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Beating the Foreign Exchange Market

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ABSTRACT

Filter rule profits found in foreign exchange markets in the early days of the current managed float persist in later periods, as shown by statistical tests developed and implemented here. The test is consistent with, but independent of, a wide variety of asset pricing models. The profits found cannot be explained by risk if risk premia are constant over time. Inclusion of the home-foreign interest rate differential in computing profits has little effect on the comparison of filter returns to those of buy-and-hold.

IN THE EARLY YEARS of the generalized managed floating that began in March 1973, filter rule profits in excess of buy-and-hold were found for many countries (Logue, Sweeney and Willett [18], Dooley and Shafer [6], Cornell and Dietrich [5]). It was unclear, however, whether such profits indicated inefficiencies. First, it was not clear that risk was adequately handled in such tests, and often risk was ignored. Second, there was no evidence such profits would be available postsample. And third, there was no statistical test of the significance of these profits.

This paper uses the logic of risk/return tradeoffs to analyze the role of risk in such tests and illustrates the logic in a discussion using the Sharpe-Lintner Capital Asset Pricing Model (CAPM), although a Breeden consumption-based CAPM, a Merton intertemporal CAPM, or an Arbitrage Pricing Model (APM) could easily be used. The paper develops a test of statistical significance appropriate to foreign exchange markets (Section I), analyzing the rate of return on foreign exchange speculation less the foreign-domestic interest rate differential. The test explicitly assumes that risk premia are constant over the sample. The excess rates of return observable in using filters in going from a risk-free dollar asset to a risk-free Deutsche Mark (DM) asset persist into the 1980's (Section II), and this is true even when taking account of transactions costs. It turns out that these results for the $/DM case do not depend very much on the interest-rate differential, but primarily on exchange rate behavior. This is useful to know because it is often quite difficult to find matching, interest-rate data of high quality. For a sample of nine other currencies, using only exchange rates, Section III shows that the excess returns made in the first 610 days of the float persist in the next 1,220 days, into the 1980's. (Dooley and Shafer [7] find similar persistence in experiments that do not use buy-and-hold and have no significance tests.)

When filter rule profits have been found in spot exchange markets, it has often been argued that the profits are due to risk. This paper uses the CAPM to analyze rates of return both to buy-and-hold and to filter strategies. It turns out that the

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CAPM may be used to explain the return to both strategies, but not any excess filter returns; in fact, significant excess filter rule profits would be an indictment of the CAPM, since it does not predict such profits. Section IV illustrates how the CAPM has been misused to attempt to explain filter rules profits as due to risk. Section V offers some conclusions and possible reasons for existence of filter profits.

I. Filter Rule Profits in the Spot Exchange Market, Using Interest-Earning Assets[1]

This section develops a statistical test of filter rule rates of return in excess of buy-and-hold in the foreign exchange market; it then compares this test to the methodology used by Dooley and Shafer [7]. Section II applies the test to the dollar-DM case.

Consider a buy-and-hold strategy that puts funds in an overnight DM asset paying the (foreign) rate, r_f, which is riskless in terms of DMs. The daily return in terms of U.S. dollars is (approximately) the percentage appreciation of the DM (u) plus r_f, or is $u + r_f$ (ignoring the cross product, ur_f, and also transactions costs which are discussed in Sections II and III). The overnight riskless rate for, say, the U.S. is the (domestic) rate, r_d. Thus, the daily excess return to buy-and-hold over the U.S. risk-free rate is $u + r_f - r_d$. An alternative filter strategy earns the excess return $u + r_d - r_d$ for days "in" in the DM asset, and the excess return $r_d - r_d = 0$ for days "out" of the DM asset (and hence in the U.S. asset).

A. Risk, Buy-and-Hold Returns, and Filter Returns

This subsection develops expressions for average returns to the buy-and-hold and filter strategies and for an X statistic based upon these. All that is required is that the excess return to being "in" the DM be stationary. The development is made more intuitive, and is more connected with the literature, by being phrased in terms of an equilibrium asset pricing model. The development is consistent with a single-period Sharpe-Lintner CAPM with a beta on "the" market; with an intertemporal Merton [20] CAPM with betas on the market and every independent state variable; with a Breeden [4] CAPM with a single beta on an asset whose return is perfectly correlated with changes in aggregate consumption (or the portfolio with returns most highly correlated with changes in aggregate consumption); and with an APM with (potentially) multiple priced factors, none of which need be the market. In each case, the expected excess return to being "in" DMs when there is a risk-free rate is equal to betas times risk premia of underlying factors (refer to these products simply as risk premia for the investment). As long as the investment's risk premia are constant over time, the development below of the X statistic goes through for all of these models. While the development is stated in terms of a Sharpe-Lintner CAPM, any unfortunate overtones of phrasing the exposition in terms of a single-period model can be removed by viewing the model as a Breeden CAPM, with the return

[1] For a more detailed discussion of the following approach to filter rule tests, see Sweeney [23]. The development is related to Praetz [21]; see Sweeney [23] for a discussion of crucial differences.

on an asset perfectly correlated with consumption changes substituted for the return on the market.

The CAPM can be used to give an explanation in terms of risk of the excess returns on either buy-and-hold or on days "in" the filter rule. As is well-known, international CAPMs often have no straightforward answer as to what "the" market index is or the appropriate risk-free rate, and both can depend on the country of residence of the investor considered.[2] Suppose the appropriate index, R_M, is known and for convenience suppose the risk-free rate applicable to the U.S. decision-maker is r_d. (The empirical work that follows does not assume knowledge of the "true" market.) Then, the CAPM implies

$$E(u) + r_f - r_d = b_f[E(R_M) - r_d] = g, \tag{1}$$

where $b_f = \text{cov}(u, R_M)/\text{var}(R_M)$ since r_f, r_d are given for any day. Call g the risk premium for this investment. g is explicitly assumed constant. The "market model" observational implementation of (1) is[3]

$$u + r_f - r_d = b_f(R_M - r_d) + e, \tag{2}$$

where by assumption $\text{cov}(R_M, e) = 0$, $Ee = 0$, $\text{cov}(e_t, e_{t+j}) = 0$ for $j \neq 0$.

Equation (1) implies that $E(u) + r_f - r_d \neq 0$ only in the case in which $b_f \neq 0$. This is the international CAPM result that expected appreciation (Eu) need not equal the interest rate differential ($r_d - r_f$) if there is a risk premium. Equation (1) also implies that *if* both the expected premium on the market ($ER_M - r_d$) and b_f are constant, then changes in expected appreciation must exactly equal changes in the interest rate differential. In this case, if $Eu \equiv \alpha$ and $r_d - r_f \equiv \alpha'$, then both α and α' may vary, but $\alpha - \alpha'$ must remain equal to the (possibly nonzero) constant g.

