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Persistence in the Variability of Daily Exchange Rates

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Abstract

Rational speculation in foreign exchange trading is often assumed to dampen exchange rate fluctuations by bringing the market back to fundamentals. Nevertheless, information congestion provides incentives for traders to follow positive feedback strategies which result in persistent and volatile exchange rate behavior by magnifying the impact of exogenous shocks. Empirical evidence is presented which is consistent with such autocatalytic effects.

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Contents

Summary

Rational speculation in foreign exchange trading is often assumed to dampen fluctuations in exchange rates by bringing the market back to fundamentals. This paper develops and analyzes a model that tests the validity of this assumption.

Traders update their information on foreign exchange fundamentals by calling upon currency specialists. In periods of low volatility, traders base their bid-ask prices on the history of prices and volumes and on their estimates of inflation and returns on assets. In periods of high volatility, traders will suspect a change in the fundamental value of the currency and will attempt to update their information by contacting currency specialists. Currency specialists ration the dissemination of information during periods of high volatility. This rationing scheme causes traders to adopt a positive feedback strategy which magnifies exogenous shocks rather than allowing the market to dampen them. As a result the effects of the shocks persist in continued volatile behavior of the exchange rate.

This paper estimates an ARCH regression model of persistence for seven currencies and six sample periods. Various statistically significant estimates of persistence are obtained. These estimates reflect trader behavior in an informationally congested market. These results suggest that public awareness of the policy interventions of monetary authorities will foster more orderly conditions in exchange markets. Nevertheless, there would seem to be a natural limit to the ability of markets to "iron out" uncertainties associated with essentially exogenous and unpredictable events, such as natural disasters and political upheaval, that may affect exchange rates.

I. Introduction

Since the move to a managed floating exchange rate system in 1973, world financial markets have been characterized by large movements in nominal exchange rates. These fluctuations have been accompanied by large swings in real exchange rates, reflecting the fact that movements in nominal exchange rates have not closely followed changes in relative prices of traded goods. An interesting empirical question is whether such exchange variations have exhibited persistence, i.e., whether such variations have been serially correlated.

This paper investigates the persistence in the variability of floating exchange rates in the period between 1980 and 1989, using a model in which externalities based on information transmission are introduced in a rationally speculative trading environment. 1/ The model assumes that foreign exchange traders periodically update their information on fundamentals by calling upon specialists. In this model, the economy is characterized as a stylized Adam Smith assembly line economy in which all of the inputs are complements. Owing to the structure of the assembly-line economy and the presence of externalities, the macroeconomic behavior of this model is characterized by booms and busts. Furthermore, the hierarchy of the costs of adjustment to the exogenous shocks filtering through the system leads to persistence (see Romer (1986), Admati and Pfleiderer (1989), and De Long, et al. (1990)). 2/ Free information flow will cause rates to remain close to fundamentals, while restricted information flow will make traders take similar positions in currencies, thus magnifying essentially neutral or innocuous exogenous shocks into persistent and volatile exchange rate behavior.

Section II describes the empirical behavior of exchange rates. The positive feedback externality model is outlined in Section III. Section IV details the econometric methodology used. The estimation results are presented in Section V. Concluding remarks are provided in Section VI.

1/ This type of model is based on Grossman and Stiglitz (1976) in which feedbacks based on information transmission were integrated into an economic model.

2/ Alternatively, economists have tried to explain persistence by looking at the statistical issues involved in aggregating macroeconomic data. A notable example of this approach is the determination that the 20-year Kuznets cycle in GNP was due to the technique used in calculating GNP. As another example, Cleveland and Tiao (1976) found that the X-11 seasonal adjustment filter introduces spurious serial correlation in the data.

II. Empirical Behavior of Exchange Rates

Nearly forty years ago, Friedman (1953) claimed that speculative forces in the market would stabilize exchange rates. 1/ Viner (1956) and others argued that this might not occur in practice. Indeed, the behavior of exchange rates since the move to a managed-floating regime rates has led to a consensus that the observed variability of exchange rates has generally been unexpected, as revealed by survey data on exchange rate expectations, and by market indicators of expected exchange rates. Three stylized facts have characterized their behavior: exchange rates are unconditionally leptokurtic (they have thicker tails in distribution when compared to the standard normal distribution); exchange rates display volatility clustering (periods of high volatility seem to precede and follow periods of high volatility); and, temporal aggregation reduces excess kurtosis (when looking at weekly and monthly exchange rate changes, the "thick-tailness" of the distribution is less prevalent).

As far back as the turn of the century, Bachelier (1900) noted that changes in asset prices were distributed approximately normal. In particular, he observed that the empirical probability density functions displayed excess weight on both tails (leptokurtosis) when compared with a gaussian density function. He nevertheless dismissed this observation as being insignificant. The leptokurtosis was overlooked by researchers until Mandelbrot (1963) argued that the tail thickness could not be dismissed as coming from a normal distribution. He proposed two explanations for this phenomenon. The first suggested that the distribution of changes in asset prices came from the paretan family of distributions. The second involved the introduction of conditionally heteroskedastic models. Fama (1965) disproved the paretan distribution theory by showing that aggregation of asset returns caused the leptokurtosis to disappear. Sampling from a stable paretan distribution would not have exhibited this phenomenon.

