THE EFFICIENCY OF THE MARKET FOR FOREIGN EXCHANGE UNDER FLOATING EXCHANGE RATES

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I. Introduction

DURING our two and a half year experience with floating exchange rates, it has frequently been asserted that various national currencies have become under- or overvalued, presumably due to "speculative runs" or intervention by central banks. Such systematic deviations of a currency from the equilibrium exchange rate is, of course, inconsistent with the notion of an efficient market (see Fama, 1970). If a rational speculator saw a currency priced above or below its equilibrium level, he would sell or purchase it with a view to realizing a profit by subsequent repurchase or sale at the correct value. Enough such speculators would prevent exchange rates from departing very far from equilibrium levels. Thus, as has been discussed extensively with respect to securities markets, observed exchange rates would fluctuate randomly about equilibrium levels and all extraordinary profit potential from exchange trading would be eliminated. The purpose of this article is to explore whether the exchange markets have been efficient (in the weak form) under the floating rate regime beginning in March 1973.

Recent experience with floating exchange rates has heightened interest in the issue of the efficiency of currency markets. For example, in mid-1973, the dollar was widely believed to be undervalued. In describing the situation of the dollar in July 1973, Katz states:

> This experience suggests that the dollar had been 'oversold' in the exchange market by early July and underscores the important absence of equilibrating private speculation in circumstances in which it might realistically have been expected. (1975, p. 37)

The Federal Reserve Bank of New York began to intervene in the exchange markets on July 10, 1973 to correct the presumed undervaluation of the dollar. Such official intervention has been frequent during the last two years.

On the other hand, the Franklin National Bank and Bankhaus Herstatt failures of 1974 provoked the fear that speculative "bandwagon" effects in currency markets produce short-term stampedes of speculators, primarily banks, in thin markets. In a frantic effort to make quick profits, these speculators, it is said, destabilize exchange markets. The fall in an exchange rate, for example, leads other market participants to dump the currency, hoping to profit by covering their positions at the market bottom. Market psychology, rather than informed opinion on true economic values, determines short-run movements in exchange rates, according to this rendering.

The presumed market inefficiency has led to official policy favoring regular intervention in the exchange markets. In the "Declaration of Rambouillet" of November 17, 1975, the heads of six leading industrial nations were led to state:

> At the same time, our monetary authorities will act to encounter disorderly market conditions, or erratic fluctuations, in exchange rates.

The purpose of the proposed intervention was to lower the cost of unnecessary exchange rate fluctuations to the world economy. If the market is efficient, intervention may retard the market's adjustment to new equilibrium levels of exchange rates. Such a policy is desirable only if the costs of intervention are outweighed by the benefits of more stable rates (Pippenger, 1973, p. 323).

R. I. McKinnon has argued theoretically that speculative capital is insufficient to provide efficiency in the exchange markets. He says:

> The contrary hypothesis, advanced here, is that the supply of private capital for taking net positions in either the forward or spot markets is currently inadequate.... Bandwagon psy-

Received for publication June 14, 1976. Revision accepted for publication October 19, 1976.

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We acknowledge the assistance of Robert Ritchey in making the computations, and the helpful comments of the members of the University of Arizona Finance Faculty Seminar.

> chologies result from the general unwillingness of participants to take net positions against near-term market movements. (1974, p. 6)

McKinnon's argument rests on the observed caution of most banks and multinational corporations in their foreign exchange dealings and the difficulties facing other potential currency speculators in the form of minimum contracts. McKinnon believes recent events have tended to exaggerate the speculative role of banks and multinational corporations, thus hiding the fact that there is an insufficient supply of speculative capital.

Empirical evidence supporting the hypothesis of inefficiency in exchange markets has been provided by William Poole (1967). Poole examined the data for nine currencies during the flexible exchange rate period following World War I and for Canada from 1950 to 1962. Poole found significant statistical relationships between daily rates of return on spot contracts, instead of the randomness associated with an efficient market (see below). Furthermore, Poole found that large profits were potentially realizable from the use of simple trading rules. On the other hand, Pippenger (1973) found little support for the hypothesis of market inefficiency in the 1920s for four currencies he studied. Pippenger did find that exchange stabilization funds tended to reduce short-term variability in two cases, including Canada in the 1952–1956 period. Giddy and Dufey (1976) likewise found no evidence for inefficiency in the market for foreign exchange in the 1920s and early 1970s for three currencies.[1]

