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# Freely Floating Exchange Rates Do Not Systematically Overshoot

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The exchange rate literature contains two inconsistent strands. There is a large theoretical and empirical literature on overshooting. In that literature overshooting is an important explanation for exchange rate volatility. A separate literature says that exchange rates are martingales and that models do not beat a random walk. Both can not be true. I show that the evidence for overshooting is highly suspect while the evidence that flexible exchange rates are approximately martingales is rock solid. Given the strength of the evidence, models that imply overshooting probably should be rejected out of hand.

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The literature on exchange rates contains two mutually inconsistent strands. On the one hand there is a large theoretical and empirical literature on overshooting.<sup>1</sup> According to that literature, overshooting is an important explanation for the volatility of exchange rates. On the other hand a large literature says that exchange rates are essentially martingales and that economic models cannot beat a random walk out of sample.<sup>2</sup> Both of these strands can not be true.

They are not both true. As shown below, the evidence for overshooting is highly suspect. The evidence that flexible exchange rates are approximately martingales is rock solid. Given the weight of the evidence, models that imply systematic overshooting probably should be rejected out of hand.

Section 1 reviews the history of ideas about speculation in foreign exchange markets. Section 2 reviews the earlier evidence on overshooting and martingales.

The frequency domain is a natural place to look for evidence of overshooting. Section 3 discusses the frequency domain implications of destabilizing speculation, bandwagons and overshooting. Section 4 describes the daily data used here to look for evidence of overshooting. An important advantage of the daily data after 1990 is that it avoids periods when central banks intervene. Section 5 presents my empirical evidence regarding overshooting. Section 6 summarizes the paper and presents the conclusions. The primary conclusion is straight forward. Freely floating exchange rates do not systematically overshoot.

## 1. A Brief History of Speculation

In the most general terms, there are three different ways that speculative markets can respond to information:<sup>3</sup> (1) Markets can over respond. This response corresponds to what was called destabilizing speculation or bandwagons and more recently has been called overshooting.<sup>4</sup> In all three cases, the short-run response to information is larger than the long-run response. (2) Markets can under respond. In that case, the

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<sup>1</sup> For most of the recent empirical work see Table 1. Some of the more recent theoretical work includes Cavallo and Ghironi (2002), Andersen and Beier (2005), Pierdzioch (2005), Bask (2007), Borgersen (2007) and Patureau (2007).

<sup>2</sup> The seminal work on prediction is Meese and Rogoff (1983). For additional work on prediction and martingales see Table 2.

<sup>3</sup> The discussion concentrates on the response to information. But it implicitly assumes that efficient markets collect all the relevant information. Markets might under or over respond to 'news' because they did not collect all the relevant information behind that news.

<sup>4</sup> The idea that foreign exchange markets suffer from destabilizing speculation, bandwagons and/or overshooting is so prevalent that it routinely appears in undergraduate textbooks. See for example Krugman and Obstfeld (2003, 383), Dunn and Mutti (2004, 441), Pugel (2004, 452) and Salvatore (2007, 550).

long-run response is larger than the short-run response. (3) Markets neither over nor under respond to information. This is usually interpreted to mean that markets are “efficient” and speculation “rational”. Although it is being challenged by Behavioral Economics, this is probably the standard view of most speculative markets other than foreign exchange markets.<sup>5</sup>

### 1.1 Over Response

The idea that speculative markets systematically over respond to information was the conventional view of the general public, businessmen and economists until the efficient market and rational expectations revolution in the early 1960s. It remains the conventional view of the general public and most business men.

The following description of speculative markets by Taussig (1921) was widely accepted by almost everyone including economists up to the early 1960s.

Thus, in a city during many a winter, a fall in the price of eggs may cause the country dealers and the cold storage people not to hold back their supplies, but to send them in hurriedly, for fear of a further fall; while city dealers, so far from buying more, will hesitate to buy, having the same fear. The bottom will drop out of the market. On the Chicago Board of Trade the bears, when they sell wheat short and pound away at the price, count on the same course of events. The lower price will not tempt others to buy, but frighten them to sell. Your equilibrium will not necessarily work out at all. It is a toss-up whether a decline in price will check itself by leading to more purchases or will intensify itself by leading to less purchases.

Taussig’s description of destabilizing speculation and bandwagons was widely accepted as an explanation for the large fluctuations in flexible exchange rates during the early 1920s. The classic reference for destabilizing speculation at that time is Nurkse (1944).<sup>6</sup> With respect to foreign exchange markets,

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<sup>5</sup> For a discussion of Behavioral Economics see Fudenberg (2006).

<sup>6</sup> Nurkse (1944) did not use the term destabilizing speculation. He referred to ‘disequilibrating’ speculation, but his definition of the term was seriously flawed. According to Nurkse, speculation was disequilibrating when capital flowed from a country with a high interest rate to one with a lower interest rates. But he failed to distinguish between real and nominal interest rates. His prime example was France in the early 1920s where capital moved out of France into the U.K. and U.S. even though they had much lower nominal interest rates. But there was nothing ‘disequilibrating’ about capital fleeing a country with relatively high and unstable inflation. Inflation, particularly increasing inflation, will cause investors to move out of monetary assets into real assets. As the price of domestic real assets rises faster than general inflation, domestic investors will find foreign real and monetary assets relatively attractive.

destabilizing speculation and/or bandwagons have continued to remain popular with some economists. See for example Aliber (1970) and Rotheli (2002).<sup>7</sup>

The modern version of destabilizing speculation is overshooting.<sup>8</sup> The classic reference for overshooting is Dornbusch (1976). According to the Google Scholar as of September 2007, this highly influential article has been cited over 1,300 times. During 2007, over 40 years after its publication, there have been at least seven published articles on overshooting, mostly delayed overshooting.<sup>9</sup> In spite of this popularity, as shown below, there is no credible evidence that freely floating exchange rates systematically overshoot.

### 1.2 Under Response.

Until recently, almost no one suggested that foreign exchange markets might under respond to information. But recent work on the microstructure of foreign exchange markets suggests that an under response is possible in the very short run. The reason is that it takes time for foreign exchange dealers to fully absorb all the information in order flows. See for example Lyons (2001), Evans and Lyons (2005), and Bacchetta and van Wincoop (2006).

Leaning against the wind by central banks also can cause exchange rates to under respond to information.<sup>10</sup> See Pippenger and Phillips (1973) and Phillips and Pippenger (1993).

### 1.3 Neither over nor under Respond.

Holbrook Working was the father of efficient markets. What he called “reliably anticipatory” expectations did not systematically over or under respond to information.<sup>11</sup> At about the same time, Muth (1961) developed the idea of rational expectations. For several years these two different approaches to speculation developed separately, but now they are usually considered equivalent.

Today the conventional view of most speculative markets like the New York Stock Exchange is that they are “efficient” and that speculation is “rational”. The primary basis for that view is that prices for financial

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<sup>7</sup> For a reply to Rotheli see Pippenger (2004).

<sup>8</sup> For a detailed discussion of overshooting in the foreign exchange market see Levich (1981)

<sup>9</sup> See Bask (2007), Borgersen and Gocke (2007) Cushman (2007), Kearns (2007), Kim and Kim (2007), Patureau (2007) and Pierdzioch (2007). In addition there are several working papers dealing with overshooting.

<sup>10</sup> The meaning of the term ‘leaning against the wind’ has blurred over time. I use the original meaning: buying as the exchange rate falls and selling as it rises.

<sup>11</sup> For a collection of the writings of Holbrook Working see Peck (1977). The classic reference for efficient markets is Fama (1970).

assets in auction markets like the NYSE are approximately martingales.<sup>12</sup> Although flexible exchange rates are also approximately martingales, foreign exchange markets are an exception.<sup>13</sup> Many, perhaps even most, economists reject the idea that foreign exchange markets are efficient and speculation in those markets rational.

Although it is strictly true only in very special cases, the standard empirical interpretation of efficient markets and rational expectations is that speculative prices are martingales.<sup>14</sup> Since a martingale implies that price changes are uncorrelated, a martingale implies that the spectrum for price changes is flat.<sup>15</sup>

## 2.0 Overshooting and Martingales

As pointed out above, martingales are inconsistent with systematic destabilizing speculation, bandwagons and overshooting. Section 2.1 critically reviews the empirical evidence on overshooting. Section 2.2 reviews the martingale literature.

### 2.1 Overshooting: The VAR Evidence

Rogoff (2002) discusses the importance of Dornbusch's overshooting article and some of the earlier evidence pro and con. This section concentrates on the vector autoregression (VAR) tests for delayed overshooting using monthly data that began with Eichenbaum and Evans (1995) and have dominated the empirical literature on overshooting ever since.

Table 1 lists all of the empirical articles on overshooting that I could find that deal with developed countries. The number of working papers is simply too large to include here. I also do not include any theoretical articles describing the many potential causes for overshooting. The second column in Table 1 describes the confidence interval for the crucial impulse responses reported in various articles. Several articles report confidence intervals for these impulse responses in terms of standard deviations rather than percentages. In Eichenbaum and Evans (1995) confidence intervals are only plus or minus one standard deviation.

Eichenbaum and Evans (1995) is always cited in later work on overshooting. But they are very cautious about claiming that their results support delayed overshooting.

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<sup>12</sup> For some of the early empirical evidence see Cootner (1964).