All three of the stylized facts are consistent with variability on an hour-to-hour, or day-to-day basis, i.e., with high frequency volatility persistence. The presence of information externalities in a speculative trading environment will cause the market dynamics to resolve themselves over an extended period of time. The exchange rate, when sampled at a high enough frequency, will display this adjustment over contiguous observations. Periods of high volatility will extend over more than one sample observation. As the sample frequency is lowered, the adjustment process will occur within the sample period itself (intra-period) and consequently will not be observed in the data. In exchange rate data, the volatility clustering and unconditional leptokurtosis are clearly observable in daily data. When sampled weekly and monthly, the data display only traces of either effect. This empirical observation provides a guideline in determining the duration of the persistence caused by the informational

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1/ However, Friedman also argued that exchange rates would be unstable if macroeconomic polices were unstable.

externality. In order to capture its effect, the frequency of the data will have to be daily or higher. Unfortunately, intra-daily exchange rates are difficult to obtain. 1/

III. Positive Feedback

It is commonly thought that rational speculators stabilize prices, buying when the price is "low" and selling when the price is "high" relative to estimates of an equilibrium price based on fundamentals. Any deviation from fundamental value drives profit maximizing investors to enter the market in a contrarian fashion, dampening the deviation and reversing its direction toward fundamentals. This type of dynamic process is known as a negative feedback mechanism.

The main theoretical contribution of this paper is to present an environment in which positive feedback speculation is present and sufficiently long-lived as to be observable. This type of behavior destabilizes the market mechanism as speculators buy when the price of the currency is high and thought to be moving even higher and sell when the price drops and is expected to fall further. The feedback movement in response to a deviation from equilibrium is in the same direction as the original deviation and causes magnification and persistence.

Many examples of positive feedback mechanisms are observed in financial markets. Stop-loss orders and the liquidation of the positions of investors who cannot meet their margin calls are two mechanisms in which market movements in one direction are reinforced by investor behavior. Technical analysis is another example of a positive feedback mechanism. Technical analysts do not attempt to anticipate trend changes in the market but focus on identifying and following the trend. 2/ Such trend chasing, based on extrapolative expectations of prices, creates positive feedback behavior. Frenkel and Froot (1988) surveyed exchange rate forecasting services and found that, during the mid-1980s, these services were advocating the purchase of the U.S. dollar. This was occurring in an environment in which the dollar was generally recognized as trading at a level well above its fundamental value. Ito (1990) looked at the yen/dollar expectations of forty-four major institutions for the period 1985-86. He found that market participants exhibited "wishful expectations." Japanese exporters, who would benefit from a yen depreciation, expected a larger-than-average yen depreciation, while Japanese importers expected a yen appreciation.

1/ Engle, et al. (1990) used opening and closing exchange rate fixes in an attempt to capture intraday volatility effects.

2/ See Balan (1989) for a thorough discussion of current technical methods used in foreign exchange trading.

In Section II, three stylized facts about exchange rate behavior were presented that are consistent with high frequency volatility persistence. The reaction of traders to financial news will be the source of the positive feedback mechanism. Unlike other studies which analyze the market dynamics in response to the news, this paper will investigate the effect of the arrival process of financial news. There will be two states of nature: one in which news flow freely to traders (the fundamentals trading state) and the second in which the information channels between the news source and the traders is congested (the positive feedback state). The switch from the first state to the information congestion state will cause speculators to switch from trading on fundamentals to engaging in trend chasing. It will be these periods of trend chasing that cause the volatility clustering and persistence.

The dynamics of trading behavior can be intuitively described as follows: imagine a foreign exchange market in which traders periodically update their information on fundamentals by calling upon foreign exchange specialists. One can think of traders as dealing in many currencies concurrently while the specialists focus only on one. Assume that the communication links between traders and specialists are initially uncongested. Traders base their bid-ask prices on both backward-looking volume and price patterns, as well as forward-looking estimates of inflation and return on assets.

Let us assume that a negative shock hits a given currency. Its exchange rate starts to fall and traders view this--correctly--as a divergence from fundamentals. Traders will treat a small divergence as a simple market fluctuation and will take advantage of the opportunity to purchase the currency at a discount. This will reverse the trend of the initial shock and bring the system back to fundamentals. A large initial shock will make traders suspect that there has been a change in the fundamental value of the currency. They will therefore attempt to access their source for information on fundamentals: the specialists. This will cause congestion in the informational channels between the traders and the specialists, as not all traders will be able to contact the specialist at once. A trader now has no other source of information on fundamentals other than the exchange rate quotes in the market, and the observed behavior of other traders. 1/ With the exchange rate falling and other traders selling their positions in the currency, the trader must decide whether to sell off now, or wait for an update on fundamentals after the information channels clear and risk losing even more money in the meantime.

Assume that traders are rewarded on their ability to make absolute profits and on their performance relative to the performance of other traders. Since their remuneration is tied to the relative performance

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1/ Such a situation may also prevail when market participants, including specialists, are themselves uncertain as to the changes in fundamentals or their impact on the equilibrium exchange rate.

versus other traders, those traders who are excluded from the information channels in periods of congestion will prefer to follow actions of the majority of other traders as a way for them to limit their relative exposure. The currency sell-off effect will be magnified by traders wanting to "get out of the market" before they find themselves with a serious losing position. As the informational channels clear up, traders will return to bid-ask pricing behavior based on correctly perceived fundamentals.

