041	-0.001	0.908	-0.042	0.000	0.003	0.855	0.017	0.102
	-0.005	0.654	-0.030	0.082	-0.007	0.508	-0.027	0.023	0.010	0.596	0.026	0.049
	0.021	0.364	-0.003	0.884	NA	NA	-0.001	0.942	0.020	0.036	0.007	0.523
U6	-0.010	0.440	-0.012	0.459	-0.012	0.341	-0.053	0.000	-0.070	0.002	-0.001	0.907
	-0.013	0.475	-0.011	0.557	-0.012	0.349	-0.060	0.000	-0.074	0.003	-0.002	0.856
	NA	NA	-0.056	0.006	0.000	0.993	-0.089	0.002	-0.106	0.003	-0.007	0.537

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig
U7	-0.011	0.485			-0.025	0.060						
	-0.011	0.485			-0.020	0.171						
	-0.041	0.103			-0.006	0.802						
U8	-0.007	0.698	0.018	0.277	-0.009	0.416	0.024	0.035	0.073	0.000	0.020	0.004
	-0.003	0.845	0.029	0.141	-0.018	0.177	0.049	0.000	0.080	0.000	0.021	0.021
	NA	NA	NA	NA	-0.044	0.097	0.000	0.989	0.032	0.291	0.041	0.000
U10	-0.019	0.390	-0.020	0.293	0.002	0.837						
	-0.017	0.438	-0.042	0.071	0.001	0.915						
	NA	NA	NA	NA	-0.005	0.663						
U11	-0.034	0.042	-0.008	0.692	-0.010	0.176						
	-0.030	0.070	-0.006	0.751	-0.011	0.154						
	0.036	0.371	0.057	0.148	-0.020	0.064						
U12	0.006	0.766			-0.007	0.514						
	0.018	0.391			-0.013	0.287						
	0.050	0.014			-0.003	0.938						
U13	-0.001	0.904	-0.002	0.883	-0.008	0.428	0.080	0.000	0.067	0.000	0.020	0.009
	0.008	0.499	0.010	0.552	-0.008	0.505	0.063	0.001	0.102	0.000	0.022	0.002
	0.021	0.497	0.021	0.550	0.032	0.004	0.036	0.157	0.126	0.000	0.044	0.002
U15	-0.014	0.289	-0.022	0.345	-0.015	0.159	-0.059	0.004	NA	NA	0.022	0.000
	-0.017	0.258	-0.045	0.345	-0.016	0.166	-0.118	0.004	NA	NA	0.028	0.000
	0.013	0.539	0.021	0.507	-0.014	0.269	-0.040	0.446	NA	NA	0.035	0.012
U17	-0.005	0.801	-0.027	0.136	-0.005	0.714						
	0.002	0.925	-0.012	0.484	-0.018	0.260						
	-0.014	0.613	-0.018	0.348	0.006	0.658						
U19	-0.023	0.161	-0.025	0.062	-0.012	0.199	-0.047	0.000	-0.039	0.030	-0.006	0.643
	-0.033	0.054	-0.024	0.107	-0.019	0.062	-0.047	0.000	-0.037	0.040	0.008	0.493
	-0.037	0.400	-0.008	0.812	-0.043	0.019	-0.068	0.000	0.000	0.995	-0.002	0.885
U20	0.008	0.577	0.010	0.448	-0.001	0.918	0.035	0.024	0.024	0.292	0.014	0.030
	0.002	0.934	0.030	0.076	-0.015	0.252	0.052	0.002	0.058	0.003	0.015	0.038
	0.080	0.027	0.028	0.183	-0.067	0.000	0.071	0.008	0.130	0.001	0.027	0.065
U24	0.030	0.062	-0.002	0.863	0.004	0.788	-0.088	0.000	-0.006	0.749	NA	NA
	0.008	0.644	0.010	0.554	0.009	0.707	-0.046	0.245	0.011	0.636	NA	NA
	0.031	0.104	-0.071	0.002	0.000	0.999	0.050	0.145	-0.026	0.622	0.013	0.369
U26	-0.014	0.195	-0.032	0.014	0.003	0.817	-0.056	0.007	-0.058	0.029	0.013	0.051
	-0.008	0.459	-0.045	0.009	0.009	0.561	-0.068	0.007	-0.078	0.143	0.013	0.051
	-0.033	0.254	-0.061	0.040	0.016	0.273	-0.042	0.087	-0.066	0.199	0.021	0.003
U29	-0.022	0.183			0.009	0.428					0.010	0.074
	-0.029	0.113			0.005	0.694					0.010	0.102
	-0.051	0.016			0.001	0.969					0.019	0.078
U30	0.020	0.220			0.000	0.968	0.038	0.017			0.017	0.009