In this article, we investigate the issue of market efficiency in the exchange markets in the period beginning with March 1973 and running through September 1975. The study will focus on the spot markets for the Canadian dollar, the Swiss franc, the Dutch guilder, the German mark, the British pound, and the Japanese yen. Daily closing bid prices for spot and forward contracts were obtained from the International Money Market (IMM).[2]

Tests of market efficiency based on the autocorrelation function of rates of return on currency positions, which we find favor the hypothesis of efficiency in exchange markets, are reported and contrasted to Poole's results in section II. Section III describes the results of applying a variety of mechanical trading rules to historical currency prices. Section IV discusses some properties of the distribution of one-day rates of return for the currencies studied, and indicates that currency prices appear to be distributed in the same way as stock and commodity prices are thought to be distributed. Our conclusions, from the viewpoints of speculators in currency markets and official policy makers, are drawn in the final section.

II. The Autocorrelation Function

The estimated autocorrelation function for one-day rates of return on spot exchange contracts for the six currencies analyzed were calculated for one- through eight-day lags. These results are presented in table 1 on line (1) for each currency. None of the estimated autocorrelation coefficients shown are as large in absolute value as 0.10, and most are substantially smaller than that. While a slight majority of the estimated coefficients (28 out of a possible 48) are positive, only 4 estimates are statistically significant (positive or negative) at the 95% confidence level. This evidence supports the conclusion that the autocorrelations are small or zero, and provide little guidance for a profitable trading strategy.

Previous autocorrelation tests of exchange market efficiency were based on the hypothesis of a random walk in one-day rates of return on currency contracts. Fama has shown (1970, p. 391) that the efficient market hypothesis implies that trading in speculative commodities is a fair game, but does not imply that one period rates of return follow a random walk. Fama states, "In the 'fair game' efficient markets model, the deviation of the return for

[1] Poole analyzed nine currencies from the period 1919 to 1924 through 1928, namely, the currencies for Argentina, Belgium, Canada, France, Italy, Japan, Norway, Sweden, and the United Kingdom, and the Canadian dollar from 1950 to 1962. Pippenger analyzed the currencies for Norway, Spain, France and the United Kingdom in the 1920s, and Canada in the 1950s. Giddy and Dufey examined the currencies for Canada, France, and the United Kingdom in the 1920s and from 1970, 1973 and 1972 to 1974, respectively, for the three currencies (unfortunately, the later period is not homogeneous with respect to floating). Since writing this article, we have become aware of a paper by Dooley and Shafer (1976) covering the same period we analyze.

[2] These exchange rates are closing bids of Continental Illinois National Bank of Chicago on the day indicated.

TABLE 1.—AUTOCORRELATION COEFFICIENTS

Currency Return		Lag Period 1	2	3	4	5	6	7	8
British pound	(1)	.0039	−.0358	.0278	.0010	.0623	.0123	−.0015	−.0151
	N	582	572	571	571	575	577	571	566
	S	.462	.197	.254	.490	.068	.384	.486	.360
British pound	(2)	.0069	−.0302	.0219	.0040	.0721	.0140	.0062	−.0180
	N	559	548	545	544	547	549	541	536
	S	.435	.240	.305	.463	.046	.372	.442	.339
Canadian dollar	(1)	.0699	−.0176	.0296	.0382	.0843[a]	−.0304	.0308	.0040
	N	575	565	563	563	566	566	560	555
	S	.047	.338	.242	.183	.022	.236	.233	.462
Canadian dollar	(2)	.0691	−.0144	.0315	.0329	.0927[a]	−.0176	.0345	−.0009
	N	548	537	531	534	536	536	527	523
	S	.053	.370	.234	.224	.016	.343	.215	.492
Dutch guilder	(1)	−.0069	−.0684	.0444	.0376	−.0042	.0378	.0420	.0313
	N	579	575	573	572	571	570	569	568
	S	.434	.051	.144	.185	.460	.184	.159	.228
Dutch guilder	(2)	.0456	−.0677	.0468	.0588	.0441	.0793	.0469	.0641
	N	517	512	509	506	503	503	501	497
	S	.150	.063	.146	.093	.162	.038	.147	.077
German mark	(1)	.0025	−.0895[a]	.0800	.0373	−.0294	.0555	.0957[a]	−.0203
	N	593	589	587	586	585	584	583	582
	S	.476	.015	.026	.184	.239	.090	.010	.313
German mark	(2)	.0076	−.1034[a]	.0316	.0501	.0016	.0469	.0938[a]	−.0174
	N	555	550	548	546	544	541	541	540
	S	.429	.008	.230	.121	.485	.015	.015	.343
Japanese yen	(1)	.0230	−.0158	.0098	.0387	.0052	.0206	−.0197	−.0031
	N	593	589	588	587	586	585	584	583
	S	.288	.351	.406	.175	.450	.310	.317	.470
Japanese yen	(2)	.0281	.0083	.0314	.0436	.0215	.0475	−.0362	.0131
	N	569	564	562	560	558	556	555	554
	S	.252	.422	.229	.151	.306	.132	.197	.379
Swiss franc	(1)	−.0247	−.0765	−.0003	−.0216	−.0184	.0395	.0997[a]	−.0201
	N	593	589	588	587	586	585	584	583
	S	.274	.032	.497	.300	.329	.170	.008	.314
Swiss franc	(2)	−.0190	−.0834	−.0496	−.0221	.0085	.0395	.0957[a]	−.0195
	N	551	546	545	542	541	541	537	535
	S	.328	.026	.124	.304	.422	.179	.013	.326