Equation (2) implies that systematic excess profits beyond the equilibrium excess returns in (1) can be obtained only by skill in forecasting R_M (market timing) or e (asset selection). Generally held views of market efficiency assume that neither can systematically be done.

Filter rule investigations in equity markets usually specify buy-and-hold as a standard of comparison (but see below for Dooley and Shafer's [7] methodology). The sample buy-and-hold arithmetic average excess rate of return,[4] over N periods, is

$$\bar{R}_{BH} = \frac{1}{N} \sum_{i=1}^{N} (u_i + r_{fi} - r_{di})$$

and hence $E\bar{R}_{BH} = g$ as long as b_f and $ER_M - r_d$ are constant. The sample mean

[2] See the discussion and references in Sharp [22].

[3] This assumes that the intercept $a = 0$ as the CAPM implies. Of course the estimate a is likely nonzero for any sample. The APM can be used to analyze cases where there are priced nonmarket factors, and hence a nonzero a in (2). Analysis based on the APM gives the same statistical test discussed later.

[4] These tests use the arithmetic rate of return rather than the geometric; the test is more easily developed and understood in the former case, but the latter is an obvious extension. Further, experiments suggest that the relative performance of a filter does not depend on which definition of the rate of return is used.

for a filter is[5]

$$\bar{R}_F = \frac{1}{N}\left\{\sum_{i=1}^{N_{in}} (u_i + r_{fi} - r_{di}) + \sum_{j=1}^{N_{out}} (r_d - r_d)\right\},$$

where N_{in} is the number of days *"in"* the DM, and N_{out} the days *"out,"* with $N \equiv N_{in} + N_{out}$. Taking expectations, $E\bar{R}_F = \frac{1}{N}\sum^{N_{in}} g = (N_{in}/N)g = (1-f)g$, where $f \equiv N_{out}/N$. Thus, the expected excess rate of return on the filter depends on beta and the ex ante market premium for days in, and is zero for days out (i.e., days in the domestic risk-free asset), with the overall excess rate of return a weighted average.[6]

B. Filter Returns in Excess of Buy-and-Hold

Instead of comparing the difference, $\bar{R}_f - \bar{R}_{BH}$, this paper uses the statistic

$$X = \bar{R}_F - \bar{R}_{BH} + f\bar{R}_{BH}, \tag{3}$$

for two reasons. First, comparing $\bar{R}_{BH}$ to $\bar{R}_F$ is biased in one direction or the other as long as $g \neq 0$. Second, suppose that $g = 0$, but for a given sample $\bar{R}_{BH} > 0$. Then, the investor would expect $\bar{R}_F > 0$, since this is an "up" market. But further, one would expect $\bar{R}_{BH} > \bar{R}_F$, since the filter is taking the investor out of an "up" market part of the time.

The adjustment factor, $f\bar{R}_{BH}$, in (3) ensures $EX = (1-f)g - g + fg = 0$, since g is assumed constant (or risk premia are constant). Notice that (3) implies that X can be positive, and the filter thus beat the market even if $\bar{R}_F < \bar{R}_{BH}$. This is so because $\bar{R}_F$ includes some days when the filter is out of the market, bears no risk, and is thus paid a zero risk premium. For example, if the filter and buy-and-hold both return \$50, but the filter had $f = 0.5$ so the investor was out of DMs 50% of the time, then the investor bore risk only half as many days with the filter as with buy-and-hold, but made the same profit. Depending on g, the investor might well prefer the expectation of \$45 from the filter to \$50 from buy-and-hold.

Confidence bounds are needed to judge the significance of nonzero values of X. Assuming that $\alpha - \alpha'$ is constant, the variance of X is

$$\sigma_X^2 = (\sigma_u^2/N)f(1-f), \qquad \text{so } \sigma_X = (\sigma_u/N^{1/2})[f(1-f)]^{1/2},$$

where $\sigma_u^2 = E(u-\alpha)^2$ is assumed constant even though α may vary over time. The sampling distribution of X will be normal if σ_u exists. There is some evidence that u might be Paretian stable (Cornell and Dietrich [5]; Logue, Sweeney, and Willett [18]. If this is accepted, one may want to require higher than conventional levels of significance before rejecting the null $X = 0$.

[5] Alternatively, $\bar{R}_F$ could be averaged over N_{in} rather than N days, as for example in Fama and Blume [11]. Sweeney [23] shows that a test can be developed using this definition of $\bar{R}_F$, one with exactly the same properties as the one developed previously.

[6] If $\bar{R}_F$ is averaged over N_{in}, then $E\bar{R}_F = g$ (for $N_{in} > 0$) and hence $E\bar{R}_{BH} = E\bar{R}_F = g$. The prediction is equal returns to both strategies.

C. Comparison of Dooley and Shafer

An alternative approach is the zero-wealth pure-exchange-risk play used by Dooley and Shafer [7]. The two approaches are not as dissimilar as they might appear; they simply use different but related filter strategies. The present paper uses long positions while Dooley and Shafer use long *and* short positions. However, the test statistic used here is more robust than Dooley and Shafer's.

Suppose the investor has taken no position, and the DM rises enough to give a buy signal. In the strategy used here, the investors puts funds, say $1 million, in DM assets, earning a per day rate of return of $u + r_f$ and earning an excess rate of return of $u + r_f - r_d$ per day. The investor can either use his/her own money or borrow the funds (though the transactions costs are higher with borrowing). In the Dooley and Shafer strategy, the funds are borrowed and the net rate of return is $u + r_f - r_d$ per day. When the DM falls enough to give a sell signal, the strategy used here has the speculator sell his/her DM assets and buy dollar assets, giving an excess return of $r_d - r_d = 0$ (or simply close out the position if the funds were borrowed). Dooley and Shafer's strategy also has the speculator sell the DM assets but then borrow DMs at the rate, r_f, and invest in dollar assets at the rate, r_d. Thus, his net return is $r_d - r_f - u \equiv -(u + r_f - r_d)$. Thus, in both strategies, the speculator takes long positions in DM assets, but in the present paper holds dollar assets when not long in DMs, while in Dooley and Shafer's strategy she is short in DMs when not long. (The issue of whether the speculator uses his own funds or only borrows is irrelevant to the difference between the two strategies.)