The model described above is an example of how a positive feedback loop develops. The congestion externality causes traders to be cut off from information on fundamentals, and creates magnification and persistence of exogenous shocks. The nonlinear nature of this externality drives the system and would seem to explain the excess volatility and persistence.

It is important to note that all traders in this stylized economy are treated as equal in their ability to analyze the financial information. This addresses one of the main objections to positive feedback trading: if these traders are dumb enough to buy when the price is high and to sell below fundamental value, how come they do not lose all their money and disappear? Treating traders as equals and not making one portion of them inherently dumber is consistent with long-lasting and recurring positive feedback periods. Since all traders are equal, the order in which they are able to access information will be based purely on chance. Different information congestion periods will have different ordering of trader access to specialists. As no trader is inherently at a disadvantage ex ante, none will be expected to earn below normal profits relative to others in the market. One can therefore justify all traders remaining in the market while still displaying positive feedback behavior.

IV. Econometric Methodology

Empirically, the Auto-Regressive Conditionally Heteroskedastic (ARCH) model, devised by Engle (1982) and further developed by Bollerslev (1986) accounts very well for the model specifications and stylized facts mentioned above. In this model, the variance of the error term at time t conditional on past information, is a nonlinear function of past residual terms (deviations from fundamentals). The squared deviation from fundamentals will serve as a proxy for the level of information congestion in our empirical analysis. It will be assumed that information congestion affects the conditional variance of the exchange rate while not affecting its unconditional mean.

The conditional one-step-ahead forecast variance of an ARCH model is allowed to vary, unlike standard linear regression models. Let y_t be a

discrete time stochastic process and let I_t be the information set available at time t. The ARCH (q) regression model is determined by:

$$y_t | I_{t-1} \sim N\ (z_t'\beta, h_t)$$

where

$$\varepsilon \equiv y - z_t'\beta,$$

$$h_t \equiv \alpha_o + \sum_{i=1} \alpha_i\ \varepsilon_{t-1} \text{ and } q>0$$

where z_t is the set of independent explanatory variables and β is a vector of coefficients. The conditional variance h_t is a sum of q past squared deviations from the mean $z_t'\beta$. The stability condition for this regression model is given by

$$\sum_{i=1}^{q} \alpha_i \leq 1$$

which corresponds to having the characteristic roots of the Taylor expansion of unconditional ε_t^2 lie outside the unit circle. The nonnegativity condition for this model corresponds to:

$$\alpha \geq 0 \qquad \text{for all } i=0\ldots q.$$

In parameterizing the ARCH regression, a value must be assigned to the variable q. Since the estimation will involve daily data and since the information congestion effect should, in theory, be fairly short-lived, the variable q will be assigned a value of one. 1/

An ARCH (1) model is imposed on the logarithmic growth of the exchange rate in order to account for the conditional heteroskedasticity. The choice of the logarithmic model enables us to abstract from magnitudes and focus on

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1/ Alternative specifications using other values of q were attempted. No other specification proved to be better across all currencies based on the Akaike Information Criterion (AIC) test statistic. The AIC is a statistic which tests alternative nested and non-nested hypotheses by comparing the maximized values of their corresponding likelihood functions.

changes. This makes the estimates of the coefficients transparent to the choice of currency. In addition, by taking logarithmic first differences, we solve any possible econometric complications arising from the presence of a unit root in the level of the exchange rate. 1/

Let s_t be the exchange rate at date t. Define x_t to equal the change in natural log of the exchange rate i.e.,

$$x_t = \text{LN}(s_t) - \text{LN}(s_{t-1}).$$

The ARCH (1) model is specified as follows:

$$\varepsilon_t \mid I_{t-1} \sim N\ (O, h_t),$$

$$h_t = \alpha_o + \sum_j \delta_j D_j + \alpha_1 \varepsilon^2_{t-1}$$

and

$$\{j\} = \{Mon, Tues, Wed, Thur\}\ .$$

The dummy variable D_j assumes a value of 1 if date t is day j, i.e., Monday, Tuesday.... A linear combination of the lags of x_t is introduced to account for any linearity in the exchange rate process. The choice of m is determined by Box-Jenkins analysis on the variable x_t.

The change in the exchange rate x_t is a linear combination of past changes having accounted for the trend and the day-of-week effect. The conditional variance of the residual ε_t is the sum of a constant term, the day-of-week effect and a weighted squared residual from the previous period. Large deviations from fundamentals will be reflected as large residuals. These residuals in turn will increase the conditional variance of the exchange rate in the following period. 2/ The day-of-week variables D_j were included to account for daily differences in market behavior. This

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1/ Many studies have shown, using autocorrelation studies and Dickey-Fuller tests, that there is strong evidence for unit roots in exchange rate levels. By not imposing a unit root when one is actually present, regression estimates will be biased downwards and will give the false impression of stationarity.

2/ The reason that the past deviations appear in the conditional heteroskedasticity specification in squared form is to make the volatility insensitive to the direction of the deviation from fundamentals. This is intuitively consistent with the positive feedback mechanism due to information congestion.

would be particularly relevant around weekends where an information congestion on Friday would have time to clear before the foreign exchange markets reopen on Monday.