<sup>13</sup> See Tables 1 and 2 for some of the relevant literature.

<sup>14</sup> See Samuelson (1965).

<sup>15</sup> The term 'white noise' is applied to an uncorrelated random variable because the spectrum is flat like the spectrum for white light.

This response pattern is inconsistent with simple overshooting models of the sort considered by Dornbusch (1976), since, in those models, a contractionary monetary policy shock generates a large initial appreciation in nominal (real) exchange rates followed by subsequent depreciations. However, our results could be viewed as supporting a broader view of overshooting in which exchange rates eventually depreciate after appreciating for a period of time. (Eichenbaum and Evans 1995, pp. 982 and 984)

As the discussion above makes clear, and Eichenbaum and Evans clearly recognize, like other over-responses to information, overshooting requires a reversal in direction. Appreciation must follow depreciation or *vice versa*. Unfortunately, apparently many readers have assumed incorrectly that their results demonstrate overshooting. At normal significance levels, their impulse responses only show evidence of appreciation after a contractionary monetary shock. There is no *significant* evidence of a later depreciation.

With the notable exception of Faust and Rogers (2003), subsequent empirical work usually has made stronger claims about overshooting. But like the impulse responses in Eichenbaum and Evans (1995), the impulse responses in the other articles in Table 1 fail to support overshooting, delayed or otherwise. With one possible exception discussed below, none of the impulse responses show evidence of a significant movement in one direction followed by a significant movement in the opposite direction.

Part of the misunderstanding about the evidence may be due to the common use of confidence intervals that are only plus or minus one standard error. Such narrow confidence intervals can cause casual readers to believe that statistically insignificant results are significant.

Part of the misunderstanding may be the result of confusing impulse responses and responses to a unit step. Consider the following hypothetical response to a decrease in the stock of money. The stock of money falls one percent at month zero. Over the subsequent six months the domestic price of foreign exchange falls each month. For  $t+1$  the fall is quite small. For  $t+2$  the fall is larger. The fall is largest for  $t+3$ . For each of the following three periods the price continues to fall, but by less and less each month.

When plotted as an impulse response, this example produces a fairly typical U shape. Although it might look like overshooting to a casual reader because the estimates reverse direction, this U shape is *not* evidence of overshooting.

Consider the same response from the perspective of a unit step. The exchange rate falls continually until it reaches its long-run equilibrium. There is no overshooting. The exchange rate never falls below its long-run equilibrium. Instead there is “undershooting”. The response to the monetary shock is spread out over several months. But because of its U shape, the impulse response can be mistaken for overshooting by a casual reader.

Often none of the impulse responses reported in the articles in Table 1 are statistically significant at standard levels. When some are significant, they imply only a gradual response to monetary shocks. If the empirical evidence reported in the articles in Table 1 support any conclusion about the effects of monetary shocks on exchange rates it is that exchange rates undershoot. They under respond to information.

One article that provides possibly significant evidence of overshooting is Kalyvitis and Michaelides (2001). They analyze monthly exchange rates for France, Germany, Italy Japan and the U.K. versus the U.S. dollar from 1975:01 to 1996:12. Using a conservative 95 percent confidence interval for their impulse responses, they claim to have found evidence of instantaneous overshooting. Part of their Figure 2 appears here as Figure 1. For every country other than the U.K., their estimates are consistent with undershooting. For the US dollar price of pound sterling (USD/BP), their estimate at zero lag is slightly negative and just significant. Estimates from the second to about the 9<sup>th</sup> month appear insignificant. From about the 10<sup>th</sup> to 30<sup>th</sup> month the estimates are positive and significant. This one instance of possible support for overshooting has the unusual implication that a monetary contraction in the United States causes the dollar price of pound sterling to rise in the long run.

In addition to these problems of interpretation and significance, estimating VARs involves imposing largely arbitrary restrictions. As Faust and Rogers (2003) point out, credible restrictions are hard to find.

In all this work, a highly contentious step is identifying which exchange rate movements are due to monetary policy shocks. All of the literature cited above identifies the policy shocks using the identified vector autoregression approach,



currently the dominant approach to identification in the literature. The reason identification is so contentious is that there are few *highly credible* identifying assumptions. (Faust and Rogers 2003, p. 1405)

Another serious problem with both undershooting and overshooting is that there is no evidence of it in the behavior of daily exchange rates. If either undershooting or overshooting in any form substantially affected exchange rates, there should be some evidence of it in the behavior of exchange rates. But as is widely recognized, exchange rates are approximately martingales. In addition, as is widely recognized, it is very difficult to beat a random walk model out of sample. Both of these stylized facts raise serious questions about undershooting and overshooting.

The next section briefly reviews some of the more recent evidence concerning martingales and the difficulty of beating a simple random walk out of sample.

## 2.2 Martingales and Prediction

Most of the recent empirical research on the behavior of exchange rates is shown in Table 2. That research provides little support for overshooting. The research can be summarized as follows: (1) Changes in flexible exchange rates are essentially white noise. (2) Exchange rates are only approximately martingales. (3) Economic models still do not predict well out of sample. (4) Some time series models predict slightly better out of sample than a random walk.

The following quote from Hong and Lee (2003, 1048), where WN means white noise, summarizes the evidence concerning items (1) and (2). "...most of the currencies we examine are WN in changes, all of them are not martingales. There exists significant and predictable nonlinearity in the conditional mean of exchange rate changes".

The following quote from Cheung, Chinn and Pascual (2005, 1150) summarizes the evidence concerning item (3):

...we re-assess exchange rate prediction using a wider set of models that have been proposed in the last decade: interest rate parity, productivity based models, and a composite specification. The performance of these models is compared against the two reference specifications – purchasing power parity and the sticky-price

monetary models. ....Overall, model/specification/currency combinations that work well in one period do not necessarily work well in another period.

Several articles in Table 2 apply a model-free econometric procedure to exchange rates. One of the most recent is Chung and Hong (2007). As the following quote from Chung and Hong (2007, 855) makes clear, such procedures can predict better than a martingale. “Based on a sample of foreign exchange spot rates and futures prices in six major currencies, we document strong evidence that the directions of foreign exchange returns are predictable not only by the past history of foreign exchange returns, but also the past history of interest rate differentials,.....”

Put briefly, exchange rates are not strictly martingales, but changes in exchange rates are white noise. Economic models, including the sticky price monetary model underlying many overshooting models, do not predict well out of sample. Finally, there is nonlinear information in exchange rates that can be used to predict the direction of changes in exchange rates. But neither Chung and Hong (2007) nor any of the other relevant articles in Table 2 suggest that overshooting is the source of the predictability.

All articles in Table 1 use monthly data. Some of that data is averaged. As Working (1960) points out, averaging introduces spurious correlation into first differences. As a result, some of the undershooting in the literature may be due to averaged data. That problem does not apply to the articles in Table 2.

The predictability in the exchange rates and the undershooting in the VAR estimates also could be, at least partly, the result of official intervention. Kim (2003, 2005) raises the issue of the effect of official intervention in the overshooting literature. In the context of the martingale literature, Hsieh (1989), Fong and Ouliales (1995) and Chung and Hong (2007) consider intervention as a possible source of predictability in exchange rates. An important contribution of this paper is that it uses data from periods when there was no intervention.

### 3.0 Spectral Implications.

The frequency domain is a natural place to test for destabilizing speculation, bandwagons and overshooting. Like lumens for light and decibels for sound, the variance in a random variable describes the “power” in that series. The spectrum decomposes that power by frequency. With the daily data used later, high

frequencies and short cycles are naturally associated with the short run and very low frequencies or long cycles with the long run. As a result, spectral analysis provides a natural way to test for systematic destabilizing speculation, bandwagons and overshooting. If such behavior is important, the spectrum for changes in exchange rates should not be flat. Spectral estimates should be higher at high or intermediate frequencies than at very low frequencies.

### 3.1 The null hypothesis: Changes in Exchange Rates are White Noise.

If markets for foreign exchange do not systematically over or under respond to information, then the change in the logarithm of the exchange rate should be approximately white noise. At the very least, there should be no structure that would allow one to make higher than normal profits. Although it is strictly true only in very special cases, the standard empirical interpretation of efficient markets and rational expectations is that prices are martingales. Since a martingale implies that changes are uncorrelated, a martingale implies that the spectrum for changes is flat.

### 3.2 Destabilizing Speculation, Bandwagons and Overshooting.

Dornbusch (1976) is the standard reference for overshooting. The Appendix derives the frequency domain implications of the short-run model in that article. The impact response to a unit step in the stock of money is  $(1+\lambda\theta)/\lambda\theta$ . Minus  $\lambda$  is the interest elasticity of the demand for money and  $\theta$  determines the expected rate of depreciation.<sup>16</sup> The steady state or long response is  $\lambda\theta v / \lambda\theta v$  or 1.0. The parameter  $v$  determines how fast  $(1+\lambda\theta)/\lambda\theta$  converges to 1.0. That parameter determines the actual rate of inflation.