In Dooley and Shafer's methodology, the daily rate of return on days "in" DM is $(u + r_f - r_d)$, and on days "out" of, or shorting, the DM is $-(u + r_f - r_d)$. Similar to Dooley and Shafer, form an average rate of return from the two positions as

$$Y = (1/N)\ \textstyle\sum_{i=1}^{N_{in}}\ (u_i + r_{fi} - r_{di}) + (1/N)\ \sum_{j=1}^{N_{out}} -\ (u_j + r_{fj} - r_{dj}). \qquad (4)$$

Then,

$$EY = (N_{in}/N)g - (N_{out}/N)g = (1 - f - f)g = (1 - 2f)g, \qquad (5)$$

where $g = b_f[E(R_M) - r_d]$, as above, and

$$\sigma_Y^2 = (1/N)\sigma_u^2,$$

$$\sigma_Y = \sigma_u/N^{1/2}. \qquad (6)$$

While Dooley and Shafer make explicit that they assume $E(u + r_f - r_d) = 0$, it is clear from (5) that their measure is biased if $E(u + r_f - r_d) \neq 0$. This, in turn, comes to the issue of the bias in the forward premium as a predictor of coming future spot rates. The evidence on this is mixed, but recent work provides some fairly strong evidence against the unbiasedness hypothesis (see Fama [10], Hodrick and Srivastava [16], and Sweeney [24]). The present test allows explicitly for $E(u + r_f - r_d) = g \neq 0$, though it assumes g is constant over time.

Similar to the development of the X statistic, Dooley and Shafer's statistic could be reformulated by subtracting an adjusted $\bar{R}_{BH}$ to give

$Y' = Y - (1 - 2f)\bar{R}_{BH}$, where

$$EY' = 0, \qquad \sigma^2_{Y'} = (\sigma^2_u/N)4f(1-f), \qquad \sigma_{Y'} = (\sigma_u/N^{1/2})2[f(1-f)]^{1/2}.$$

Thus, the present paper's comparison of filter returns to buy-and-hold is not only intuitively plausible, but also some comparison to (an adjusted) buy-and-hold is necessary to give an unbiased test statistic.[7]

The present test looks only at long positions unlike Dooley and Shafer who look at both long and short positions. Efficiency requires that neither strategy make systematic risk-adjusted profits. Fama and Blume [11] use a long-and-short strategy in examining U.S. equity markets. It is clear from their Table 3 (and pp. 236–40) that the shorting part of the strategy is generally unprofitable and indeed masks the evidence of profits (*before* commissions!) provided by the long part of the strategy. This suggested *not* running a long-and-short test in the foreign exchange markets. However, it is easy to show that[8] $Y' = 2X$ and $\sigma_{Y'} = 2\sigma_X$. Thus, if an appropriate measure of profits is used, the long and long-and-short strategies give identical t-statistics. The approach of Dooley and Shafer, appropriately modified, will give the same conclusions as this paper's.

II. Empirical Results for the X Test

The data used here were kindly provided by the Board of Governors of the Federal Reserve System. Daily data on the dollar-DM exchange rate, the overnight federal funds rate, and the one-day Frankfurt interbank loan rate were used; to avoid problems of political risk it might have been preferable to use Euro rates, but these were not readily available. The data were cleaned carefully and checked with other sources. After cleaning, there remained 1,289 trading days between 1975 and 1980 for which interest rate data were available.[9] The three series were not collected at exactly the same time as each other; further, some rates were averages across firms and may not be actual trading data. Nevertheless, the quality of the data seems adequate; in any case, it was not possible to obtain better data or indeed obtain data for comparable experiments for other countries. In particular, the intra-day variability of the interest rate differential seems small enough (on the basis of casual observation) that conclusions below would not be altered if simultaneously collected data on interest rates were used.

[7] Even if $EY = 0$, Y' is a better test statistic than Y in at least the following sense. Suppose the filter puts the speculator in DMs on the first day and keeps him or her there throughout ($f = 0$). Y' will, of course, say there are zero profits. Y will say there are profits equal to $\bar{R}_{BH}$; but we know this from $\bar{R}_F = \bar{R}_{BH}$ when $f = 0$. In such a case, Y will be significantly different from EY 5% of the time at the 95% confidence level. In other words, this would be a test of whether it was smart to pursue a buy-and-hold strategy for the DM this period, *not* a test of whether getting in and out of the DM produced profits beyond buy-and-hold.

[8] Under the null hypothesis, X has chances to be nonzero only on days "in," while Y' can also be nonzero on days "out" because of the shorting.

[9] Days with missing observations on any of the three variables were deleted from the sample. Since many of the missing observations were due to markets being closed, this amounts to a decision to run the filter only when all markets are open. The Board gathered these data at (approximately) noon from a number of firms and averaged the results. Further, these exchange rates were not collected at exactly the same time as the interest rates. All series are "indications" rather than necessarily actual trading data.

Table I shows that, for the dollar price of the DM, the mean percentage rate of change of the exchange rate on a daily basis is $[(Ex_t - Ex_{t-1})/Ex_{t-1}]\cdot 100 = 0.027$, while the mean interest rate differential on the basis of 262 business days per year is $(r_f - r_d)/262 = -0.0113$ (r_f and r_d are quoted at annual percentage rates). However, the variances are much more divergent, with that for the exchange rate 0.270, and the differential 0.0000875. In forming $(\Delta Ex/Ex)\cdot 100 + (r_f - r_d)/262$, the mean falls from that of $(\Delta Ex/Ex)/100$ to 0.016, while the variance rises marginally to 0.271. Table I shows that the autocorrelation function for $\Delta Ex/Ex$ is approximately white, save for spikes at lags 8 and 10; the Box-Pierce Q statistic (adjusted) is borderline significant. $r_f - r_d$ appears highly nonstationary. Nevertheless, the series for exchange rate changes adjusted for the interest rate differential is essentially that of $\Delta Ex/Ex$ adjusted for the mean of the differential.

The test developed above is, of course, independent of exactly how decisions are made to buy and sell assets. The actual filter rule used here is based on the long positions in Alexander [1] and Fama and Blume [11]. It says "buy when the dollar value of the DM rises $Y\%$ above its previous local low; sell when it falls $Z\%$ from its previous local high." Further, the Y and Z were set equal, and no attempts were made to find values that improved filter performance.