Note: N is number of observations. S is significance level.
[a] Significantly non-zero at 5% level (using two-tailed test).

$t+1$ from its conditional expectation is a 'fair game' variable, but the conditional expectation itself can depend on the return observed for t" (p. 392).

More specifically, the fair game model of an efficient market says that the sample covariance, c_j, defined as

$$\hat{c}_j = \sum_{t=1}^{t=n} \left[r_t - E(r_t \mid \Phi_{t-1}) \right] \times \left[r_{t-j} - E(r_{t-j} \mid \Phi_{t-j-1}) \right]$$

where r_t is the daily rate of return from holding foreign exchange, Φ_t is the vector of all information available at time t, and E is the expectations operator, should not be significantly different from zero. The autocorrelation coefficients, ρ_j, on the other hand, are defined by

$$\hat{\rho}_j \equiv \sum_{t=j}^{n} (r_t - \bar{r})(r_{t-j} - \bar{r}) \Big/ \left\{ \left[\sum_{t=j}^{n} (r_t - \bar{r})^2 \right] \times \left[\sum_{t=j}^{n} (r_{t-j} - \bar{r})^2 \right] \right\}^{1/2}$$

where $\bar{r}$ is just the sample mean of r_t.

Comparison of the expressions for $\hat{c}_j$ and $\hat{\rho}_j$ demonstrates that it is possible for $\hat{\rho}_j$ to be significantly different from zero when $\hat{c}_j$ is not if there is sufficient variation over time in $E(r_t \mid \Phi_{t-1})$. For this reason the autocorrelation function may be an inappropriate indicator of market efficiency. A better test involves finding a measurable proxy for $E(r_t \mid \Phi_{t-1})$.

Expectations concerning the rate of currency appreciation, that is, the expected rate of return on a spot exchange contract, are reflected in the premium on forward exchange contracts and can thus be used as a proxy for $E(r_t \mid \Phi_{t-1})$.[3] Expected rates of daily currency appreciation were calculated using premiums of 30- and 90-day forward exchange contracts. The deviations of 1-day rates of return from these estimates of expected rates of currency appreciation were calculated and the coefficient $\hat{\rho}_j$ was estimated for values of j from one to eight. The results using 30-day contracts are reported in table 1 on line (2) for each currency. There is no substantial change from the results presented on line (1).[4]

The results reported in table 1 are in marked contrast to Poole's (1967) results concerning the autocorrelation function. Whereas Poole (1967, table II, p. 470) found strong evidence of first-order autocorrelation in the ten currency series he analyzed, we found none of the first-order autocorrelation estimates to be significantly nonzero. Furthermore, nine of Poole's estimated first-order autocorrelation coefficients are larger than 0.05 in absolute value, and three are larger than 0.10, while the largest estimate we obtain is 0.0699 (for the Canadian dollar), and the other five are all less than 0.05 in absolute value.

The higher order autocorrelation coefficients we estimated reflect no reliable pattern of time dependency. The four coefficients statistically significant at the 95% confidence level are all less than 0.10. One significant estimate (for the Canadian dollar) is for a five-day lag, one for a two-day lag (German mark), and two for a seven-trading-day lag (German mark and Swiss franc). There does not appear to be any reason to attribute these significant estimates to anything but sampling errors.