Figure 2 in Dornbusch (1976) illustrates how exchange rates overshoot. In that figure,  $(1+\lambda\theta)/\lambda\theta$  equals about 2.5. Figure 2 here shows the spectrum for changes in exchange rates implied by Dornbusch's short-run model where income is held constant and  $v$  equals 0.5. Figure 3 shows the spectrum implied by that model when  $v$  equals 0.05. In both figures  $(1+\lambda\theta)/\lambda\theta$  equals 2.5. Without any overshooting the spectrum would equal 1.0 at all frequencies and the exchange rate would be a martingale. Although the details vary as the various

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<sup>16</sup> Equation 2 in Dornbusch is the following:  $x = \theta(e - \bar{e})$  where  $x$  is the expected rate of depreciation and  $e - \bar{e}$  is the difference between the current and long-run value of the exchange rate  $e$ .

parameters change, the pattern implied by Dornbusch's type of overshooting is that the spectrum declines as frequency declines. There is more short-run volatility than long-run volatility. Delayed overshooting would appear as a hump in the spectrum at intermediate frequencies.

Figures 2 and 3 also illustrate the kind of spectra we would expect with systematic destabilizing speculation and bandwagons. The speculative behavior described in Taussig (1921) would cause markets to over respond to information. That over response would cause the short-run volatility of exchange rates to be greater than the long-run volatility. That is, the short-run component of the variance in the difference of the logarithm of exchange rates would be larger than the long-run component. Spectra for those differences would tend to rise as frequency increases. Of course the spectral pattern would not be as well behaved as in Figures 2 and 3. Instead of a smooth transition from high to low frequencies there might be one or more significant peaks at high frequencies, particularly at frequencies like one week or one month where bandwagons might be likely.

### 3.3 Undershooting.

Until recently, the possibility of undershooting in foreign exchange markets has been largely ignored. But recent work on the microstructure of the foreign exchange market suggests that, at least in the very short run, undershooting is a possibility. Leaning against the wind by central banks also can cause exchange rates to under respond to information. Systematic undershooting would produce the opposite kind of spectra as in Figures 2 and 3.<sup>17</sup>

For all of the periods analyzed in Table 2, at least part of the time central banks were intervening in the foreign exchange market. If intervention offset undershooting or overshooting, it could be the reason that changes in exchange rates are approximately white noise. If exchange rates are martingales in the absence of intervention, then intervention is a likely source for the structure found in the articles in Table 2.

The recent daily data used here are from periods when central banks did not intervene. Central banks have yet to provide any detailed information about their intervention during the early 1920s.

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<sup>17</sup> Pippenger and Phillips (1973, 1993) show how leaning against the wind affects the spectra for exchange rates.

#### 4.0 The data.

The early 1920s was the first modern experience with flexible exchange rates between several developed countries. The standard interpretation of that experience was that flexible exchange rates suffered from destabilizing speculation. I revisit the early 1920s using daily U.S. dollar prices of currencies for England, France, Italy, Norway and Spain. All exchange rates are noon buying rates in New York from Statistical Release H10 published by the Board of Governors of the Federal Reserve System.

To analyze all five countries over the same interval, the period runs from 1921:01 to 1924:12. The beginning date allows some time for foreign exchange markets to recover from the artificially pegged rates during and just after World War I. The ending date is just a few months before England returns to the gold standard. As pointed out below, while these exchange rates were flexible in the 1920s, most were not what we would call freely floating. In most cases the literature suggests some form of interference.

An important advantage of data from the recent float is that we can choose periods when exchange rates are freely floating. We can do so because several countries now provide information about daily intervention. Several articles use that information to try to determine the effects of intervention.<sup>18</sup> However that information also provides an opportunity to examine the behavior of exchange rates when central banks do not intervene and exchange rates float freely. To the best of my knowledge, this is the first time that the information on intervention has been used to look for evidence of overshooting when central banks do not intervene. The data for the recent float come from different sources. Table 3 describes the sources, the countries and intervals when we can be reasonably certain that exchange rates were freely floating.<sup>19</sup>

#### 5.0 The Evidence

This section looks for evidence of destabilizing speculation, bandwagons and overshooting in daily exchange rates. The null hypothesis is that the difference in the logarithm of the exchange rate,  $\Delta S_t$ , is white noise. In the frequency domain, destabilizing speculation, bandwagons and overshooting should increase the

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<sup>18</sup> See for example Payne and Vitale (2003) and Fatum and Hutchison (2006)

<sup>19</sup> The Bank of Canada does not release information about intervention. However the Bank re-estimated some equations in Phillips and Pippenger (1993) with actual intervention data and the two results are similar. The intervention data for England and Japan are available on the web sites for their central bank. Germany and Switzerland routinely provide data to *bone fide* researchers.

short-run volatility relative to the long run volatility. That is, there should be evidence of more power at some high frequencies than at the lowest frequencies. In the time domain, destabilizing speculation, bandwagons and overshooting should produce structure in  $\Delta S_t$ . Rises should follow declines or *vice versa*.

The analysis begins in Section 5.1 with the 1920s and continues in Section 5.2 with the modern float. In each case the analysis begins with three tests for white noise in  $\Delta S_t$ . The first test is the Q statistic. The second is the Kolmogorov-Smirnov test statistic that uses the cumulated periodogram. Both of these tests assume autocovariance stationarity. The third test uses estimates of equation 1.

$$\Delta S_t = \alpha_0 + \sum_{i=1}^{120} \alpha_i \Delta S_{t-i} \quad (1)$$

These estimates are corrected for conditional heteroscedasticity.

### 5.1 The 1920s

Table 4 reports the three tests for white noise in the 1920s. The second row in Table 4 shows the Q statistic for  $\Delta S_t$  for all 5 countries during the 1920s. The number in the brackets is the significance. All of the Q statistics are significant at the 1 percent level.

The third row shows the K-S statistic. The number between parentheses is the frequency at which the estimated periodogram differs the most from the periodogram for white noise. Except for France, all of the K-S statistics are significant at the 1 percent level. The K-S statistic for France is not significant.

The rows below the K-S statistic show the estimates from equation 1. To save space, only the first 10 estimates are always reported in Table 2. Additional estimates are reported when they exceed the cutoff reported at the end of the estimates. For each country, the penultimate row reports the most significant Q statistic for the error terms. If that Q test is not significant, no test is significant. The bottom row reports the ARCH test from Eviews for conditional heteroscedasticity.

The key evidence for destabilizing speculation, bandwagons and overshooting is evidence of reversals. To help identify such evidence, significant estimates appear in bold type.

For every country the coefficient for  $\Delta S_1$  is positive and significant. For England, Norway and Spain, the estimates are significant at the 1 percent level. For every country there are also additional lags that are significant. For the 1920s,  $\Delta S_t$  is clearly not white noise. But rejecting white noise does not imply destabilizing speculation, bandwagons or overshooting. In the time domain, that behavior implies that significant positive estimates should be followed by significant negative estimates. Except possibly for France, no such pattern appears in Table 4.

Figures 4 through 8 show the spectral density estimates for the 1920s.<sup>20</sup> Those estimates show no evidence of destabilizing speculation, bandwagons or overshooting. All three kinds of behavior should increase short-run volatility relative to long-run volatility. Spectral density estimates for France in Figure 5 show no tendency to rise or fall as frequency rises from 0.0 to 0.5 cycles per day. For Spain the spectral density estimates in Figure 8 show at most a small tendency to fall as frequency increase. England, Italy and Norway all show strong evidence of undershooting. In all three cases the spectral density tends to decline as frequency increases from 0.0 to 0.5.

The spectral pattern for Norway in Figure 7 is the easiest to explain. The central bank of Norway actively intervened in the foreign exchange market.

N. Rygg, Managing Director of the Bank of Norway described the Bank's intervention as follows:

There has been no interference either by legislation or by administrative measures, with dealings in foreign exchange and the market has accordingly been left free. The Norges Bank has, however, felt obliged to play an active part in the market in order to prevent unsound speculation in exchange. Rygg (1925, 216).

As shown in Pippenger and Phillips (1973), a central bank that "leans against the wind" will introduce the kind of spectral pattern shown in Figure 7 into an exchange rate that is otherwise a random walk.

There is a strong possibility of intervention in the Spanish peseta in the early 1920s. In 1917 the Spanish government established the Institute of Foreign Exchange. This institute was modified over the years, but

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<sup>20</sup> The spectral density is the spectrum normalized so that the variance is unity. Spectral density is to the spectrum as autocorrelation is to autocovariance.

remained in existence over the period examined here. The Institute's main function was to obtain foreign exchange for the government and, apparently, to stabilize the exchange rate.<sup>21</sup>

The structure in the pound sterling is more difficult to explain. Tsiang (1959) treats sterling as though it were freely floating. But an examination of the combined gold holdings of the Bank of England and the Treasury shows small fluctuations from 1921 through 1924. From January 1921 to December 1924 the combined holdings rose from £128.3 million to £128.6 million. The largest month on month change was £0.7 million from November to December 1923. Except for the £0.5 million change from June to July 1922, all other month on month changes were only about £0.1 million. However from January 1921 to December 1924, there were 12 such changes. These changes in the combined gold holdings could be interpreted as evidence of intervention.

France is the most interesting case. France during the early 1920s is often identified as the classic example of destabilizing speculation. France in the 1920s is also an ideal place to look for overshooting because of the unstable monetary policies of various French governments.<sup>22</sup> Although it is clear that the French franc was not a martingale, there is no evidence of overshooting in the frequency domain. Spectral estimates do not rise as frequency increases. Not a single spectral estimate exceeds the upper confidence interval.