Table II shows results for seven different filters. The X statistics are reported as percent per day. Thus, the entry for the 0.5% rule shows profits of 0.016% per day or, on the basis of 250 trading days per year, profits of 4% per year (= 0.016% × 250). Table II shows that any filter but 10% beats buy-and-hold and that the X statistic is significant for filters of 0.5% and 1%. Note that the confidence bounds are contingent on the f for each particular rule.[10]

Similar to the results of Fama and Blume [11] on long positions, small filters seem to work best, but also have the largest number of transactions. However, unlike the Fama and Blume results, transaction costs do not seem to eliminate risk-adjusted excess filter returns. It is estimated (Sweeney and Lee [26]) that, in the foreign exchange-market, each round trip costs one-eighth of 1% of asset value on average for large, regular customers (separate bid/ask daily prices were not readily available).[11] Distributed over the 1,289 trading days of the sample,

[10] If $\alpha - \alpha'$ equals a constant, but α shifts over the sample, using the sample variance $(\Delta Ex/Ex)\cdot 100 + (r_f - r_d)/262$, as Table II does in the X test, gives a better estimate of σ_u^2 than does the sample variance of $(\Delta Ex/Ex)\cdot 100$. However, these two estimates of σ_u^2 are so close that the choice makes no practical difference.

[11] Frenkel and Levich [13, 14] use a method based on triangular arbitrage to estimate the cost of transactions in the market for foreign exchange. They emphasize that their "estimate should be interpreted to encompass the total cost associated with a transaction. Thus, it includes elements like brokerage fees, time cost, subscription costs, and all other components that compromise the cost of being informed" [14, p. 1212]. Using their method, McCormick [19] estimates spot market transactions costs for the period April–October 1976 to be 0.182 of 1% for the DM, based on triangular arbitrage from U.S. dollars to pounds sterling to DMs. However, the essence of McCormick's point is that the estimates require simultaneous quotes on the currencies involved in the triangular arbitrage, and this estimate for the DM has a difference of up to one hour. Using his estimates of transactions costs based on the Canadian dollar, transactions costs measured simultaneously are only 57% of those measured with a lag of up to one hour. Hence, the triangular arbitrage of the DM would imply transactions costs of 0.104 (= 0.57 × 0.182) of 1%, or about 1/10 of 1%, less than the 0.125 or 1/8 of 1% assumed in the text.

Table I

Properties of Dollar-DM Exchange Rate, with and without Adjustment for Interest Rate Differentials

Panel A: Autocorrelation Function of $(\Delta Ex/Ex)\cdot 100$

Lag	1	2	3	4	5	6	7	8	9	10	11	12	Estimated Standard Error
Estimated Coefficient	0.02	0.00	0.02	−0.01	0.02	0.04	−0.01	0.08*	0.02	0.08*	−0.01	−0.02	0.03

Mean: 0.027 Variance: 0.270 $Q(12) = 22.8$

Panel B: Autocorrelation Function of $(r_f - r_d)/262$

Lag	1	2	3	4	5	6	7	8	9	10	11	12	Estimated Standard Error
Estimated Coefficient	0.95*	0.95*	0.90*	0.88*	0.87*	0.86*	0.85*	0.84*	0.82*	0.81*	0.80*	0.79*	0.03

Mean: −0.0113 Variance: 0.0000875 $Q(12) = 11{,}500$

Panel C: Autocorrelation Function of $\Delta(r_f - r_d)/262$

Lag	1	2	3	4	5	6	7	8	9	10	11	12	Estimated Standard Error
Estimated Coefficient	−0.30*	0.01	−0.08*	−0.05	−0.03	0.01	0.03	0.00	−0.02	0.03	−0.03	0.03	0.03

Mean: 0.45×10^{-5} Variance: 0.891×10^{-5} $Q(12) = 126$

Panel D: Autocorrelation Function of $(\Delta Ex/Ex)\cdot 100 + (r_f - r_d)/262$

Lag	1	2	3	4	5	6	7	8	9	10	11	12	Estimated Standard Error
Estimated Coefficient	0.02	0.00	0.02	−0.01	0.02	0.04	−0.01	0.08*	0.02	0.08*	−0.01	−0.02	0.03

Mean: 0.016 Variance: 0.271 $Q(12) = 23.4$

* Significant at the 95% confidence level.

Table II

Tests of Significance of Filter Rule Profits*

Filter (%)	$\bar{R}_F$	$\bar{R}_{BH}$	f	X	Transactions (Round Trips)	X (Net of Transaction)	$\bar{R}'_F$	$\bar{R}'_{BH}$	X'
0.5	0.024	0.0156	0.446	0.016**	94	0.0064	0.029	0.027	0.014**
				(0.002, 0.030)					(0.000, 0.028)
1	0.028	0.0156	0.388	0.019**	42	0.0148**	0.034	0.027	0.017**
				(0.005, 0.033)					(0.003, 0.031)
2	0.022	0.0156	0.422	0.013	18	0.0112	0.028	0.027	0.013
				(−0.001, 0.027)					(−0.001, 0.027)
3	0.016	0.0156	0.423	0.007	13	0.0057	0.021	0.027	0.006
				(−0.007, 0.021)					(−0.008, 0.020)
4	0.018	0.0156	0.250	0.007	8	0.0062	0.026	0.027	0.006
				(−0.006, 0.018)					(−0.007, 0.018)
5	0.016	0.0156	0.265	0.005	6	0.0042	0.024	0.027	0.005
				(−0.008, 0.017)					(−0.008, 0.017)
10	0.003	0.0156	0.396	−0.006	4	−0.0064	0.009	0.027	−0.007
				(−0.020, 0.008)					(−0.021, 0.007)

* Bounds in parentheses (n = 1,288). $\mathrm{Var}[(\Delta Ex/Ex)\cdot 100] = 0.27041$; $\mathrm{Var}[(\Delta Ex/Ex)\cdot 100 + (r_f - r_d)/262] = 0.27063$; $\hat{\sigma}_X = \frac{1}{N^{1/2}}[f(1-f)]^{1/2}(\mathrm{Var}[(\Delta Ex/Ex)\cdot 100 + (r_f - r_d)/262])^{1/2}$; $\hat{\sigma}_{X'} = \frac{1}{N^{1/2}}[f(1-f)]^{1/2}(\mathrm{Var}[(\Delta Ex/Ex)\cdot 100])^{1/2}$.

** Significant at the 95% confidence level.

one round trip reduces $\bar{R}_F$ and hence X by (1/8)/1,289 or by approximately 0.0001 on a daily basis. The column "X, Net of Transactions Costs" shows the adjusted Xs. All are smaller, of course, but all retain their previous signs. The 1% filter is still significant, and both the 1% and 2% filters look very good after transactions costs.