The log-likelihood function for a sample of size T is given by:

$$L_T(\theta) = T^{-1}\sum l_t(\theta) \qquad \textit{where}$$

$$l_t(\theta) = -0.5\, LN(h_t) - 0.5\varepsilon_t^2 h_t^{-1} \qquad \textit{and}$$

$$\theta = (\alpha', \beta', \gamma', \delta').$$

The Berndt, Hall, Hall and Hausman (BHHH) [1974] iterative algorithm provides efficient estimates of the parameters, namely:

$$\theta^{(i+1)} = \theta^{(i)} + i^{-1}\Big[\sum_{t=1}^{T} \frac{\partial l(\theta^{(i)})}{\partial\theta} \frac{\partial l_t(\theta^{(i)})}{\partial\theta'}\Big]^{-1} \sum_{t=1}^{T} \frac{\partial l_t(\theta^{(i)})}{\partial\theta}$$

where i indexes the iteration. A convergence criterion for the parameters is chosen and the log-likelihood is maximized until the criterion is met for all parameters. Having gotten a consistent estimator of the parameter θ, an estimate of the conditional heteroskedasticity h_t can be reconstructed. The ARCH regression is corrected in the Generalized Least Squares manner and re-estimated.

V. Empirical Results

This paper uses daily exchange rate data of the U.S. dollar (US$) versus seven other currencies, four from the European Monetary System (EMS) and three from outside the EMS. These currencies are the deutsche mark (DM), the French franc (F), the Italian lira (LIT), the Netherlands guilder (NLG), the pound sterling (LSTG), 1/ the Swiss franc (SWF) and the Japanese yen (Y). The total number of daily observations is 2,510. The observations span the period from January 2, 1980 to December 31, 1989.

Table 1 presents summary statistics of the data set. It is important to note that the kurtosis of all the currencies is substantially larger than that coming from a standard normal distribution. Standard normal

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1/ The pound sterling had not yet participated in the exchange rate mechanism of the EMS during the period observed.

distributions have a kurtosis equal to three. Distributions with a kurtosis larger than three are leptokurtic in that they have more observations in the tails, away from the mean, when compared with a normal distribution.

The variables in Table 1 are log exchange rate changes expressed in percentage terms. The average daily change of the exchange rates relative to the U.S. dollar is -0.0004 percent for 1980-89. The largest change in magnitude was that of the yen which on average appreciated 0.0190 percent daily in this period. The most volatile currency was the Swiss franc whose standard deviation of the change was 0.8023 percent. The Swiss franc depreciated steadily against the U.S. dollar in the period 1980-85 and reversed that trend in 1985-89. The least volatile currencies in the 1980-89 period were the Italian lira and the Japanese yen with standard deviations of 0.6881 and 0.6592, respectively. All currencies with the exception of the pound sterling show a slightly negative skewness. This characterizes a distribution of exchange rate changes where large positive changes are outnumbered by negative ones of smaller magnitude. All seven currencies display leptokurtosis.

Tables 2A-2D present the ARCH regression results for the full 1980-89 sample and its five two-year subsamples. For all currencies and sample periods, the unrestricted model shown in Section IV was estimated. For a majority of the estimations, either the stability or the nonnegativity condition of the parameters did not hold. 1/ A restricted version of the model was successfully estimated. In the restricted model, the parameters β_i, γ_i, and δ_i were set to zero for all $i \neq 0$. 2/ Consequently, the restricted model that was estimated and is reported in Tables 2A-2D is:

$$x_t = \beta_o + \varepsilon_t$$

where

$$\varepsilon_t | I_{t-1} \sim N(O, h_t)$$

and

$$h_t = \alpha_o + \alpha_1 \varepsilon^2_{t-1}.$$

1/ The stability condition ensures that the estimated model has finite variance. The non-negativity condition prevents the possibility of obtaining a negative variance.

2/ Alternative specifications were attempted using only Monday as a day-of-week variable, omitting the lagged exchange rate variables and using a holiday variable in lieu of the day of the week. All proved unsuccessful in meeting the stability and non-negativity conditions.

Table 1. Summary Statistics of Log Price Changes, 1980-89

Currency	Mean	Standard deviation	Skewness	Kurtosis
Deutsche mark	-0.0011	0.7478	-0.5159	6.3332
French franc	0.0132	0.7448	-0.2012	8.5114
Italian lira	0.0168	0.6881	-0.3687	6.5170
Netherlands guilder	-0.0002	0.7398	-0.5390	6.4686
Pounds sterling	-0.0106	0.7263	0.2400	6.3443
Swiss franc	-0.0022	0.8023	-0.4617	5.5497
Japanese yen	-0.0190	0.6592	-0.4715	6.4434

Source: Treasurer's Department, International Monetary Fund.