The time domain tells a slightly different story. Running from lag 58 through lag 108 in Table 4 there are seven consecutive negative estimates. If the exchange rate rose on Monday, it was likely to rise again on Tuesday, and then likely to fall some 10 to 18 weeks later.<sup>23</sup>

The behavior of flexible exchange rates during the 1920s can be summarized as follows: Exchange rates were not martingales, but they also show little evidence of systematic destabilizing speculation, bandwagons or overshooting. The typical pattern seems to be undershooting. The result for France is particularly interesting. With substantial inflation and deflation, France in the early 1920s would seem to be a prime candidate for evidence of destabilizing speculation, bandwagons and overshooting. But there is little evidence of such

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<sup>21</sup> For more details see Young (1925) and McGuire (1926).

<sup>22</sup> For a detailed discussion of those policies see Wolf (1925), Dulles (1929) and Tsiang (1959).

<sup>23</sup> During the 1920s the foreign exchange market was open six days a week.



behavior. The time domain shows some possible evidence of reversals, but the spectral density estimates are consistent with white noise.

## 5.2 Post 1990.

The world has changed dramatically since the 1920s. Improved communications and the introduction of computers have affected all auction markets including foreign exchange markets. If markets for foreign exchange were close to efficient in the 1920s, they should be even more efficient now. If they were dominated by destabilizing speculation, bandwagons or overshooting in the 1920s, those effects could be even stronger now because speculators can move more money across more markets faster than ever.

Table 5 shows the tests for white noise for Canada, England, Germany, Japan and Switzerland when there was no official intervention. A Q statistic for England is almost significant at the 1 percent level. A Q statistic for Canada is almost significant at the 5 percent level. Finding a few statistics significant out of 600 estimates should not be surprising. None of the Kolmogorov-Smirnov tests using the cumulated periodogram reject the null of white noise.

For all five countries, estimates of equation 1 show fewer significant coefficients than we would expect. Unlike Table 4, no estimate for the first lag is significant. There is also no evidence of reversals. As many significant coefficients are positive as negative and there is no tendency for these estimates to “bunch up” by sign. That is, there is no tendency for changes in one direction to be followed by changes in the opposite direction.

The spectral densities for freely floating currencies reinforce the time domain results. The spectral densities in Figures 9 through 13 all indicate that, as a reasonable first approximation, freely floating exchange rates are martingales. The spectra suggest that  $\Delta s_t$  is approximately white noise. In no case is there any evidence that there is more short-run or intermediate volatility than long-run volatility.

When there is no official intervention, daily exchange rates between developed countries are approximately martingales. The first differences are white noise. There is no evidence of destabilizing speculation, bandwagons or overshooting. For the 1920s there is some evidence that exchange rates under

responded to information rather than over responded. One possibility is that this under response was the result of intervention by the central bank. How a central bank could introduce structure into an otherwise efficient market remains an open issue.

Whether or not the kind of departure from a martingale that Hong and Lee (2003) find or the kind of predictability that Chung and Hong (2007) find would still hold when there is no intervention also remains an open issue.

## 6.0 Summary and Conclusions

Exchange rate economics suffers from a serious bi-polar condition. On the one hand there is a general consensus that exchange rates suffer from overshooting and that overshooting helps explain the large volatility in exchange rates. On the other hand, there is a general consensus that exchange rates are martingales and that economic models cannot beat a random walk out of sample. It does not seem possible that both of these views can be true. As the review of the recent literature on both issues shows, there is ample evidence supporting exchange rates as approximately martingales, but almost no significant evidence supporting overshooting. Rather than supporting overshooting, the VAR estimates in the overshooting literature suggest that exchange rates undershoot. That is they respond slowly to monetary shocks.

Earlier analyses of the behavior of exchange rates covered periods when central banks intervene. I add to the work on exchange rate behavior by examining daily exchange rates for five countries during the 1920s when intervention was likely and for five countries after 1990 when there is no intervention. Exchange rates during the 1920s were not martingales, but there was no evidence of overshooting. Quite the opposite. On balance it appears that exchange rates under responded to information.

When there is no intervention, flexible exchange rates are approximately martingales. The difference in the logarithm of the exchange rate is essentially white noise. Analyzing exchange rates without intervention rules out the possibility that exchange rates might overshoot in the absence of central bank intervention. The fact that flexible exchange rates are approximately martingales in the absence of intervention is inconsistent with systematic overshooting.

Since freely floating exchange rates are approximately martingales, any model that is not consistent with a freely floating exchange rate being approximately a martingale probably should be dismissed out of hand.

Whether or not the small deviations from a martingale reported in the literature are the result of intervention remains an issue for future research. The empirical results reported here also do not necessarily apply to developing countries. How freely floating exchange rates might behave in developing countries also remains an open issue.

## APPENDIX

Except where noted, the Appendix uses the same notation as Dornbusch (1976). With real income  $y$  given, Dornbusch's equation 5 describes the equilibrium price level  $\bar{p}$ .

$$\bar{p} = m + \lambda r^* - \phi y. \quad (\text{I})$$

Where  $m$  is the stock of money,  $r^*$  is the foreign interest rate, and  $\lambda$  and  $\phi$  are positive parameters.

Equation 10 describes how prices adjust.

$$Dp = -v(p - \bar{p}) \quad (\text{II})$$

Where  $Dp \equiv dp/dt$  and  $v = \Phi \{[(\delta + \sigma\theta)/\theta\lambda] + \delta\}$ .

Equation II implies the following solution for  $p$ .

$$p = [v/(v+D)]\bar{p} = [v/(v+D)][m + \lambda r^* - \Phi y] \quad (\text{III})$$

Dornbusch's equation 9 describes the equilibrium exchange rate  $\bar{e}$ .

$$\bar{e} = \bar{p} = (1/\delta)[\sigma r^* + (1-\gamma)y - u] \quad (\text{IV})$$

His equation 6 describes the relationship the exchange rate  $e$  and the price level  $p$ .

$$e = \bar{e} - (1/\lambda\theta)(p - \bar{p}) = Am + (1/\delta)u + [(\sigma/\delta) + A]r^* - [A + (1 - \gamma)]y. \quad (\text{V})$$

Where  $A \equiv \{[\lambda\theta v + (1 + \lambda\theta)D]/[\lambda\theta(v + D)]\} + (1 - \gamma)$ .

Using Fourier transforms to shift equation V from the time domain to the frequency domain produces equation VI where  $x(f)$  is the frequency domain analog of  $x(t)$ .

$$e(j2\pi f) = A(j2\pi f)m(j2\pi f) + (1/\delta)u(j2\pi f) + [(\sigma/\delta) + A(j2\pi f)]r^*(j2\pi f) - [(1-\gamma)/\delta + \Phi A(j2\pi f)]y(j2\pi f). \quad (VI)$$

Where  $j \equiv \sqrt{-1}$  and  $\pi = \text{pi}$ .

The spectrum for  $x(f)$  denoted  $\Gamma_{x,x}(f)$  equals  $\mathbf{E}\{x(f)x(f)^*\}$  where  $x(f)^*$  is the complex conjugate of  $x(f)$  and  $\mathbf{E}$  is the expectations operator. Assuming that the inputs  $m$ ,  $u$ ,  $r^*$  and  $y$  are independent, the spectrum for the change in  $e$  is the following:

$$\begin{aligned} \Gamma_{\Delta e, \Delta e}(f) &= \mathbf{E}\{(A(2\pi f)A(2\pi f)^* \Gamma_{\Delta m, \Delta m}(f) + [(\sigma/\delta) + A(j2\pi f)][(\sigma/\delta) + A(j2\pi f)]^* \Gamma_{\Delta r^*, \Delta r^*}(f) \\ &\quad - [(1-\gamma)/\delta + \Phi A(j2\pi f)][(1-\gamma)/\delta + \Phi A(j2\pi f)]^* \Gamma_{\Delta y, \Delta y}(f) + (1/\delta)(1/\delta)^* \Gamma_{\Delta u, \Delta u}(f)\} \\ &= \{[(\lambda\theta v)^2 + ((1 + \lambda\theta)(2\pi f))^2]/[(\lambda\theta v)^2 + (\lambda\theta 2\pi f)^2]\} \Gamma_{\Delta m, \Delta m}(f) \\ &\quad + \{(\sigma/\delta)^2 + (\lambda\sigma/\delta)\{[2(\lambda\theta v)^2 + 2\lambda\theta(1 + \lambda\theta)(2\pi f)^2]/[(\lambda\theta v)^2 + (\lambda\theta 2\pi f)^2]\} \\ &\quad + \lambda^2\{[(\lambda\theta v)^2 + ((1 + \lambda\theta)(2\pi f))^2]/[(\lambda\theta v)^2 + (\lambda\theta 2\pi f)^2]\} \} \Gamma_{\Delta r^*, \Delta r^*}(f) \\ &\quad + \{[(1-\gamma)/\delta]^2 + [\Phi(1-\gamma)/\delta]\{[2(\lambda\theta v)^2 + 2\lambda\theta(1 + \lambda\theta)(2\pi f)^2]/[(\lambda\theta v)^2 + (\lambda\theta 2\pi f)^2]\} \\ &\quad + \Phi^2\{[(\lambda\theta v)^2 + ((1 + \lambda\theta)(2\pi f))^2]/[(\lambda\theta v)^2 + (\lambda\theta 2\pi f)^2]\} \} \Gamma_{\Delta y, \Delta y}(f) \\ &\quad + (1/\delta)^2 \Gamma_{\Delta u, \Delta u}(f) \end{aligned}$$