No explicit account is taken of the possible extra transactions costs of putting funds in interest-bearing assets. If all transactions are with a single bank, presumably the marginal cost of switching overnight interest-bearing assets among currencies is quite low and likely infra-marginal.

The period examined for the dollar-DM rate, adjusted for the interest rate differential, begins roughly around the end of the period for which Logue, Sweeney, and Willet [18], Dooley and Shafer [6] and Cornell and Dietrich [5] found excess filter rule profits. Hence, this test is evidence that profits persisted into the 1980's. Further, the present test takes account of risk as well as providing confidence bounds.

III. The Text When Interest-Rate Differentials Are Neglected

One problem with implementing the X test is that good data on the overnight differential, $r_d - r_f$, are hard to accumulate. Under certain circumstances, neglecting $r_d - r_f$ is low cost, e.g., if α' equals a constant. More generally, suppose that the average α' for days in ($\bar{\alpha}'_{in}$) equals the average for days out ($\bar{\alpha}'_{out}$), so $\bar{\alpha}' = \bar{\alpha}'_{in} = \bar{\alpha}'_{out}$. Then

$$\begin{aligned} X &= (1/N) \textstyle\sum^{N_{in}} (u - \alpha'_{in}) - [(1-f)/N] \textstyle\sum^{N}(u - \alpha) \\ &= (1/N) \textstyle\sum^{N_{in}} u - (N_{in}/N)\bar{\alpha}'_{in} - [(1-f)/N] \textstyle\sum^{N} u + (1-f)\bar{\alpha}' \\ &= (1/N) \textstyle\sum^{N_{in}} u - [(1-f)/N] \textstyle\sum^{N} u. \end{aligned} \tag{7}$$

In other words, when $\bar{\alpha}'_{in} \cong \bar{\alpha}'$, it is legitimate to simplify and instead of using X, use

$$X' = \bar{R}'_F - \bar{R}'_{BH} + f\bar{R}'_{BH}, \tag{8}$$

where $\bar{R}'_F = (1/N) \sum^{N_{in}} u_j$, $\bar{R}'_{BH} = (1/N) \sum^{N} u_j$, with $\bar{R}'_F$ the filter's sample return due solely to exchange rate appreciation and $\bar{R}'_{BH}$ the buy-and-hold return due to appreciation. Of course, when the dollar faces trend depreciation, $\bar{R}'_{BH} > \bar{R}_{BH}$ due to neglecting the fact than $r_f < r_d$. However, $\bar{R}'_F$ is similarly overstated, so on net X and X' are unaffected by omitting the differential as long as $\bar{\alpha}'_{in} \cong \bar{\alpha}'_{out}$.

As a practical matter, it should be true that $\bar{\alpha}'_{in} \cong \bar{\alpha}'_{out}$ whenever the out periods are scattered roughly evenly through the total, N. However, some insight into the difference in results due to neglecting the differential is available by considering the case of the \$/DM exchange rate, where results can be compared for both the X and the modified X' tests.

A. Empirical Results for the X' Test

Table II also shows the X′ statistic for the same sample where X was calculated;[12] the X and X' are very close. The difference results from the fact

[12] X' has exactly the same days in and out as X. The difference is solely the exclusion in X' of the interest-rate differential in calculating all rates of return.

that the average interest rate differential for the sample is $\bar{\alpha}' = 0.0113$, while $\bar{\alpha}'_{in}$ is smaller for each rule and over the seven rules averages 0.0103; hence, on average $\bar{\alpha}' - \bar{\alpha}'_{in} = 0.0113 - 0.0103 = 0.001$. This implies $\bar{\alpha}'_{out} > \bar{\alpha}' > \bar{\alpha}'_{in}$. Inspection of (7) shows that $\bar{\alpha}'_{out} > \bar{\alpha}'_{in}$ makes the sample $X > X'$.

For the X' test, all filter rules save for 10% beat buy-and-hold, with both the 0.5 (borderline) and 1.0% rules beating buy-and-hold significantly, just as before.[13]

B. X′ Test Results for 10 Countries

The results for the X and X' tests for the \$-DM exchange rate in Table II cannot, of course, prove that it is always safe to neglect interest-rate differentials. Nevertheless, since finding matching overnight interest rates is so difficult, the X' test is used here for 10 countries for 1,830 days of the floating rate period from April 1, 1973 into 1980. The period is broken into two parts, the first 610 days and the remaining 1,220 days.

Table III shows that for the first period, a substantial fraction of rules produced significant X' values. For example, the buy-and-sell filter of ½ of 1% for the Belgian franc gave an $X' = 0.035$ which is highly significant at the 95% confidence level; thus, the speculation earned an average 0.035% profits each day, or for a 250-day year, an annual rate of 8.75%. Of the 70 cases given by the seven rules and ten countries, 22 cases are significant.[14] A major question is whether knowledge of these results would have helped obtain profits after the first 610 trading days. Table IV shows that many rules gave significant X' values in the next 1,220 trading days; there are 21 significant cases of the 70 total.[15] In both Tables III and IV, adjustments for transactions costs affects results to about the same degree as in Table II.

Table V sheds light on how helpful the results in Table III are in exploiting the profit potential revealed in Table IV. First, eight rules significant in the first

[13] Use of X' in place of X will of course be misleading if $\bar{\alpha}'_{in} \neq \bar{\alpha}'_{out}$. For example, for a given value of X', inspection of (7) shows that if $\bar{\alpha}'_{in} < \bar{\alpha}'_{out}$, $X = X'$ and hence the filter rule's success is underestimated. However, this example may be misleading *if* α and α' tend to move in offsetting directions as theory suggests. Hence, when $\bar{\alpha}'_{in} > \bar{\alpha}'_{out}$, $\bar{\alpha}_{in}$ will tend to exceed $\bar{\alpha}_{out}$ and thus raise X'; in such cases, it is illegimate to hold X' constant when conceptually increasing $\bar{\alpha}'_{in}$ relative to $\bar{\alpha}'_{out}$.

Using X requires, strictly speaking, stationarity of $u_t - \alpha'_t$, and using X' requires stationarity of u_t. If $\alpha' =$ constant, then $\bar{\alpha}'_{in} = \bar{\alpha}'_{out}$, and stationarity implies $\alpha_t - \alpha'_t =$ constant so $\alpha_t =$ constant, and it is economically and statistically legitimate to use X'.