Table 2A. ARCH Model Estimates 1/

Currency Coefficient	Period 1980-89	1980-81	1982-83	1984-85	1986-87	1988-89
Deutsche mark						
βo	0.00004	0.00064	0.00042	-0.00011	-0.00092	0.00019
	(0.277)	(1.897)	(1.592)	(0.289)	(2.839)	(0.632)
αo	0.00005	0.00005	0.00003	0.00006	0.00005	0.00004
	(25.35)	(10.76)	(12.45)	(10.57)	(11.04)	(12.56)
$\alpha 1$	0.14553	0.18120	0.11777	0.23038	0.09232	0.08830
	(4.945)	(2.357)	(1.650)	(2.789)	(1.383)	(1.724)
LL	4.40244	4.34105	4.56145	4.24922	4.41819	4.47096
LM	6.37611	4.11515	4.05618	6.15666	9.51634	4.30390
AIC	8.80409	8.67817	9.11897	8.48191	8.88324	8.93799
French franc						
βo	0.00017	0.00066	0.00090	-0.00009	-0.00081	0.00020
	(1.232)	(1.990)	(3.077)	(0.258)	(2.656)	(0.712)
αo	0.00004	0.00005	0.00003	0.00006	0.00004	0.00004
	(23.32)	(11.24)	(8.533)	(9.871)	(9.975)	(12.59)
$\alpha 1$	0.19219	0.16910	0.24785	0.26994	0.17345	0.09326
	(5.347)	(2.380)	(2.165)	(2.908)	(2.185)	(1.865)
LL	4.40703	4.36946	4.45794	4.26676	4.44316	4.50822
LM	5.41486	4.01838	5.02326	6.19324	15.9674	4.46678
AIC	8.81327	8.73499	8.91195	8.52959	8.88238	9.01250

1/ The values in parentheses are t-ratios. These are based on asymptotic standard errors evaluated using the Hessian matrix. The log-likelihoods (LL) at the final iteration estimates were evaluated. The Lagrange multiplier (LM) and Akaike Information Criterion (AIC) statistics were also computed.

Table 2B. ARCH Model Estimates 1/

Currency Coefficient	Period 1980-89	1980-81	1982-83	1984-85	1986-87	1988-89
Italian lira						
βo	0.00012	0.00075	0.00073	0.00020	-0.00073	0.00019
	(1.450)	(2.480)	(2.895)	(0.615)	(2.339)	(0.682)
αo	0.00004	0.00004	0.00003	0.00004	0.00005	0.00004
	(23.67)	(10.91)	(29.93)	(8.614)	(11.34)	(12.59)
$\alpha 1$	0.19135	0.16981	0.15200	0.42070	0.07376	0.09654
	(5.811)	(2.296)	(1.831)	(3.954)	(1.158)	(1.960)
LL	4.48884	4.46059	4.64400	4.35262	4.45052	4.56138
LM	8.34589	4.14051	5.22983	7.93029	9.45336	5.08283
AIC	8.97687	8.91725	9.28398	8.70131	8.89711	9.11883
Netherlands guilder						
βo	0.00005	0.00064	0.00054	-0.00011	-0.00094	0.00020
	(0.354)	(1.946)	(1.975)	(0.289)	(2.947)	(0.670)
αo	0.00005	0.00004	0.00003	0.00006	0.00005	0.00004
	(24.68)	(10.38)	(13.06)	(10.07)	(10.84)	(12.49)
$\alpha 1$	0.16328	0.21212	0.09695	0.26633	0.11254	0.08770
	(5.270)	(2.603)	(1.283)	(2.952)	(2.952)	(1.689)
LL	4.41441	4.37040	4.58487	4.24670	4.42415	4.47393
LM	5.69039	5.11616	5.00385	6.00552	10.5958	4.37862
AIC	8.82802	8.73688	9.16581	8.48947	8.84436	8.94393

1/ The values in parentheses are t-ratios. These are based on asymptotic standard errors evaluated using the Hessian matrix. The log-likelihoods (LL) at the final iteration estimates were evaluated. The Lagrange multiplier (LM) and Akaike Information Criterion (AIC) statistics were also computed.

Table 2C. ARCH Model Estimates 1/

Currency Coefficient	Period 1980-89	1980-81	1982-83	1984-85	1986-87	1988-89
Pound sterling						
βo	-0.00013	-0.00015	-0.00057	-0.00037	0.00057	-0.00034
	(0.944)	(0.486)	(2.392)	(0.994)	(1.951)	(1.147)
αo	0.00004	0.00004	0.00002	0.00005	0.00003	0.00004
	(23.67)	(10.23)	(11.55)	(9.759)	(11.88)	(11.57)
$\alpha 1$	0.26668	0.21698	0.18176	0.46626	0.13128	0.15416
	(8.424)	(2.862)	(2.175)	(5.234)	(2.406)	(2.526)
LL	4.44854	4.45462	4.65287	4.21211	4.50009	4.46400
LM	5.68497	5.76461	4.99535	4.23562	8.69120	4.57731
AIC	8.88963	8.90531	9.30181	8.42029	8.99614	8.92407
Swiss franc						
βo	0.00003	0.00037	0.00043	0.00013	-0.00106	0.00034
	(0.167)	(0.970)	(1.434)	(0.381)	(2.946)	(1.023)
αo	0.00006	0.00006	0.00004	0.00006	0.00006	0.00005
	(25.17)	(11.60)	(10.74)	(9.832)	(11.55)	(12.65)
$\alpha 1$	0.12457	0.15333	0.11290	0.33449	0.09367	0.09914
	(4.348)	(2.412)	(1.069)	(3.558)	(1.272)	(1.942)
LL	4.32787	4.24560	4.45073	4.25988	4.31621	4.37047
LM	4.84988	4.01220	4.02468	4.02582	4.54934	4.65191
AIC	8.65495	8.48727	8.89754	8.51583	8.86848	8.73702

1/ The values in parentheses are t-ratios. These are based on asymptotic standard errors evaluated using the Hessian matrix. The log-likelihoods (LL) at the final iteration estimates were evaluated. The Lagrange multiplier (LM) and Akaike Information Criterion (AIC) statistics were also computed.