An overall test for a flat autocorrelation function can be carried out using the Q-statistic. Under the hypothesis that all autocorrelations are zero,

$$Q = N \sum_{j=1}^{8} \hat{\rho}_j^2,$$

where

N = the number of observations

$\hat{\rho}_j$ = the estimated autocorrelation of lag j,

will be distributed as χ^2 with eight degrees of freedom. The calculated values of Q for our six currencies are given in table 2. Only for the case of the German mark can the hypothesis of a flat autocorrelation function be rejected at the 5% level, and then only by a narrow margin. Thus we find little reason to reject the hypothesis that daily rates of return on foreign exchange contracts are uncorrelated over the period we analyze.[5]

A runs test, the results of which are also reported in table 2, tends to support the hypothesis of efficiency. Of the six currencies, only one, the Canadian dollar, was significantly

[3] Solnik (1974, p. 519) shows that, under certain circumstances, the forward premium is a biased estimator of the rate of appreciation, where the bias represents a "hedging pressure" term. We assume that this term is relatively stable over the period analyzed.

[4] Fama (1970, p. 392) likewise found no significant changes in the autocorrelation function for stock prices, although his adjustment for expectations consisted simply of calculating the departure from the mean rate of return.

[5] Dooley and Shafer (1976) used the same observation period but employed data from the New York Federal Reserve Bank. They estimated the autocorrelation function out to 20 days and calculated the Q-statistic. While their results indicate more evidence of autocorrelation, a caveat should be added. If daily rates of return are non-normal, a situation we later confirm, the Q-statistic will no longer be distributed as χ^2; in this case the estimated value of Q will tend to have larger values than a χ^2 variate.

TABLE 2.—Q-TEST AND RUNS TEST RESULTS

	Q-Test		Runs Test	
Currency	Q-statistics	Observations	Observed Runs	Expected Runs (from random series)
British pound	3.58	592	281	297
Canadian dollar	9.17	585	261[a]	294
Dutch guilder	6.99	583	291	292
German mark	17.01[a]	597	296	299
Japanese yen	1.88	597	270	299
Swiss franc	9.88	597	298	299

Note: All tests based on results reported on line (1) of table 1.
[a] Significantly different from expected value at the 5% level.

non-random at the 5% level. For the Swiss franc, Dutch guilder and German mark the observed number of runs was essentially equal to the number expected from a random series.

In summary, there is very little evidence from our estimated autocorrelation functions of any departure from a fair game in the exchange market, implying that (by these tests) the market is efficient. The lack of any significant autocorrelation implies, further, that rates of return on spot exchange contracts have had no regular time dependency. Box and Jenkins (1970, p. 44) show that the autocorrelation function is a transform of the spectrum, hence insignificance of one implies insignificance of the other. Since we find no reason to expect significant autocorrelation with longer lags than we estimated, we conclude that there was no predictable relationship between time and exchange rate movements over the period studied that was not already impounded in market prices.

III. Trading Rule Profits

The existence of a flat autocorrelation function and insignificant runs tests does not, of course, prove that the foreign exchange market is efficient. If the stochastic process generating daily exchange rates is non-stationary, the autocorrelation function may fail to detect the underlying pattern. Accordingly, numerous technical trading rules have been devised in an attempt to uncover dependencies that are not strict functions of calendar time. Two of the most commonly used techniques are filter rules and moving average rules.

The filter rules, first employed by Alexander (1961), can be used to test for possible bandwagon effects. The rule, in the context of the foreign exchange market, states: When a given currency appreciates $x\%$ from a previous low, switch funds into that currency; when the currency then depreciates $y\%$ from a previous high move funds back into dollars. The rule, quite clearly, is designed to help the investor "move with the momentum of the market."

Moving average rules can be designed to have the same effect. A moving average of a specified length is calculated; when the exchange rate moves $x\%$ above the moving average, the investor moves into the foreign currency; when it falls $y\%$ below the moving average, the investor moves back into dollars.

In using these rules to test for market efficiency we take the viewpoint of an American speculator who calculates his profits in U.S. dollars. Each of the six foreign currencies is considered separately. For each currency the speculator has a choice between holding that currency and holding U.S. dollars. The situation is exactly analogous to the problem an investor faces in determining when to hold cash and when to invest in equities. The filter and moving average rules are used to provide signals for switching from dollars to foreign exchange and back. In applying the rules we assume that all transactions are made in the spot market—hence there are no short sales or margined positions. To reduce the number of permutations, buy and sell filters (x and y above) were set equal in all cases. These buy and sell limits range from 0.1% to 5% for the Alexander filter rule and from 0.1% to 2% for the moving average rule. Moving averages of 10, 25 and 50 days were used.