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TABLE 1  
Articles Using VAR to Test for Delayed Overshooting

Author(s) and (Year)	Confidence Interval	Currency Versus US\$	Interval
Eichenbaum & Evans (1995)	±1 SD	C\$, DM, FF, IL, JY, £	1974:01-1990:05
Grilli & Roubini (1996)	±1 SD	C\$, DM, FF, IL, JY, £	1974:12-1991:12
Cushman & Zha (1997)	±2 SD	C\$	1974:??-1993:??
Kim & Roubini (2000)	±1 SD	C\$, DM, IL, JY, £	1974:07-1992:05
Kalyvitis & Michaelides (2001)	95%	DM, FF, IL, JY, £	1975:01-1996:12
Faust & Rogers (2003)	68%	DM, £	1974:01-1997:12
Kim (2003)	90%	Trade Weighted	1974:01-1996:12
Jang & Ogaki (2004)	±1 SD	JY	1974:01-1990:05
Kim (2005)	90%	C\$	1975:01-2002:02
Kearns (2007)	±1 SD	A\$	1984:07-2000:12

A\$ Australian \$, C\$ Canadian \$, DM German mark, FF French franc, IL Italian lira, JY Japanese yen, £ pound sterling.

Table 2  
Spot Exchange Rates, Martingales and Predictability

Author(s) (Year) Observations	U.S. \$ versus	Interval	
Callen, Kwan & Yip (1985)	C\$, DM, FF, JY, SF, £	1973:04-1983:06	End of Month
Hsieh (1988)	C\$, DM, JY, SF, £	1974:01-1983:12	Daily
Hsieh (1989)	C\$, DM, JY, SF, £	1974:01-1983:12	Daily
Engel, Charles (1994)	C\$, DM, FF, IL, JY, SF, £	1973:2-1986:4	Quarterly
Fong & Ouliaris (1995)	C\$, DM, FF, JY, £	1974:08-1989:03	Wednesdays
Kuan & Liu (1995)	C\$, DM, JY, SF, £	1980:03-1985:01	Daily
Lisi & Media (1997)	C\$, DM, FF, IL, JY, SP, £	1972:01-1994:01	Monthly
Hong (1999)	DM	1976:01-1995:11	Wednesdays
Hong & Lee (2003)	C\$, DM, FF, JY, £	1975:01-1998:12	Wednesdays
Cheung, Chinn & Pascual (2005)	C\$, DM, JY, SF, £	1973:2-2000:4	Quarterly
Chung & Hong (2007)	A\$, C\$, DM, JY, SF, £	1987:01-2003:04*	Daily

\* DM ends 1998:12. A\$ Australian \$, C\$ Canadian \$, DM German mark, FF French franc, IL Italian lira, JY Japanese yen, SP Spanish peseta, £ pound sterling.

TABLE 3

Sources for Daily Dollar Exchange Rates during Current Float

Country	Data Source	Interval
Canada	Bank of Canada Close	1999:07-2005:12
England	Bank of England Close	1993:03-2007.09
Germany	FRED Noon buying rates	1996:01-1998:12
Japan	Galati, Melick and Micu (2005) Noon London	1993:09-1994:02 2000:05-2001:08
Switzerland	FRED Noon buying rates	1996:01-2005:12

FRED is on the St. Louis Federal Reserve Bank's web site.

TABLE 4  
Tests for White Noise for 1920s

Test	England	France	Italy	Norway	Spain
Q (Lag) [Significance]	30.488 (5) [0.000]	15.578 (5) [0.008]	21.643 (6) [0.000]	25.104 (1) [0.000]	20.418 (2) [0.000]
K-S (Cycles/Day)	0.064** (0.364)	0.033 (0.079)	0.052** (0.267)	0.104** (0.342)	0.095** (0.270)
Regression 1					
$\Delta S(1)$ [Sig.]	<b>0.0881</b> [0.0063]	<b>0.0785</b> [0.0152]	<b>0.0743</b> [0.0434]	<b>0.1361</b> [0.0009]	<b>0.2066</b> [0.0000]
$\Delta S(2)$ [Sig.]	-0.0454 [0.1586]	0.0200 [0.5374]	<b>-0.0675</b> [0.0396]	<b>-0.0871</b> [0.0337]	<b>-0.0833</b> [0.0111]
$\Delta S(3)$ [Sig.]	0.0566 [0.0786]	0.0613 [0.0585]	<b>-0.0656</b> [0.0422]	0.0557 [0.1015]	<b>-0.0690</b> [0.0356]
$\Delta S(4)$ [Sig.]	0.0393 [0.2222]	-0.0397 [0.2213]	0.0454 [0.1260]	0.0311 [0.3547]	-0.0185 [0.5741]
$\Delta S(5)$ [Sig.]	<b>0.0665</b> [0.0387]	0.0524 [0.1060]	0.0090 [0.7375]	<b>0.0909</b> [0.0061]	0.0494 [0.1335]
$\Delta S(6)$ [Sig.]	-0.0085 [0.7921]	-0.0262 [0.4186]	<b>-0.0550</b> [0.0350]	0.0297 [0.4345]	-0.0175 [0.5951]
$\Delta S(7)$ [Sig.]	0.0002 [0.9994]	0.0100 [0.7574]	0.0204 [0.3750]	<b>0.1094</b> [0.0025]	0.0067 [0.8394]
$\Delta S(8)$ [Sig.]	0.0049 [0.8780]	<b>-0.0549</b> [0.0903]	<b>0.0580</b> [0.0285]	<b>0.0648</b> [0.0440]	0.0273 [0.4063]
$\Delta S(9)$ [Sig.]	0.0442 [0.1670]	0.0588 [0.0698]	<b>0.0464</b> [0.0285]	0.0194 [0.5316]	-0.0088 [0.7895]
$\Delta S(10)$ [Sig.]	<b>-0.0638</b> [0.0463]	0.0337 [0.2984]	<b>-0.0575</b> [0.0077]	-0.0532 [0.0939]	-0.0463 [0.1585]
$\Delta S(\text{Lag})$ [Sig.]	<b>0.0781</b> (20) [0.0145]	<b>0.0656</b> (16) [0.0424]	<b>-0.0837</b> (23) [0.0000]	0.1125 (24) [0.0001]	<b>0.0767</b> [0.0191]
$\Delta S(\text{Lag})$ [Sig.]	<b>0.0637</b> (48) [0.0448]	<b>0.0676</b> (19) [0.0366]	<b>-0.0820</b> (46) [0.0000]	<b>-0.0710</b> (26) [0.0077]	<b>0.0895</b> (15) [0.0065]
$\Delta S(\text{Lag})$ [Sig.]	<b>-0.0669</b> (59) [0.0355]	<b>-0.0757</b> (26) [0.0186]	<b>0.0769</b> (55) [0.0000]	<b>0.0840</b> (40) [0.0021]	<b>0.0734</b> (20) [0.0066]
$\Delta S(\text{Lag})$ [Sig.]	<b>-0.0753</b> (63) [0.0181]	<b>0.0583</b> (27) [0.0702]	<b>-0.0662</b> (69) [0.0000]	<b>-0.0713</b> (41) [0.0061]	<b>0.0626</b> (22) [0.0206]
$\Delta S(\text{Lag})$ [Sig.]	<b>-0.0625</b> (78) [0.0479]	<b>0.0641</b> (45) [0.0456]	<b>-0.0803</b> (79) [0.0000]	<b>0.0699</b> (55) [0.0129]	<i>0.0905</i> (33) [0.0008]
$\Delta S(\text{Lag})$ [Sig.]	<b>0.0626</b> (82) [0.0474]	<b>-0.0944</b> (58) [0.0032]	<b>-0.0658</b> (81) [0.0000]	<b>-0.0643</b> (63) [0.0167]	<b>-0.0540</b> (35) [0.0470]
$\Delta S(\text{Lag})$ [Sig.]	NA	<b>-0.0701</b> (61) [0.0287]	<b>0.0600</b> (86) [0.0000]	NA	<b>0.0656</b> (46) [0.0150]
$\Delta S(\text{Lag})$ [Sig.]	NA	<b>-0.0838</b> (69) [0.0088]	<b>-0.0655</b> [0.0000]	NA	<b>0.0610</b> (52) [0.0232]
$\Delta S(\text{Lag})$ [Sig.]	NA	<b>-0.0757</b> (73) [0.0179]	<b>-0.0619</b> (112) [0.0000]	NA	<b>-0.0617</b> (70) [0.0213]
$\Delta S(\text{Lag})$ [Sig.]	NA	<b>-0.0702</b> (83) [0.0278]	NA	NA	<b>0.0735</b> (75) [0.0061]
$\Delta S(\text{Lag})$ [Sig.]	NA	<b>-0.0779</b> (95) [0.0141]	NA	NA	<b>0.0757</b> (77) [0.0049]
$\Delta S(\text{Lag})$ [Sig.]	NA	<b>-0.0611</b> (108) [0.0457]	NA	NA	
Cutoff	0.050	0.050	0.0000	0.020	0.050
ARCH(a,b)	(0,0)	(0,0)	(2,2)	(9,8)	(0,0)
Q(Lag) [Sig.]	0.028 (1) [0.866]	0.000 (1) [0.991]	3.149 (1) [0.076]	45.780 (42) [0.318]	0.002 (1) [0.965]
Arch(Lag) [Sig.]	90.4368 (1) [0.000]	276.253 (1) [0.000]	9.852 (7) [0.197]	48.102 (42) [0.239]	19.543 (1) [0.000]

Q statistics and regression estimates are from Eviews4. The K-S statistic is from RATS Version 6.