Table 2D. ARCH Model Estimates 1/

Currency / Coefficient	Period					
	1980-89	1980-81	1982-83	1984-85	1986-87	1988-89
Japanese yen						
βo	-0.00017	-0.00011	0.00017	-0.00015	-0.00088	0.00021
	(1.334)	(0.359)	(0.571)	(0.472)	(2.906)	(0.717)
αo	0.00004	0.00004	0.00004	0.00003	0.00004	0.00004
	(27.12)	(13.87)	(11.86)	(41.74)	(10.85)	(11.04)
$\alpha 1$	0.09454	0.02068	0.09623	0.08613	0.13193	0.20950
	(3.742)	(0.583)	(1.723)	(1.279)	(1.861)	(2.876)
LL	4.51791	4.48966	4.49196	4.67131	4.45643	4.48553
LM	4.35672	7.00969	4.15247	4.69421	4.00769	4.73682
AIC	9.03502	8.97539	8.97999	9.33870	8.90893	8.96517
Japanese yen/ Deutsche mark						
βo				-0.00167		
				(0.709)		
αo				0.00002		
				(8.783)		
$\alpha 1$				0.36225		
				(4.299)		
LL				4.67818		
LM				18.7533		
AIC				9.35242		

1/ The values in parentheses are t-ratios. These are based on asymptotic standard errors evaluated using the Hessian matrix. The log-likelihoods (LL) at the final iteration estimates were evaluated. The Lagrange multiplier (LM) and Akaike Information Criterion (AIC) statistics were also computed.

The model formulated above is essentially a random walk with a constant term and with ARCH residuals. The constant term in returns is included to take into account a possible trend in the level. This is sensible when looking at currencies that have steadily depreciated against the dollar in the sample period such as the French franc and the Italian lira. Under the null hypothesis, daily exchange rate returns would follow a random walk with normally distributed residuals. Under the alternative, an ARCH structure on the residuals is imposed.

The specification test for first-order ARCH disturbances is based on the first-order autocorrelation of the squares of the residuals. This Lagrange multiplier (LM) test statistic for the presence of ARCH is asymptotically distributed $\chi^2(1)$ under the null hypothesis of no first-order ARCH effects. The critical values of the $\chi^2(1)$ distribution at the 5 and 1 percent levels are 3.841 and 6.635, respectively. The absence of first-order ARCH effects is rejected at the 5 percent level for all the currencies and sample periods. In a majority of cases, the null hypothesis is rejected at the 1 percent level. This would appear to be strong evidence in support of the ARCH specification.

Looking at the 1980-89 sample, none of the trend coefficients in the exchange rate change regressions are significantly different from zero. This applies to all seven currencies and is consistent with the unit-root hypothesis for exchange rates. On the other hand, all of the conditional heteroskedasticity coefficients are significant at the 5 percent level. The values for the parameter α_0 range from 0.00004 to 0.00006 across currencies. It is important to remember that these are variance estimates and that one needs to take square roots to get the standard errors of the regression. The parameter α_1 represents the relative contribution of the previous period's squared deviation from fundamentals to the conditional variance in the current period. This parameter serves as a proxy for the persistence due to the information congestion externality. The parameter values range from 0.09454 for the Japanese yen to 0.26668 for the pound sterling. In the case of the yen, this means that about 10 percent of one day's deviation from fundamentals is carried over into the following day. For the pound sterling, over one quarter of a day's deviation from fundamentals is carried over to the following day's volatility. For the decade of the 1980s, the yen has displayed the lowest persistence in volatility while sterling has had the highest.

In order to account for institutional and behavioral differences across time, the ten-year sample period was divided into five two-year periods and the ARCH model was re-estimated for all the currencies. In practically all the regressions, the estimates of the trend term β_0 are not significantly different from zero. The notable exception is the 1986-87 period. All of the trend estimates for this period are large, significant, and show an

appreciation of the currencies with respect to the U.S. dollar. 1/ One explanation of this phenomenon is the Group of Five meeting in September 1985. At this meeting, the central banks of the countries agreed to intervene in the financial markets and cause the U.S. dollar to depreciate. Through repeated monetary interventions, the U.S. dollar depreciated with respect to the other major currencies in the years 1986-87.