In applying the filter rules, we assume that no interest is earned on any of the funds. An approximation of the interest earned can be added in at the end by multiplying the average interest rate in each currency by the fraction of time the investor was in that currency. The difficult problem, which we shall discuss later, is deciding which interest rates are appropriate to use for the case at hand.

The results from application of the rules are reported in tables 3 and 4. As the tables show, none of the rules led to annual profits of over 4% in the case of the British pound, Canadian dollar, or Japanese yen. These results provide no evidence for the existence of bandwagon effects or other market inefficiencies for these currencies.

For the German mark, Dutch guilder, and Swiss franc, on the other hand, the situation was quite different. The maximum profits reported in table 4 are by no means unique; the 25-day moving average rule consistently produced profits of more than 15% per annum for all three currencies and for filters ranging from 0.2% to 2%. Because of the numerous transactions generated, use of the Alexander rule and the ten-day moving average rule produced smaller profits. Even so, profits exceeding 10% were typical. Profits were also smaller for the 50-day moving average rule. Apparently the bandwagon effects were not long-lived enough to be uncovered by a 50-day rule.

Poole (1967) also applied Alexander's filter rule to the ten currency series he studied. Poole's results (shown in his table IV, p. 473) indicate the possibility of large gross returns (up to 52% annually), and half of the ten series he analyzed showed gross returns over 10%. Our estimated rates of profits using the Alexander trading rule, both before and after transactions costs, are substantially smaller than Poole's estimates. However, Poole did not adjust for transactions costs and assumed that the speculator could take a short position (borrow) in spot currency, increasing the speculator's leverage.

Interpretation of both Poole's results and ours is difficult, because there is no complete distribution theory applicable to trading rule profits. However, Praetz (1976) has derived an approximate distribution of trading rule returns under the assumption that daily rates of return are normally and independently distributed with constant mean and variance. While his assumptions are strong and, as evidence reported later documents, do not strictly characterize our sample, applying Praetz's test shows that the returns reported on the mark, franc and guilder are significantly greater (at the 1% level) than the returns provided by a buy and hold strategy.[6]

One explanation for the higher returns on the franc, mark and guilder positions is that the high returns are compensation for risk. The three currencies showing the highest rates of return also had the largest variance in daily rates of return.[7] On the other hand, modern

[6] The Praetz test amounts to dividing the difference between the daily return provided by the trading rule and the daily return from buy and hold by the standard deviation of the mean daily return (which is the standard deviation of the daily return divided by N where N is the sample size). For large samples this ratio will be approximately normal. For the mark, franc and guilder the ratios are 12, 7 and 10 for the profits reported in table 3, and 13, 9 and 11 for the profits reported in table 4.

[7] The standard deviations of the daily rates of return are as follows: British pound: 0.0004269; Canadian dollar: 0.00014632; German mark: 0.00074226; Dutch guilder: 0.00068893; Japanese yen: 0.0004316; Swiss franc: 0.00084476.

TABLE 3.—ALEXANDER FILTER RULE: RATES OF RETURN

	Highest Annual Rate of Return (per cent)			
Currency	Gross Return	Return Net of Transaction Costs	Filter Size	Annual Rate of Return from Buy and Hold
British pound	2.3	1.9	2	−6.4
Canadian dollar	1.6	1.4	1	−1.4
Dutch guilder	14.3	13.	1	4.8
German mark	15.9	15.7	4	4.3
Japanese yen	3.0	2.5	1.5	−4.6
Swiss franc	10.6	10.2	4	8.3

Note: Filters used were 0.1%, 0.2%, 0.3%, 0.4%, 0.5%, 0.75%, 0.8%, 1%, 1.5%, 2%, 3%, 4%, 5%. Transactions costs were calculated by using the average bid-ask spread for all trades. The existence of these costs substantially reduced profits when using the smaller filters. Complete results are available from the authors.