\* Significant at 5 percent. \*\* Significant at 1 percent.

TABLE 5  
Tests for White Noise when There Is no Intervention

Test	Canada 99:07-05:12	England 99:01-07:07	Germany 96:01-98:12	Japan 04:05-07:06	Switzerland 96:01-06:06
Q (Lag) [Significance.]	44.427 (31) [0.056]	10.649 (3) [0.014]	12.468 (10) [0.255]	1.494 (1) [0.222]	46.739 (37) [0.131]
K-S (Cycles/Day)	0.033 [0.312]	0.030 (0.260)	0.022 (0.094)	0.042 (0.234)	0.026 (0.411)
Regression 1					
$\Delta S(1)$ [Sig.]	0.0046 [0.8716]	0.0217 [0.2209]	0.0126 [0.8188]	-0.0434 [0.3440]	-0.0051 [0.8151]
$\Delta S(2)$ [Sig.]	0.0078 [0.7862]	0.0213 [0.2376]	-0.0677 [0.1787]	-0.0004 [0.9937]	0.0019 [0.9323]
$\Delta S(3)$ [Sig.]	-0.0232 [0.4067]	<b>-0.0490</b> [0.0110]	-0.0259 [0.5399]	-0.0062 [0.8945]	-0.0237 [0.2768]
$\Delta S(4)$ [Sig.]	-0.0269 [0.3742]	0.0095 [0.5852]	-0.0070 [0.8697]	0.0145 [0.7579]	0.0325 [0.1399]
$\Delta S(5)$ [Sig.]	-0.0535 [0.0581]	0.0088 [0.6431]	-0.0539 [0.3067]	-0.0436 [0.3671]	-0.0186 [0.3886]
$\Delta S(6)$ [Sig.]	0.0067 [0.8046]	-0.0310 [0.0687]	0.0347 [0.4602]	-0.0241 [0.6112]	0.0171 [0.4314]
$\Delta S(7)$ [Sig.]	0.0431 [0.1341]	0.0211 [0.2369]	-0.0280 [0.5744]	0.3579 [0.3579]	0.0094 [0.6669]
$\Delta S(8)$ [Sig.]	-0.0218 [0.4327]	-0.0065 [0.7160]	0.0124 [0.7808]	0.0054 [0.9116]	-0.0336 [0.1381]
$\Delta S(9)$ [Sig.]	-0.0047 [0.8682]	-0.0083 [0.6452]	0.0799 [0.0760]	-0.0263 [0.5361]	0.01181 [0.6027]
$\Delta S(10)$ [Sig.]	-0.0119 [0.6645]	0.0037 [0.8439]	<b>0.0956</b> [0.0264]	-0.0034 [0.9415]	-0.0203 [0.3477]
$\Delta S(\text{Lag})$ [Sig.]	<b>0.0573</b> (27) [0.0481]	<b>-0.0389</b> (21) [0.0378]	<b>-0.1320</b> (45) [0.0059]	<b>-0.0987</b> (56) [0.0318]	<b>-0.0469</b> (37) [0.0300]
$\Delta S(\text{Lag})$ [Sig.]	<b>-0.0694</b> (49) [0.0162]	<b>0.0390</b> (28) [0.0212]	<b>-0.1181</b> (76) [0.0296]	<b>0.0931</b> (109) [0.0354]	
$\Delta S(\text{Lag})$ [Sig.]	<b>0.0648</b> (76) [0.0165]	<b>-0.0448</b> (30) [0.0126]	<b>.1380</b> (106) [0.0031]	<b>-0.1074</b> (113) [0.0148]	
$\Delta S(\text{Lag})$ [Sig.]	<b>0.0781</b> (109) [0.0040]				
Cutoff	0.050	0.050	0.50	0.050	0.050
ARCH(a,b)	(1,1)	(4,4)	(5,5)	(1,1)	(2,2)
Q(Lag) [Sig.]	0.0112 (1) [0.912]	0.1722 (1) [0.678]	44.142 (35) [0.138]	0.004 (1) [0.999]	0.007 (1) [0.934]
Arch(Lag) [Sig.]	118.6845 (113) [0.339]	35.815 (29) [0.179]	0.7589 (2) [0.685]	12.796 (14) [0.543]	55.924 (46) [0.150]

Q statistics and regression estimates from Eviews4. K-S statistic from RATS Version 6.

\* Significant at 5 percent. \*\* Significant at 1 percent.

FIGURE 1.

Figure 2 from Kalyvitis and Michaelidies (2001)

Effects of contractionary U.S. monetary policy on interest rates and exchange rates:  
5-variable VAR with relative output and prices.