For all the two-year samples and currencies, the estimates of the α_0 parameters range from 0.00003 to 0.00005. They are all significant at the 5 percent level. The estimates of the persistence parameter α_1 span a much wider range of values. Chart 1 provides a graphical representation of the estimates. In the case of the EMS currencies, the persistence parameter has decreased from an average of 0.18306 to 0.09145, approximately 50 percent, between 1980-81 and 1989-90. For the same period, the non-EMS currencies display an average increase in the parameter α_1 from 0.13033 to 0.15427. The slight decreases in persistence of the pound sterling and Swiss franc are overshadowed by the tenfold increase in the case of the Japanese yen. All currencies, except the yen, show a marked increase in persistence in 1984-85 compared to all other sample periods. The pound sterling has the highest parameter estimate for that period, 0.46626, followed by the Italian lire with 0.42070. The 1984-85 coefficient estimate of α_1 for the Japanese yen actually decreases slightly to 0.08613 compared with the estimate for 1982-83. Nevertheless, the Japanese yen is the only currency of those investigated which displays a clear upward trend in persistence for the 1980s.

As discussed earlier, the existence of volatility persistence in exchange rates is based on externalities due to information congestion. In particular, uncertainty about fundamentals because of mixed signals and unexpected measures in monetary and fiscal policy could create an environment which could trigger the positive feedback mechanism and cause day-to-day volatility persistence. Several of the persistence estimates described above and presented in Chart 1 are consistent with such uncertainty about fundamentals. Comparing 1980-81 and 1982-83, the persistence parameter for the French franc rises from 0.16910 to 0.24785. This is in contrast to the three other EMS currencies where the parameter estimates fall. The French franc experienced three devaluations within the EMS system in the period 1982-83: the first was 3.0 percent on October 5, 1981 (fifth EMS realignment), the second was 5.75 percent on March 21, 1983 (sixth EMS realignment), and the third was 2.0 percent on July 22, 1983 (seventh EMS realignment). 2/ The uncompounded sum of the two devaluations amounts to 11.75 percent which, for the three realignments, amounted to the largest devaluation across all EMS currencies. Following

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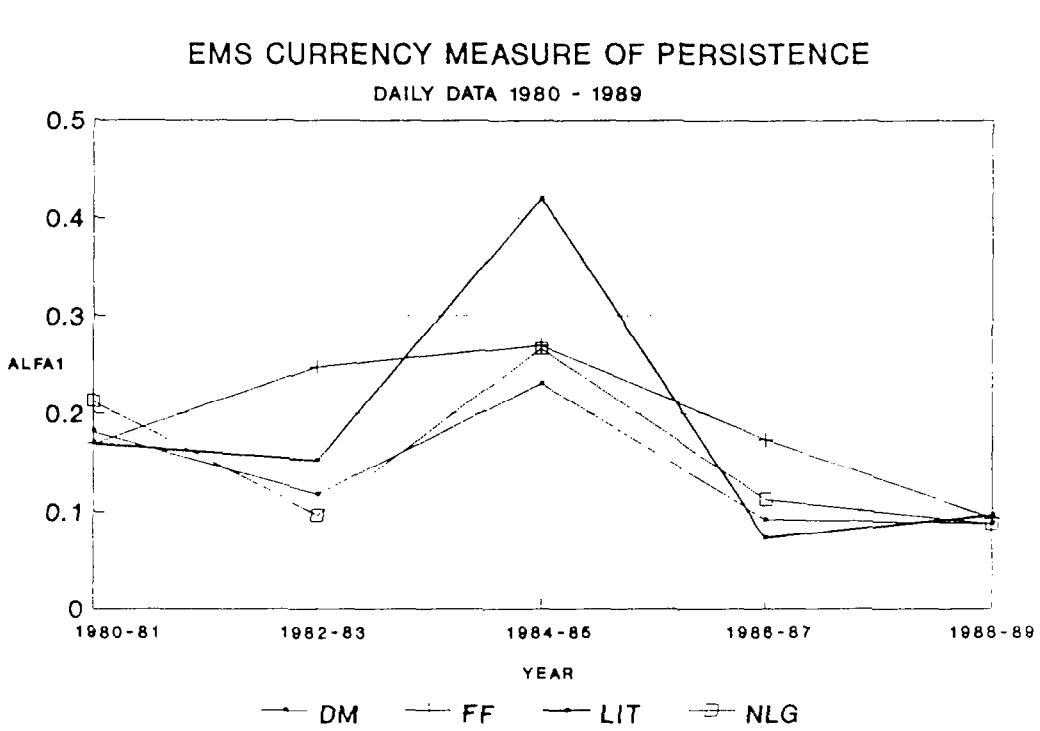
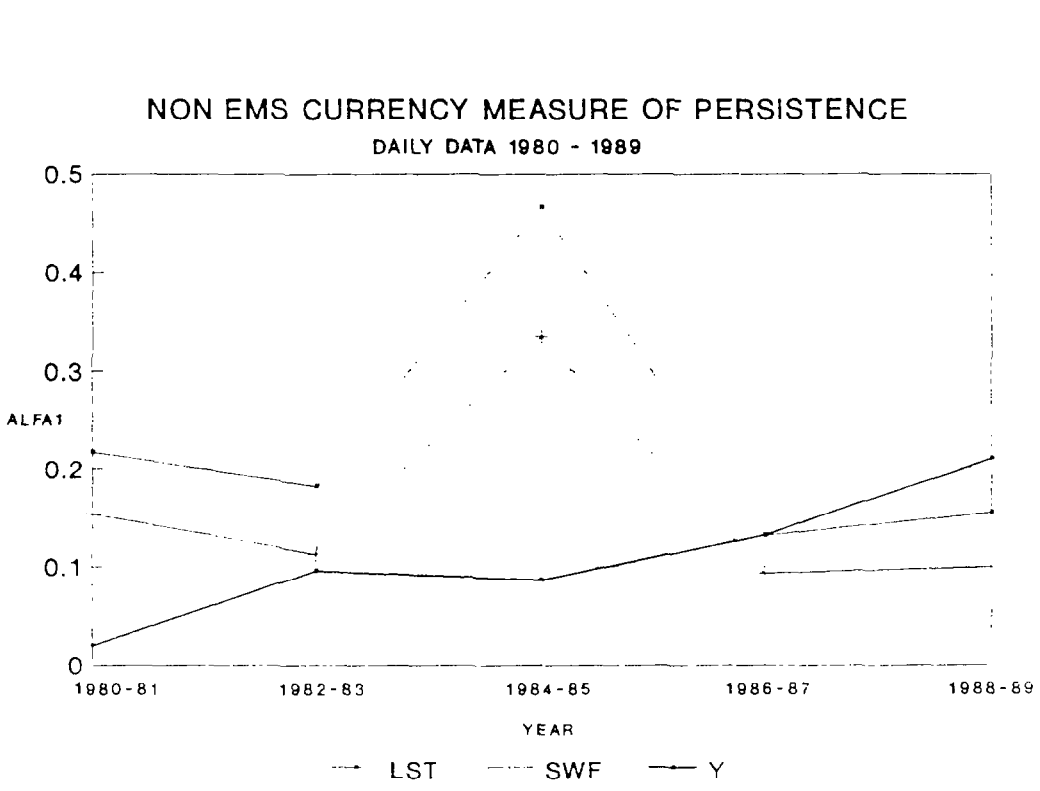
1/ In the case of the pound sterling, the exchange rate is expressed as U.S. dollar per pound sterling. Consequently, a positive trend in the exchange rate change corresponds to a depreciation of the U.S. dollar.