Suppose X' is used when α_t varies over time but $\alpha - \alpha' =$ constant. Then X' may be either larger or smaller than the "true" X. This is ameliorated somewhat by the fact that the estimate $\hat{\sigma}_{X'}$ will tend to exceed the estimate $\hat{\sigma}_X$, because $\hat{\sigma}_u$ now includes not only the effect of random exchange rate changes but also the effect of the shifting mean α_t. Hence, any upward bias in X' is to some extent offset by an upward bias in $\hat{\sigma}_{X'}$.

[14] For any one country, the success of various filters will be correlated. Hence, the 70 cases are not independent, and no overall test can be done. Note that one of these cases, the Japanese yen for the 10% filter, produces significantly negative excess returns.

[15] The results for X' for the DM differ across Tables II and IV for two reasons. First, the beginning of the sample for Table II includes some of the (latter part of the) first 610 days. Second, Table II's sample does not include any days where the foreign exchange market was open but one of the money markets was closed (or interest rate data were unavailable.).

Again, the 10% filter produces significantly negative profits in one case, this time the Swedish krone.

Table III

Filter Rule Results: First 610 Observations*

	0.5%	1%	2%	3%	4%	5%	10%
Belgian franc	0.035**	0.029**	0.024	0.028**	0.026	0.033	0.007
	(2.80)	(2.32)	(1.92)	(2.24)	(1.93)	(2.64)	(0.74)
Canadian dollar	0.004	0.005	0.006**	0.004	0.003	0.002	0
	(1.60)	(1.67)	(2.40)	(1.60)	(1.50)	(1.00)	(0.00)
Deutsche mark	0.019	0.026	0.035**	0.018	0.043**	0.031**	−0.006
	(1.36)	(1.86)	(2.50)	(1.29)	(3.07)	(2.21)	(−0.46)
French franc	0.027**	0.034**	0.031**	0.027**	0.036**	0.041**	0.018
	(2.08)	(2.62)	(2.39)	(2.16)	(3.13)	(3.42)	(1.57)
Italian lira	0.028**	0.020**	0.016	0.016	0.008	−0.005	−0.005
	(3.11)	(2.86)	(1.88)	(1.88)	(1.07)	(−0.59)	(−0.63)
Japanese yen	0.005	0.007	0.017**	0.008	0	0.002	(−0.015**
	(0.63)	(0.82)	(2.13)	(0.89)	(0.00)	(−0.24)	(−3.00)
Swiss franc	0.024	0.036**	0.023	0.030	0.027	0.026	0.013
	(1.50)	(2.25)	(1.48)	(1.88)	(1.69)	(1.63)	(0.93)
Swedish krone	0.013	0.030**	0.016	0.021	0.035**	0.025**	0.003
	(1.08)	(2.50)	(1.33)	(1.68)	(2.80)	(2.08)	(0.33)
Spanish peseta	−0.002	−0.007	0.002	0	−0.005	0	0
	(−0.36)	(−1.27)	(0.44)	(0.00)	(−1.11)	(0.00)	(0.00)
U.K. pound sterling	0.009	0.015	0.024**	0.017**	0.010	0.004	−0.006
	(1.13)	(1.89)	(3.00)	(2.27)	(1.25)	(0.50)	(−1.00)

* t-statistic in parentheses.
** Significant at the 95% confidence level.

Table IV

Filter Rule Results: Final 1,220 Observations*

	0.5%	1%	2%	3%	4%	5%	10%
Belgian franc	0.009	0.017**	0.010	0.006	−0.001	−0.001	−0.008
	(1.29)	(2.43)	(1.43)	(0.92)	(−0.17)	(−0.15)	(−1.60)
Canadian dollar	0.012**	0.012**	0.004	0	−0.003	0.004	0
	(3.43)	(3.43)	(1.14)	(0.00)	(−1.00)	(1.33)	(0.00)
Deutsche mark	0.008	0.014**	0.008	0	−0.001	−0.002	−0.007
	(1.14)	(2.00)	(1.14)	(0.00)	(−0.20)	(−0.44)	(−1.27)
French franc	0.013	0.014**	0.006	0.005	0.005	0.005	−0.016
	(1.86)	(2.15)	(0.86)	(0.77)	(0.77)	(−0.77)	(−1.52)
Italian lira	0.022**	0.015**	0	0.003	0.005	−0.004	0
	(3.14)	(2.14)	(0.00)	(0.43)	(0.77)	(−0.57)	(0.00)
Japanese yen	0.020**	0.027**	0.010	0.010	0.009	0.018**	0.022**
	(2.50)	(3.18)	(1.33)	(1.33)	(1.29)	(3.00)	(2.93)
Swiss franc	0.015	0.023**	0.012	0.019	0.015	−0.002	−0.002
	(1.50)	(2.42)	(1.20)	(1.90)	(1.43)	(−0.21)	(−0.20)
Swedish krone	0.009	0.015**	0.009	0.003	0.009	0.002	−0.014**
	(1.39)	(2.31)	(1.39)	(0.55)	(1.39)	(0.33)	(−2.33)
Spanish peseta (last	0.018	0.019**	0.023**	0.015	0.011	0.006	0.002
1,218 observations)	(1.90)	(2.00)	(2.30)	(1.58)	(1.10)	(0.60)	(0.20)
U.K. pound sterling	0.019**	0.026**	0.015**	0.020**	0.018**	0.007	0.007
	(2.71)	(3.71)	(2.00)	(2.85)	(2.57)	(1.08)	(1.08)

* *t*-statistic in parentheses.

** Significant at the 95% confidence level.

Table V

Values of X': Final 1,220 Observations

Filter	Belgian Franc	Canadian Dollar	Deutsche Mark	French Franc	Italian Lira	Japanese Yen
0.5%	0.009*	0.012**	0.008	0.013*	0.022*,**	0.020**
1%	0.017*,**	0.012**	0.014**	0.014*,**	0.015*,**	0.027**
2%	0.010	0.004*	0.008*	0.006*	0.00	0.010*
3%	0.006*	0	0	0.005*	0.003	0.010
4%	−0.001	−0.003	−0.001*	0.005*	0.005	0.009
5%	0.001	0.004	−0.002*	−0.005*	−0.004	0.018**
10%	−0.008	0	0.007	−0.016	0	0.022**
$\Sigma/7$	0.005	0.004	0.005	0.003	0.006	0.017
$\Sigma{\neq}/N$	0.008	0.004	0.002	0.006	0.019	0.010
$\Sigma/3$	0.011	0.007	0.002	0.005	0.010	0.016

Filter		Swiss Franc	Swedish Krone	Spanish Peseta	U.K. Pound Sterling
0.5%		0.015	0.009	0.018	0.019**
1%		0.023*,**	0.015*,**	0.019**	0.026**
2%		0.012	0.009	0.023**	0.015*,**
3%		0.019	0.003	0.015	0.020*,**
4%		0.015	0.009*	0.011	0.018**
5%		−0.002	0.002*	0.006	0.007
10%		−0.002	−0.014	0.002	0.007
	$\Sigma/7$	0.011	0.005	0.013	0.016
	$\Sigma{\neq}/N$	0.023	0.009	0.000	0.018
	$\Sigma/3$	0.017	0.009	0.019	0.020

* Rules that for this country generated *positive* values of X' significant at the 95% confidence level in the first 610 observations (22 did so).