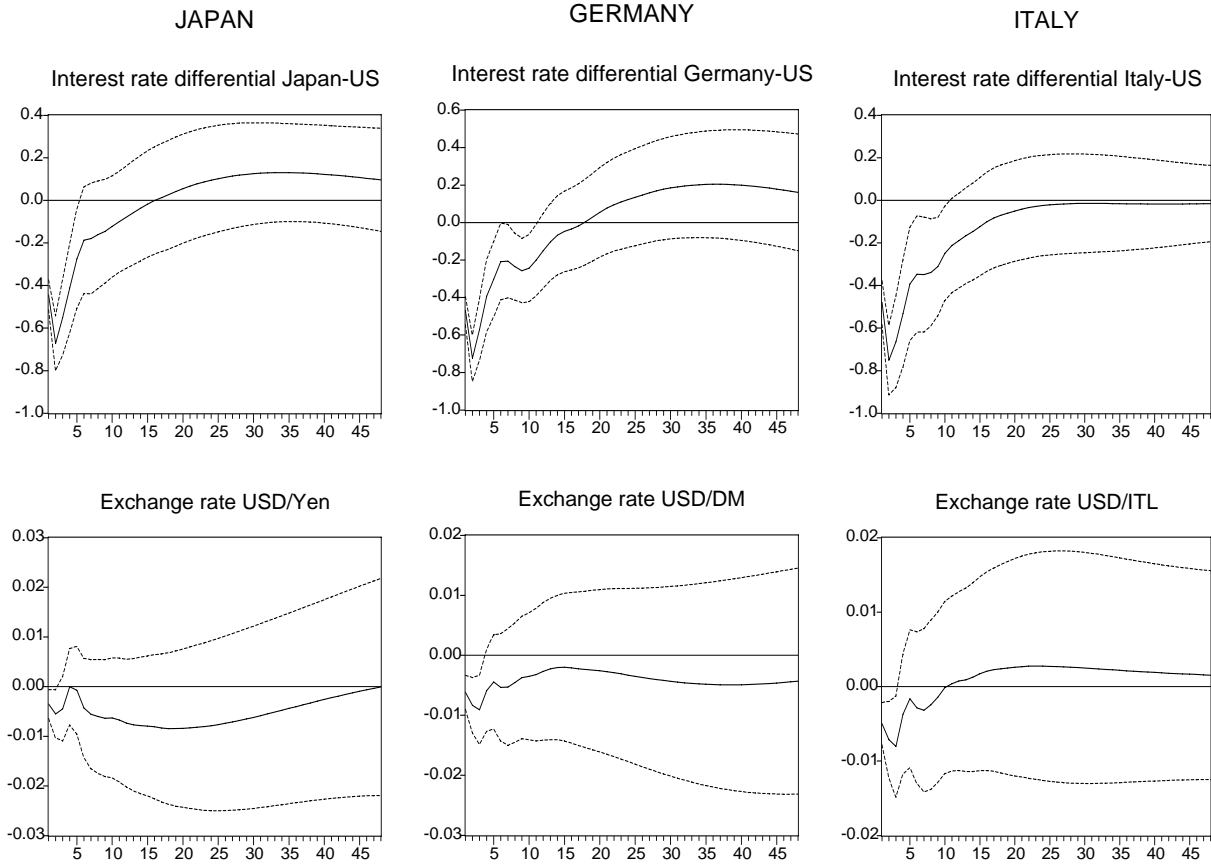


FIGURE 1  
Continued

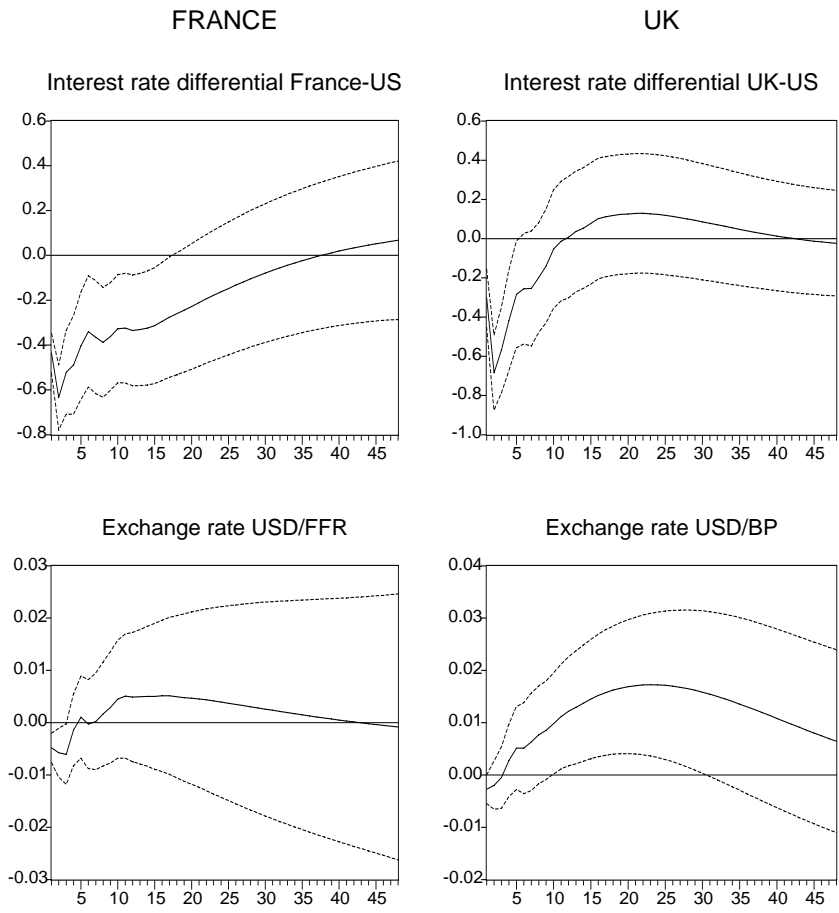


Figure 2  
Dornbusch Overshooting Model:  $\nu$  Equals 0.5

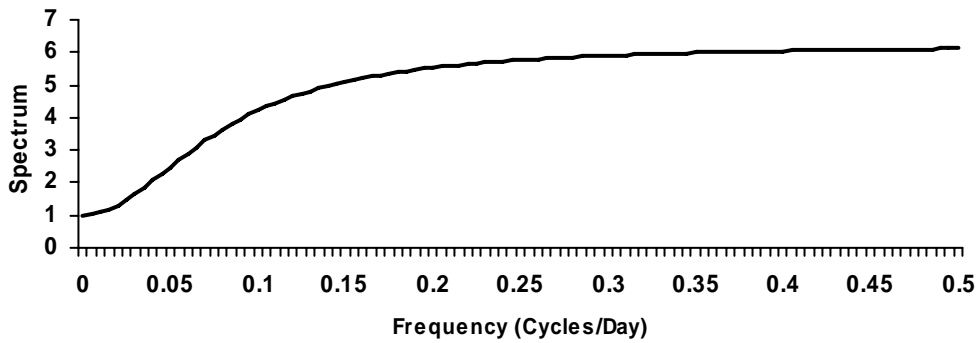


Figure 3  
Dornbusch Overshooting Model:  $\nu$  Equals 0.05

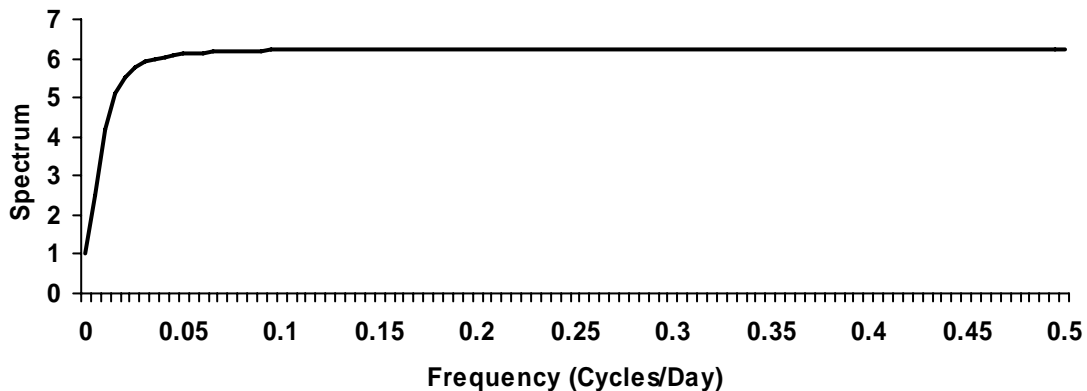


Figure 4  
Spectral Density for England: 1921:01-1924:12

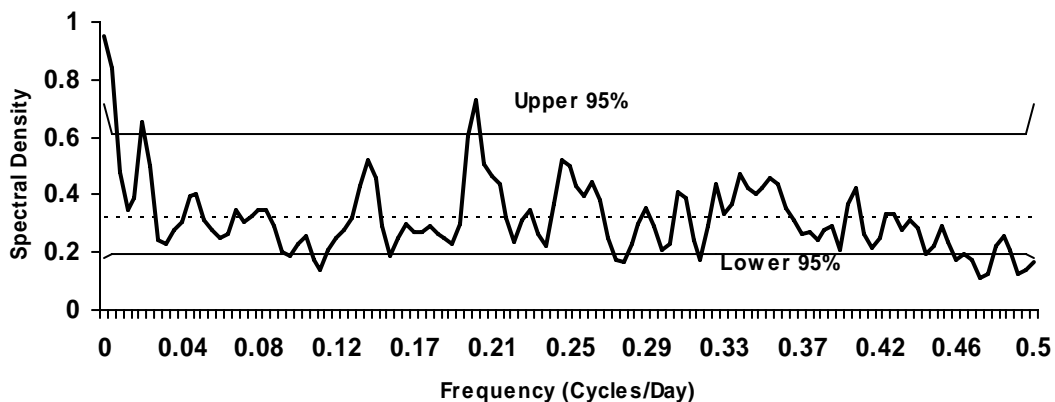


Figure 5  
Spectral Density for France: 1921:01-1924:12

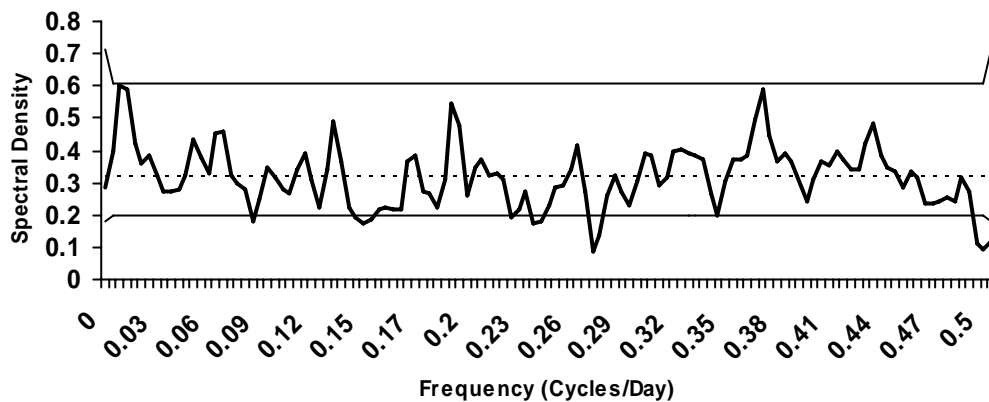




Figure 6  
Spectral Density for Italy: 1921:01-1924:12

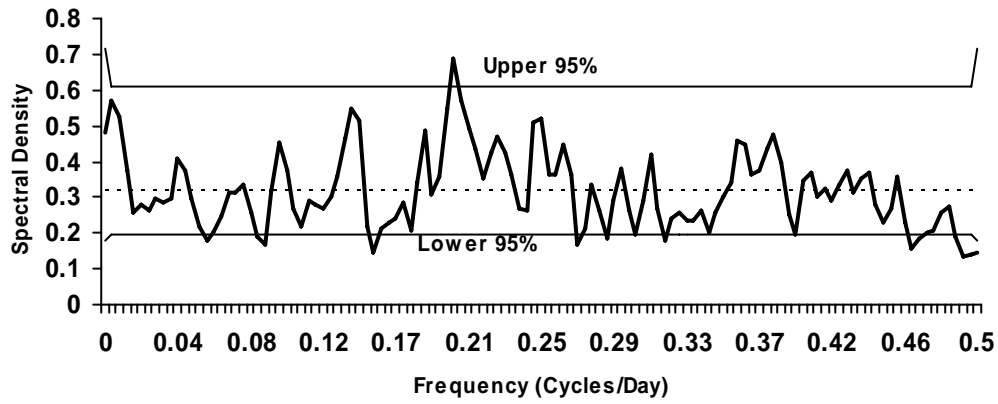


Figure 7  