	0.008	0.630			-0.003	0.823	0.040	0.027			0.020	0.022
	-0.016	0.536			0.002	0.950	0.059	0.001			0.036	0.000

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig
U31	-0.036	0.029	0.014	0.438	-0.004	0.679						
	-0.048	0.006	0.019	0.388	-0.014	0.153						
	-0.021	0.000	0.109	0.000	-0.009	0.509						
G1	-0.021	0.304					-0.033	0.005				
	-0.014	0.578					-0.026	0.053				
	0.014	0.651					-0.013	0.600				
G2	-0.010	0.434	-0.013	0.456	-0.001	0.910	0.054	0.000	-0.022	0.402	-0.017	0.003
	-0.008	0.632	-0.012	0.598	-0.023	0.329	0.061	0.000	-0.019	0.530	-0.017	0.003
	-0.085	0.067	-0.056	0.057	0.003	0.898	0.075	0.000	-0.073	0.016	-0.015	0.395
G3	-0.020	0.184	-0.004	0.764	-0.011	0.217	0.008	0.694	-0.038	0.091	-0.009	0.005
	-0.026	0.067	-0.005	0.760	-0.007	0.478	0.011	0.515	-0.061	0.026	-0.010	0.020
	0.028	0.131	-0.093	0.001	-0.006	0.778	0.001	0.972	0.023	0.322	0.003	0.537
G4	-0.017	0.349	-0.001	0.956	-0.006	0.613	-0.014	0.582	-0.074	0.001	0.005	0.375
	-0.011	0.462	-0.004	0.823	-0.007	0.465	-0.012	0.675	-0.074	0.001	0.005	0.407
	-0.026	0.187	-0.066	0.032	-0.021	0.058	-0.003	0.941	-0.016	0.579	0.004	0.497
G5	-0.019	0.235	0.001	0.956	-0.008	0.494	-0.030	0.156	-0.044	0.102	-0.001	0.910
	-0.016	0.301	-0.003	0.872	-0.008	0.479	-0.037	0.176	-0.050	0.225	0.001	0.940
	-0.086	0.001	-0.035	0.103	0.027	0.081	0.005	0.887	-0.175	0.000	0.022	0.048
G7	0.015	0.293					0.044	0.006				
	0.023	0.082					0.042	0.014				
	0.032	0.000					0.001	0.965				
G8	-0.014	0.262	-0.014	0.337	-0.026	0.007	0.014	0.368	0.033	0.002	0.010	0.035
	-0.025	0.186	-0.019	0.319	-0.021	0.013	0.026	0.089	0.087	0.000	0.013	0.007
	0.002	0.951	0.008	0.782	-0.017	0.050	0.028	0.437	0.073	0.000	0.025	0.000
G9	0.032	0.012	0.032	0.015	-0.008	0.335	0.009	0.757	0.011	0.705	0.017	0.096
	0.034	0.027	0.053	0.019	-0.003	0.689	0.009	0.757	0.000	1.000	0.011	0.131
	NA	NA	0.014	0.526	0.033	0.040	0.074	0.001	0.032	0.424	0.035	0.002
G10	-0.028	0.062	-0.018	0.222	-0.029	0.000	-0.023	0.193	0.020	0.355	0.008	0.086
	-0.024	0.144	-0.018	0.378	-0.032	0.000	-0.016	0.281	0.034	0.109	0.009	0.075
	-0.079	0.002	-0.062	0.173	-0.019	0.024	-0.006	0.853	0.085	0.053	0.018	0.023
G11	-0.014	0.390	-0.003	0.739	-0.014	0.168	0.023	0.073	-0.031	0.310	0.019	0.005
	-0.001	0.940	-0.006	0.652	-0.012	0.221	0.038	0.022	-0.034	0.298	0.021	0.003
	-0.015	0.567	0.038	0.058	-0.026	0.161	0.056	0.070	-0.048	0.302	0.028	0.023
G12	-0.014	0.205	-0.027	0.027	-0.007	0.335	0.003	0.760	0.037	0.041	-0.008	0.182
	-0.016	0.140	-0.019	0.158	-0.012	0.102	0.003	0.760	0.037	0.041	-0.008	0.182
	-0.032	0.040	-0.039	0.078	-0.022	0.157	0.007	0.693	0.058	0.001	-0.002	0.644
G13	-0.018	0.285	-0.016	0.367	-0.006	0.510	0.008	0.723	0.095	0.000	0.009	0.311
	-0.019	0.313	-0.017	0.408	-0.005	0.658	0.017	0.524	0.117	0.000	0.008	0.401
	-0.026	0.264	-0.011	0.634	-0.003	0.855	0.021	0.655	0.083	0.188	0.011	0.229