2/ See Ungerer, et al. (1983) and Ungerer, et al. (1986) for a description of EMS developments.

Chart 1. EMS and Non-EMS Currency Persistence





the election of a new administration in 1981, there was much uncertainty about the monetary and fiscal regimes in France. It was only in the second half of 1983 that the French Administration imposed strong fiscal and monetary measures and thus clarified its position in support of the French franc.

Perhaps the most striking observation stemming from Chart 1 is the large increase in volatility persistence in 1984-85 when compared to the remainder of the decade. The increase applies to six of the seven currencies investigated, the notable exception being the Japanese yen. As Krugman (1985, 1989) has shown, appreciation of the dollar in 1984-85 cannot have been based on fundamentals alone, even though some appreciation of the dollar could have been expected on the basis of the configuration of monetary and fiscal policies in the United States, on the one hand, and in Japan, Germany, and the United Kingdom on the other. Krugman's analysis starts with the observation that the "market" must have expected a subsequent depreciation of the dollar at a rate no greater than the interest differential between comparable assets denominated in dollars, Japanese yen, and the deutsche mark. On generous assumptions about the impact of such expected depreciation on trade flows, Krugman shows that U.S. external debt would have grown explosively, i.e., unsustainably. This simple calculation suggests that market participants were not paying adequate attention to the underlying fundamentals, but rather were following their own lead in a bubble, until it burst in early 1985.

The "1984-85 dollar effect" on persistence in volatility was tested by estimating an ARCH model for the Japanese yen/deutsche mark exchange rate over the same two-year sample period. The coefficient estimates are presented in Table 2d. The presence of ARCH effects is strongly supported by an LM statistic of 18.7533. The coefficient for the volatility persistence is 0.36225 and it is statistically significant. This parameter value is significantly larger than those presented in Chart 1 for non-1984-85 sample periods. This result suggests that while the "dollar effect" may be useful in explaining persistence in 1984-85, the issue is not fully settled.

The only currency whose persistence has steadily increased in the 1980s is the Japanese yen. This result is rather surprising in view of the evidence of closer coordination of exchange rate intervention at the end of the decade. As Dominguez (1990) suggests, however, one possible cause of the increase in volatility is the adoption of non-sterilized U.S. dollar interventions by the Bank of Japan since 1986. The unannounced and unsterilized moves by the Bank of Japan might have regularly caught most traders by surprise, and the ensuing information congestion might have led to the estimated persistence of volatility.

VI. Concluding Remarks

This paper has examined the persistence in the volatility of exchange rates. It is assumed that market participants experience information congestion in periods where there is a large deviation from fundamentals or uncertainty about them. Speculators then adopt positive feedback trading strategies in which exogenous shocks are magnified and turned into persistent fluctuations.

An ARCH regression model of persistence was estimated for seven currencies and six sample periods. Various estimates of persistence were obtained, all of which are statistically significant. These estimates are consistent with significant uncertainty levels in the fundamental value of foreign currencies. These results suggest that greater availability to the public of information regarding the policy intentions of monetary authorities would foster more orderly conditions in exchange markets. However, there would seem to be a natural limit to the ability of markets to "iron out" uncertainties associated with essentially exogenous or unpredictable events, e.g., natural disasters or political events, that may affect exchange rates.

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