** Rules that for this country generated *positive* values of X' significant at the 95% confidence level in the last 1,220 observations (20 did so).

period are also significant in the second. However, 15 rules were significant in the first period but not in the second, while there were 12 rules significant in the second period but not the first. Two further counts may be more revealing. The row "$\Sigma \neq/N$" shows the second period's average X' values for rules that were significant in the first period. In other words, suppose the first period's significant rules were used in the second period. For every country, $\Sigma \neq/N$ is positive. As a second experiment, for each country pick the three best rules in Table III, based on X' values, and use these in the second period. The resulting average X' values for the second period are shown in the row for $\Sigma/3$. For every country, $\Sigma/3$ is positive, and $\Sigma/3 > \Sigma/7$ for every country but Germany and Japan.

Finally, Table VI shows the average t-statistic across countries for each filter size. It is clear that smaller filters work somewhat better in the later than earlier period. If a finite variance exists for each exchange rate, the t-statistic for each is distributed $N(0, 1)$. Because the t-statistics should show no correlation across countries for the same filter,[16] the overall significance of the profits across countries from any filter can be tested by looking at the average t-statistic, $\bar{t}$, which is distributed $N(0, 1/N^{1/2})$ where N is the number of countries (10 in this case). The t-statistics for this test of $\bar{t}$ for each filter are in the third row of Table VI. For all filters of 4% or less, the profits are significant.

IV. Are Filter Rule Excess Profits Explicable by Risk?

A number of authors, e.g., Cornell and Dietrich [5], and Levich [17], have conjectured that existence of observed filter rule profits may be due to the risk involved in speculative efforts to exploit them (which would reduce them as a side effect). Indeed, this risk has sometimes been cast in the CAPM framework.

Cornell and Dietrich [5] estimated betas (b) for various currencies relative to the dollar in hopes of explaining their filter rule profits (Table VII). They argue that, in their tests, "... none of the rules led to annual profits of over 4% in the case of the British pound, Canadian dollar, or Japanese yen ... For the German mark, Dutch guilder, and Swiss franc ... the situation was quite different". This passage, however, fails to focus on the difference between the return to the filter rule versus buy-and-hold. The key issue is not how well the filter rule did, but how it did relative to buy-and-hold. Column (3) shows that, contrary to Cornell and Dietrich, filter rules did an impressive job for the mark and guilder *and also* the pound and yen vis-à-vis buy-and-hold, but *not* for the Swiss franc. Cornell and Dietrich go on to argue that "[o]ne 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 ... [M]odern finance theory indicates that only undiversified risk must be compensated for via higher expected rates of re-

[16] Movements in exchange rates are correlated, as are rates of return on equities in, say, the U.S. Nevertheless, excess rates of return on filter strategies should be virtually uncorrelated because the in-out positions are only randomly synchronized across currencies. For example, if the DM rises and the 1% filter has the investor "in," the yen may also rise but the speculator is equally likely to be "out" or "in" the yen: For details as applied to U.S. equities, see Sweeney [23].

Table VI

Average t-Statistics for X' for Various Filters

	0.5%	1%	2%	3%	4%	5%	10%
First 610 observations	1.49	1.75	1.95	1.59	1.53	1.27	0.15
Final 1,220 observations	2.09	2.58	1.28	1.03	0.87	0.42	−0.27
Final 1,220 observations; t-statistic multiplied by $\sqrt{10}$	6.60	8.15	4.05	3.26	2.75	1.33	−0.85

Table VII

Filter Rule Profits and Beta Risk

Currency	(1) Annual Rate of Return From Filter Rule, Net of Transactions Costs	(2) Annual Rate of Return from Buy-and-Hold	(3) = (1–2)	(4) $\hat{b}$	(5) $t(\hat{b})$
British pound	1.9	−6.4	8.3	0.03	0.85
Canadian dollar	1.4	−1.4	2.8	−0.003	0.22
Dutch guilder	13.0	4.8	8.2	0.12	2.18
German mark	15.7	4.3	11.4	0.11	1.85
Japanese yen	2.5	−4.6	7.1	0.08	1.71
Swiss franc	10.2	8.3	1.9	0.05	0.72

Source: Based on Tables 3 and 5, Cornell and Dietrich [5, pp. 116–17]. For (1), they report the *highest* rate. They do not compute (3).

turn . . . " They then provide the estimated betas and t-statistics in columns (4) and (5).

In conjunction with the risk premium on the market, $\hat{b}$ can be used to explain the buy-and-hold returns in (2). As a best guess, $\bar{R}_{BH}$ equals $\bar{r}_d + \hat{b}(\bar{R}_M - \bar{r}_d)$, where $\bar{R}_M$ is the sample return on the market and $\bar{r}_d$ the average risk-free rate. If $\bar{R}_F$ is measured over N_{in} rather than N (as in Section I), the best guess for $\bar{R}_F$ is *also* $\bar{r}_d + \hat{b}(\bar{R}_M - \bar{r}_d)$.[17,18] Thus, b can "explain" both columns (1) and (2) but cannot explain their difference, column (3). The issue is whether (3) is significantly different from zero, and judging this requires an explicit statistical test, such as Section I developed. The CAPM cannot "explain" (3), but worse, any significant values in (3) call for rejecting the CAPM since it predicts zero values in (3).

V. Conclusions

Major exchange markets showed grave signs of inefficiency over the first 1,830 days of the generalized managed floating that began in March 1973. This paper

[17] See footnote 6.

[18] As in footnote 3, this assumes the market model intercept is zero. Alternatively, one could use its estimate, $\hat{a}$, to form a best guess of R_{BH} as $\hat{a} + \hat{b}\,(\bar{R}_M - \bar{r}_d)$, and of R_F over N_{in} days as $\hat{a} + \hat{b}\,(\bar{R}_M - \bar{r}_d)$. This again, gives a best-guess difference of zero.

develops a test of the significance of filter rule profits that explicitly assumes constant risk/return trade-offs due to constant risk premia. While the test is discussed in terms of Sharpe-Lintner CAPM, it is fully consistent with Breeden or Merton CAPMs or with APMs. Excess filter rule returns over buy-and-hold are not explicable in terms of risk as modelled within CAPMs or APMs.