TABLE 4.—MOVING AVERAGE RULES: RATES OF RETURN

	Highest Annual Rate of Return (per cent)				
Currency	Gross Return	Return Net of Transaction Costs	Filter Size	Length of Moving Average	Annual Rate of Return from Buy and Hold
British pound	4.5	4.0	0.4	25	−6.4
Canadian dollar	1.3	1.0	0.5	25	−1.4
Dutch guilder	16.3	15.7	0.4	25	4.8
German mark	18.6	17.9	0.2	25	4.3
Japanese yen	2.3	2.0	0.3	25	−4.6
Swiss franc	17.0	16.5	1.0	25	8.3

Note: Filters used were 0.1%, 0.2%, 0.3%, 0.4%, 0.5%, 0.75%, 0.8%, 1%, 2% and moving averages were 10, 25 and 50 days. The moving average rules generated substantially fewer transactions than the Alexander rule and hence maximum profits occurred at finer filters.

portfolio theory indicates that only undiversifiable risk must be compensated for via higher expected rates of return (Sharpe 1970). The market risks of foreign exchange holdings are best measured relative to the world market portfolio. Because we lack data on this portfolio, we use the Standard and Poor's 500 index as a surrogate.[8] Holdings of foreign exchange can be viewed as a marginal addition to a portfolio of U.S. securities, where the exchange is treated as common stock. Our estimated risk measures (betas) are given in table 5.

TABLE 5.—FOREIGN EXCHANGE BETAS

Currency	Beta	t-statistic
British pound	0.03	0.85
Canadian dollar	−0.003	0.22
Dutch guilder	0.12	2.18
German mark	0.11	1.85
Japanese yen	0.08	1.71
Swiss franc	0.05	0.72

Note: All betas are calculated by treating investment in a foreign currency precisely as one would treat investment in a common stock.

There appears to be little, if any, systematic relationship between the excess returns on the market portfolio and on foreign exchange. None of the estimated risk measures exceeded 0.012, and only the risk measure for the Dutch guilder was statistically significant. These risk estimates do not support the argument that the high returns associated with the three currencies are compensation for market risk.

The fact that holding foreign exchange involves no systematic risk for the speculator implies that the excess return on exchange holdings should be zero. If we assume that the Euromarket rate of interest can be earned on whatever currency the investor is holding, the profits reported on marks, francs and guilders are excess returns and constitute evidence against the efficient market hypothesis. The problem with such an interpretation is that it may be inconsistent with application of the trading rules. To implement the rules, an investor must be able to transfer his funds at a moment's notice. If he were holding certificates of deposit or money market securities this would involve added transaction costs. If the investor places his funds in Eurocurrency deposits, he must limit his investment to overnight deposits. The use of overnight deposits, however, means that the investor's funds are not continually invested and that he cannot take advantage of the higher rates on longer term deposits. As a result, the interest rate earned is likely to be several percentage points below the three-month deposit rate that could be earned if the trading rules were not employed. It is reasonable, therefore, to adjust the profit figures downward by as much as three percentage points before interpreting them as excess returns. Making such an adjustment, however, does not eliminate the profits on the mark, guilder and franc. They remain, according to the Praetz test, significant at the 5% level.

Finally, it is possible that a risk premium may exist even if the historical betas are zero. When taking a position in foreign exchange, the speculator faces the possibility of unexpected government intervention, for example, to support a non-market clearing exchange rate, or of outright exchange controls hampering repatriation of funds. These elements of risk cannot be captured by estimating beta over a period devoid of exchange controls.

In summary, the trading rules provide some evidence for inefficiency in the market for the mark, guilder and franc, in contrast to the result of the autocorrelation tests. Given the statistical problems associated with measuring the significance of trading rule profits, we do not feel that this marginal evidence constitutes a case for increased intervention in the exchange market to correct for market inefficiency in the sense used here.

IV. The Distribution of Daily Returns

Substantial evidence has accumulated that speculative rates of return on common stocks and commodities are not normally distributed (for example, Fama, 1965 and Dusak, 1973). Mandelbrot (1963) and others have contended that the appropriate distributions are instances of the class of stable Paretian distributions, of which the normal is a special case, where the variance (second moment) is not defined, and

[8] There is no obvious relation between the betas estimated for the U.S. and the world portfolios. We assume that the U.S. portfolio is a large part of the world portfolio.

the distribution is peaked at the mean relative to the normal.