G14	0.013	0.347	0.004	0.754	-0.007	0.505	-0.025	0.173	-0.064	0.002	0.007	0.468
	0.009	0.569	-0.004	0.830	-0.021	0.098	-0.012	0.597	-0.091	0.034	0.006	0.548
	-0.010	0.762	-0.049	0.104	-0.018	0.536	-0.028	0.489	-0.051	0.088	0.023	0.004

	DEM 3mth		STG 3mth		JPY 3mth		DEM 12mth		STG 12mth		JPY 12mth	
	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig	Coeff	Mgn Sig
G15	-0.005	0.678	0.013	0.337	-0.015	0.101	-0.038	0.015	-0.006	0.774	0.011	0.182
	-0.010	0.457	0.016	0.322	-0.019	0.005	-0.041	0.037	0.000	0.999	0.012	0.128
	0.014	0.684	-0.016	0.597	-0.015	0.169	-0.034	0.213	-0.019	0.734	0.018	0.095
G16	-0.044	0.012										
	-0.053	0.003										
	-0.048	0.156										
G17	0.002	0.877					**0.037**	0.003				
	0.005	0.695					**0.035**	0.004				
	0.000	0.997					**0.078**	0.000				
G18	-0.018	0.237	0.024	0.228	0.005	0.552	0.044	0.000				
	-0.022	0.207	0.034	0.188	0.010	0.319	0.054	0.000				
	-0.054	0.279	0.117	0.000	0.001	0.932	0.043	0.232				
G19	-0.004	0.810	-0.012	0.569	0.003	0.796	0.002	0.918	0.042	0.073	**0.020**	0.001
	0.004	0.860	-0.004	0.849	0.004	0.762	0.004	0.885	0.035	0.096	**0.022**	0.001
	0.012	0.805	0.033	0.363	-0.008	0.470	-0.085	0.129	0.033	0.694	**0.036**	0.002
G20	-0.038	0.116	0.019	0.156	-0.003	0.801	-0.007	0.580	0.007	0.721	0.019	0.068
	-0.031	0.207	0.010	0.581	-0.010	0.482	-0.002	0.892	0.006	0.780	0.011	0.393
	-0.017	0.742	0.042	0.185	0.011	0.588	-0.036	0.374	0.022	0.551	0.027	0.133
G22	-0.019	0.263	-0.016	0.398	-0.004	0.738	0.006	0.642	**0.095**	0.000	0.006	0.335
	-0.023	0.227	-0.020	0.340	-0.012	0.306	0.022	0.373	**0.095**	0.000	0.015	0.012
	-0.003	0.928	0.076	0.140	-0.035	0.063	0.077	0.046	**0.083**	0.083	0.021	0.079
G23	-0.008	0.455					0.032	0.180				
	-0.006	0.625					0.040	0.119				
	0.016	0.559					0.008	0.804				

NOTES: The first column of figures for each forecaster/currency/maturity combination gives the estimated slope coefficient from the three directional ability tests detailed in section 3.3. The first related to a zero neutral band, the second to a one percent neutral band, and the third to a five percent neutral band. The second column of figures for each combination gives the marginal significance of each slope coefficient, based on GMM standard errors. A bold typeface indicates that we can reject the null that all three slopes are equal to zero, against the null that the slopes are greater than zero, at the five percent level. Some cells have Not Available (NA) entries. These are caused either by the forecasts always indicating an appreciation or depreciation of a currency (in which case the dependent variable is a series of ± 1 and the regression with a constant collapses due to singularity) or because all forecasts fall within the neutral band (in which case the dependent variable becomes a series of zeros and the regression collapses).