If one decides to judge filter rule profits on the basis of average daily rates of return versus buy-and-hold, it is theoretically more sound to use percentage exchange rate changes net of the interest rate differential, rather than just the percentage exchange rate changes themselves. However, there are instances when it does not matter which measure is used. In particular, if the interest differential is a constant, the two tests are identical. In the test performed on 1,289 daily observations of the dollar-DM exchange rate, net of the federal funds, and overnight Frankfurt interbank loan rate differential, both tests give virtually identical results, that the filter profits are often substantial and sometimes statistically significantly better than buy-and-hold's returns. While the differential is not constant, its day-to-day variability is orders of magnitude smaller than the percentage change in the exchange rate's and its average for "days in" versus "days out" is quite close. For practical purposes, then, the differential can be taken as constant and either test used. This seems likely to be the case in all of the major exchange markets under floating. This result is a great convenience, since it says filter tests need only look at exchange rates, and not also at the differentials which are more difficult to gather.

Some authors have argued that the filter profits found in exchange markets are explicable in light of the speculative risk involved in earning them and may perhaps not be excessive or indicative of inefficiency. Indeed, it is sometimes suggested that this issue should be looked at in terms of the CAPM. As shown previously, however, the CAPM explains returns to buy-and-hold, and to the filter, and implies that expected excess returns to the filter over buy-and-hold should equal zero. Thus, the significant returns previously found, rather than being explicable in terms of the CAPM, are evidence for rejecting the hypothesis that the CAPM describes exchange markets.

This evidence of excess speculative returns says nothing about why these returns exist. Two classes of explanations are of interest. One accepts the evidence of significant speculative profits and inefficiency, while the other class retains the efficient market hypothesis by explaining measured profits in terms of time-varying risk premia.

Discussions of exchange market behavior suggest three hypotheses to explain speculative profits and inefficiency. First, many policy discussions view exchange markets as subject to greater or lesser destabilizing speculation. Woo [28] has developed evidence of speculative "bubbles." He uses a rational expectations model where an explosive root governs exchange rate movements for a time. A difficulty with such a model is that knowledge of eventual shift to a stable path is inconsistent with the model's description of even temporary movement along an explosive path.

Second, the present generalized managed float has involved a great, although varying, amount of management. Ill-conceived government intervention can create profit opportunities such as those found above. There is substantial evidence suggesting at least some intervention to lean against the wind (Dornbusch [8], Genberg [15], Branson [3]). Some studies argue that central banks lose money on their intervention, and hence their actions are destabilizing (Taylor [27]). Whether this is so is a complicated and controversial issue, with definitive results not yet available (Federal Reserve Bulletin [12], Argy [2]). If appropriate data were made publicly available, the issue could be convincingly investigated along lines somewhat similar to those used previously. For example, suppose an exchange stabilization fund intervenes only with U.S. dollars. If one has daily figures on the fund's holdings of dollars and home currency, a statistic similar to the X statistic can be calculated and tested (Sweeney [25]). Significantly positive results would suggest the fund was stabilizing the exchange rate and reducing measured profits; further intervention might be beneficial. Significant negative results would suggest the fund contributed to the measured profits and that its intervention was counterproductive.

Third, the potential profits may be due to insufficient stabilizing speculation. Of course, in one sense this must be true, for with sufficient stabilizing speculative funds, even very great government intervention or private destabilizing speculation should leave no trace of profits in the data. However, some who hold this hypothesis point particularly to restrictions on the open positions that bank exchange traders can take. These restrictions are often imposed by the banks themselves, but many times with at least informal pressure by regulators. With access to daily data on banks' exchange positions, a test similar to that described for governments could be done (although this is more complicated with a portfolio of currencies). Significant positive results for such a test would suggest that increased activity by banks would reduce measured profits at the margin (while significant negative results would suggest that banks contribute to destabilizing the exchanges).

It is possible to reconcile this paper's results with generally held views of the efficient market hypothesis by asserting that risk premia vary over time, and hence expected returns both to the filter and to buy-and-hold also vary with time. In this view, the filter on average puts the investor "in" the foreign currency when the risk premia and hence the expected returns are larger than average. Positive X's are then a reflection of higher average risk borne, not true profits. This view can be tested if one is willing to specify a particular asset model and find estimates of premia. Fama [10], Hodrick and Srivasatava [16], and Sweeney [24] report evidence that risk premia in forward exchange rates vary over time; such premia are intimately related to the premia involved in spot market speculation.[19] Sweeney [22] reports preliminary results, using a single-period

[19] Assuming interest rate parity holds, as it does to a good approximation for *Euro* rates, speculative positions in the forward market are equivalent to borrowing and lending in the two currencies and taking a spot market position (if the transactions costs of borrowing and lending are neglected). The variable $u + r_f - r_d$, used in the text for spot market speculation, can be thought of as arising from borrowing dollars at r_d, converting them in the spot market to DMs, and investing the DMs at r_f. Thus, the risk premium in the forward speculation is in principle the same as that in $u + r_f - r_d$. However, the present paper analyzes overnight spot positions while Fama, Hodrick, and Srivastava and Sweeney look at thirty-day forward rates. Hence, the risk premia in these forward rates can only throw indirect light on the premia in overnight spot speculations.

international CAPM, that do not very strongly support the view that variations in risk premia can be used to explain speculative profits in forward markets.

Many more tests of time-varying premia are possible and desirable, in the context of international CAPMs and other APMs. Since any test of efficiency is inevitably a test of a joint hypothesis (e.g., that an international CAPM holds), efficiency can always be preserved as an hypothesis in the face of negative evidence by abandoning other components of the joint hypothesis, as is well known. That is, one can stay a jump ahead of negative evidence, such as that presented here, by embodying efficiency in a joint hypothesis that has yet to be tested. From the practical point of view of evaluation of portfolio performance, one may be forced to proceed on the assumption of inefficiency. The portfolio manager may believe that the measured profits reported above may well be due to time-varying risk premia. But in the absence of measures of the extent to which this is true, a Bayesian manager is going to make some attempts to exploit these profits, i.e., act on the assumption of inefficiency. Indeed, in the absence of evidence that the profits are explicable by time-varying risk premia, the manager who forgoes these measured profits is going to have a hard sale justifying his or her behavior to those who put up the funds (see Dybvig and Ross' [9] example of market timing).

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