Spectral Density for Norway: 1921:01-1924:12

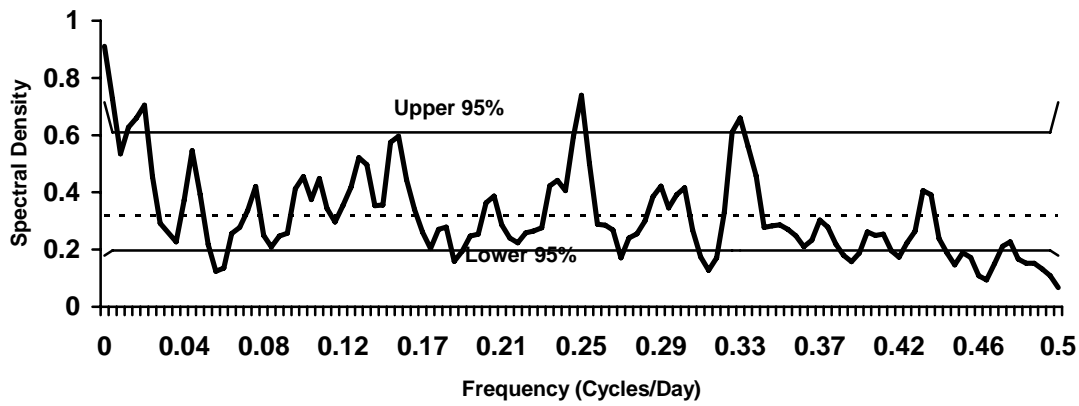


Figure 8  
Spectral Density for Spain: 1921:01-1924:12

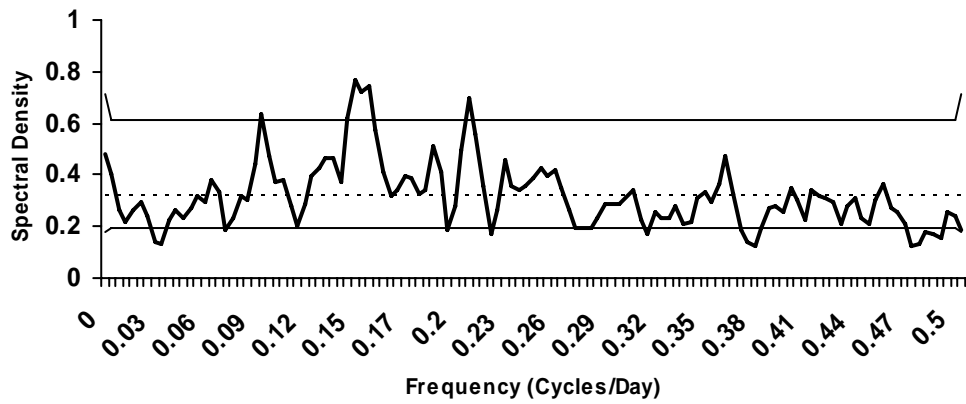
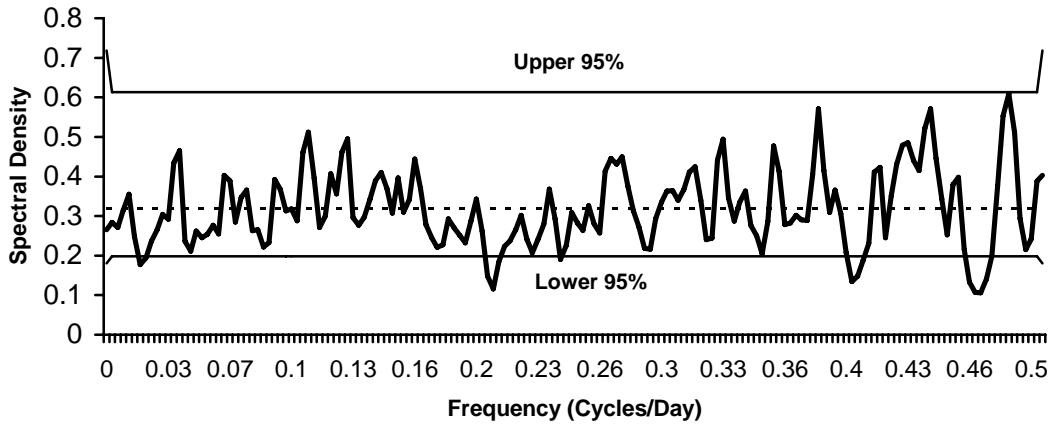


Figure 9  
Spectral Density for Canada: 1999:07-2005:12



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Figure 10  
England 1999:01 to 2007:07

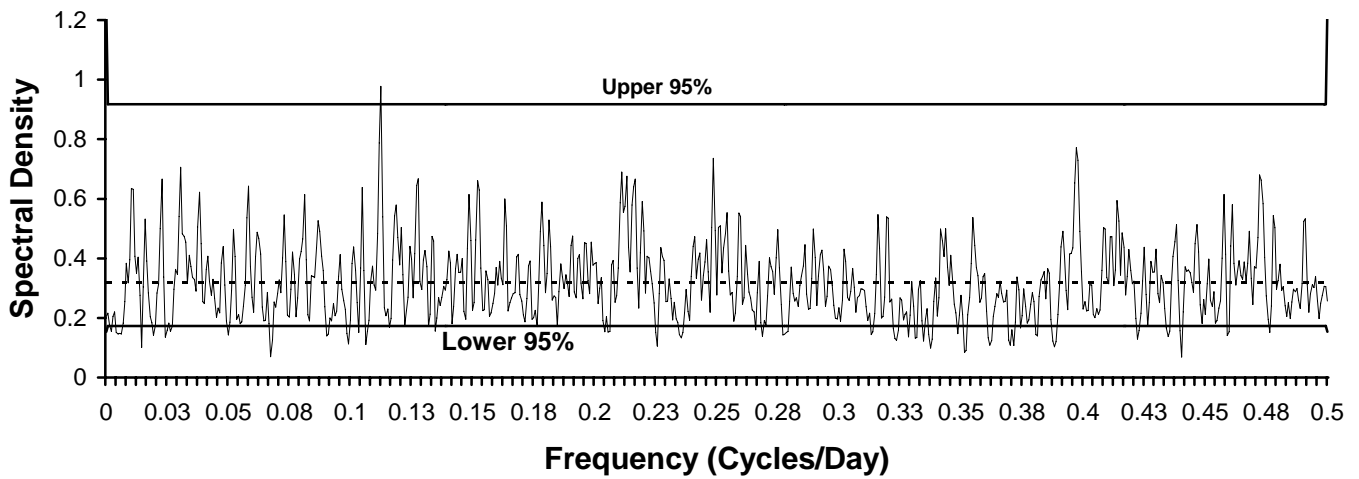


Figure 11  
Spectral Density for Germany: 1996:01-1998:12

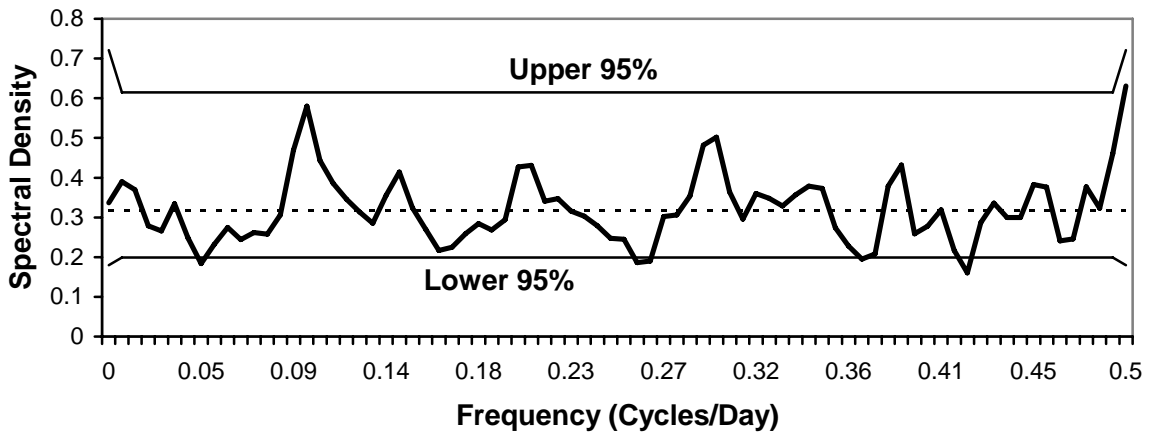


Figure 12  
Spectral Density for Japan: 2004:05-2007:06

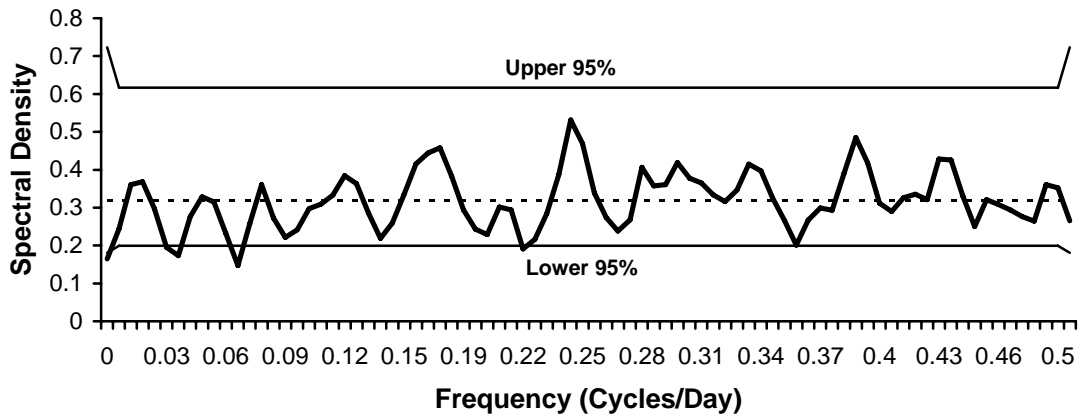


Figure 13  
Switzerland 1996:01 to 2006:06