The infinite variance associated with certain classes of stable Paretian distribution is associated with the observation of thick tails and peakedness of sample distributions.[9] Figure 1 graphs the actual daily rates of return, arranged by size, for the six currencies we study against the unit normal at estimated fractile points. Normally, distributed price relatives would plot as a straight line. The S-shape curves observed in figure 1 are similar to those in Fama (1965, figure 2, p. 53) and Dusak (1973, figures 1–3, pp. 1396f) for common stocks and commodity futures contracts, respectively. The S-curvature indicates more large values than would be expected given the observations around the mean; that is, the observed extreme observations suggest a flatter distribution than is observed in the central region of the sample distribution of returns. The evidence suggests that currency prices, like common stock and commodity prices, are distributed according to a stable Paretian distribution with an undefined variance.[10]

We also investigated the possibility that large price changes tend to succeed large price changes, as was found to be the case for common stock prices by Fama (1965, pp. 85f). In table 6, we show the distribution of successors to one-day rates of return in excess of a "large" value, where large is defined as annual absolute rate of return of between 2% and 5%, depending on the currency. There were very few changes for the Canadian dollar within this range.

There is a clear tendency for the successor to large daily rates of return for all currencies, except the Canadian dollar, to lie on the extreme tails of the distribution of all daily rates of return for the currency. For example, table 6 shows that only 47% of the successors to absolute annual rates of return of 2% or more on the British pound were within the middle 4 sextiles of the overall distribution, whereas nearly 5% were outside the 99th percentile of the standard normal. Other currencies display similar tendencies.

TABLE 6.—DISTRIBUTION OF SUCCESSORS TO LARGE CHANGES

Currency	Large Change[a] (1)	Inter-Sextile (2)	2% (3)	1% (4)	> 1% (5)	Total (6)
			Number			
British pound	2%	40	78	81	4	85
	3	14	27	30	5	35
Canadian dollar	2	2	2	2	1	3
	—	—	—	—	—	—
German mark	3	31	76	80	4	84
	4	20	48	51	3	54
Dutch guilder	3	56	102	106	4	110
	4	32	61	64	2	66
Japanese yen	2	21	50	54	4	58
	3	11	27	28	2	30
Swiss franc	4	37	74	76	5	81
	5	21	45	46	4	50
			Frequency			
Expected frequency		.6667	.98	.99	.01	N
British pound	2	.4706	.9177	.9529	.0471	85
	3	.4000	.7714	.8571	.1429	35
Canadian dollar	2	.6667	.6667	.6667	.3333	3
	—	—	—	—	—	—
German mark	3	.3691	.9048	.9524	.0476	84
	4	.3704	.8889	.9444	.0556	54
Dutch guilder	3	.5091	.9273	.9636	.0364	110
	4	.4849	.9242	.9697	.0303	66
Japanese yen	2	.3621	.8621	.9310	.0690	58
	3	.3667	.9000	.9333	.0667	30
Swiss franc	4	.4568	.9136	.9383	.0607	81
	5	.4200	.9000	.9200	.0800	50

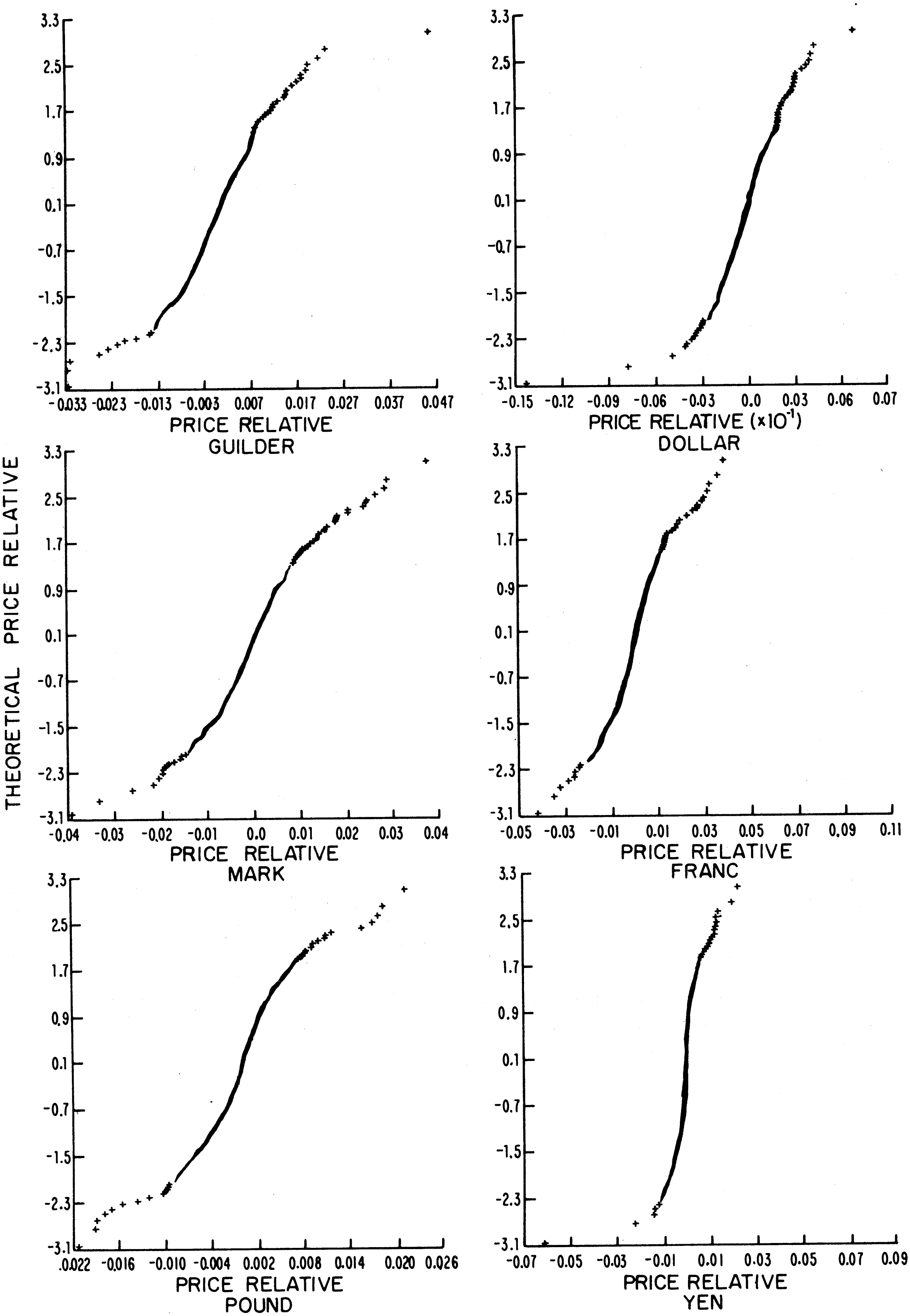
[a] Annual rate of change.

The fact that large price changes tend to follow large price changes does not violate the hypothesis of an efficient market if no trading rule can be based on this relation. In fact, none of the correlation coefficients between a large daily rate of return and their successors were significantly different than zero at the 5% level. One interpretation of the fact that large changes tend to follow large changes is that unexpected events, such as the collapse of the Herstatt bank, temporarily alter this distribution of price changes. This explanation is consistent with market efficiency.

[9] Since this paper was written, we have become aware of a paper by Janice M. Westerfield (1975) analyzing the behavior of one week rates of return on spot and future currency contracts. Westerfield's conclusions support the hypothesis of a stable Paretian distribution for currency rates of return.

[10] As Press (1968) has shown, this distribution can also be attributed to a random sum of normal variables with differing variances.

FIGURE 1.—NORMAL PROBABILITY GRAPH FOR DAILY RATES OF RETURN ON FOREIGN EXCHANGE



V. Conclusions

The period covered by our study included the Arab oil embargo, unprecedented worldwide inflation, the collapse of several major financial institutions and the deepest recession of the post-war years. This unlikely sequence of dramatic events led to large swings in exchange rates and, consequently, to repeated assertions that one currency or another was improperly valued. Our results, however, indicate that the market for foreign exchange is efficient, at least in the weak form. In fact, the market for foreign exchange behaves surprisingly like the market for common stock, despite the dominance of large transactors in exchange markets: international banks, multinational corporations and governments. The distribution of daily rates of return on spot currency contracts appears to be similar to those observed for common stock and commodity futures contracts.

What little evidence we found for market inefficiency, namely, profitable trading rules in three currencies (two of which were tied in the joint European Common Market float), does not appear to constitute a strong case for official intervention in order to correct for under- or over-evaluation of currencies. Market efficiency (in the sense used here) does not mean that fluctuations in exchange rates are minimized. If central banks could determine changes in equilibrium exchange rates caused by new information, they could operate to reduce the size of periodic adjustments to the new equilibrium rates. In so doing, they would necessarily incur exchange operation losses and retard the market adjustment to the new equilibrium. Whether the reduced variability warrants the implied inefficiency is a policy question. Our analysis cannot determine whether or not central banks have reduced variability in exchange rates in the period analyzed. We can only conclude that our evidence does not support the hypothesis of large departures from market efficiency.

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