Foreign Exchange Market Efficiency

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  - » Pictures of Efficient Markets
  - » Interpreting Efficient Market Studies
  - » Defining the Available Information Set
- Empirical Evidence on Exchange Market Efficiency
  - » Market Efficiency with Certainty and Risk-Free Investment
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  - » Market Efficiency with Uncertainty and Risky Investment
    - ◆ Spot speculation – Profitability of technical trading rules
    - ◆ Forward speculation – Regression tests of forward as predictor, does forward reflect all information, value of professional forecasts

Theory of Market Efficiency

- A capital market is said to be efficient if prices in the market “fully reflect” “available information”.
  - The definition begs two obvious questions:
    - What does the term “fully reflect” mean? How to make precise?
    - What is available information? When and to whom available?
- When the market efficiency condition is satisfied, market participants cannot earn economic profits on the basis of available information.
- The term “fully reflect” implies the existence of equilibrium prices and equilibrium expected returns.

Interpreting Efficient Market Studies

A Key Result

- All tests of market efficiency are tests of a *joint hypothesis*:
  1. the hypothesis that defines market equilibrium prices or returns as some function of the available information set (there is an equilibrium, or benchmark, model)
  2. the hypothesis that market participants have actually set prices or returns "to conform to" their equilibrium expected values.*(We'll be precise about meaning of "to conform to")*
- Corollary of market efficiency
  - » If market is efficient, then no unusual, risk-adjusted profits can be earned based on available information
  - » Begs the question: What are unusual, risk-adjusted profits?

Interpreting Efficient Market Studies

- For studies that reject market efficiency,
  1. It could be that we were using the wrong benchmark model, and that the market actually is efficient. Our extra returns were only added compensation for extra costs of risks, or perhaps the trading model itself was not feasible. **Or**
  2. Our model is right and the market may be inefficient.
- For studies finding evidence consistent with market efficiency,
  1. Critics can object that (a) we are using the wrong benchmark pricing model, or (b) we are using an inadequate trading model.
  2. Consequently, critics can claim that changes in (a) or (b) would change the results, and reveal a market inefficiency.

Defining the Equilibrium Benchmark

- Let $\tilde{r}_{j,t+1}$ be the actual one-period rate of return on asset *j* in the period ending at time *t*+1.
- Let $E(\tilde{r}_{j,t+1} \mid I_t)$ be the expected return conditional on available information *I* at time *t*.
- Then the excess market return

$$Z_{j,t+1} = r_{j,t+1} - E(\tilde{r}_{j,t+1} \mid I_t)$$

- In an efficient market, $E(Z_{j,t+1} \mid I_t) = 0$, and $Z_{j,t}$ is uncorrelated with $Z_{j,t\pm k}$ for any value of *k*.

  $\Rightarrow \{Z_t\}$ is a "fair game" with respect to I_t.

Defining the Equilibrium Benchmark

- Today's price P_t is linked to the expected future price $E(P_{t+1}|I_t)$ as follows :

$$E(P_{t+1} \mid I_t) = [1 + E(\tilde{r}_{t+1} \mid I_t)]P_t$$

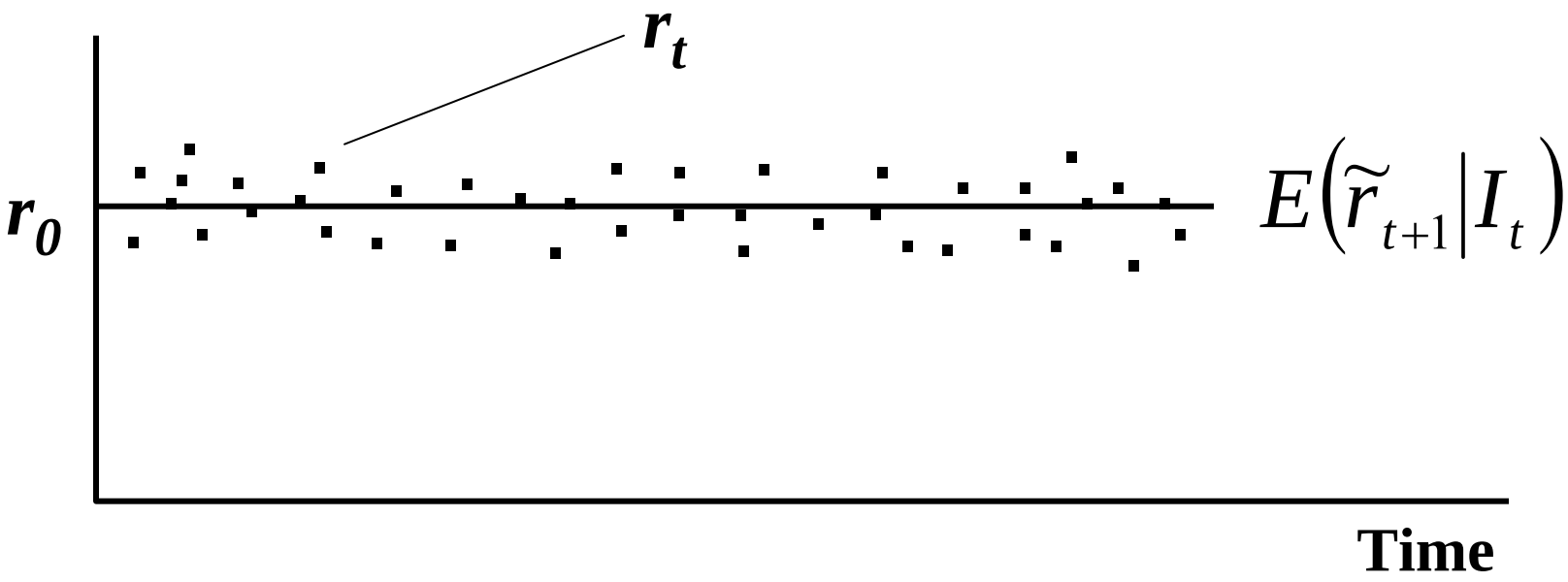
where $E(\tilde{r}_{t+1}|\, I_t)$ is the expected equilibrium return on spot market speculation.

- Market efficiency requires that the sequence of errors in our expectations (X) follows a fair-game process.

$$X_{t+1} = P_{t+1} - E(\tilde{P}_{t+1} \mid I_t)$$

Pictures of Efficient Markets

When the equilibrium expected return is constant ...



Pictures of Efficient Markets

- When prices evolve as a *random walk*, then tomorrow's price (P_{t+1}) is equal to today's price (P_t) augmented by an error term (u_{t+1}).

$$P_{t+1} = P_t \times e^{(r_0 + u_{t+1})}$$

$$\Rightarrow \quad \ln(P_{t+1}) - \ln(P_t) = r_0 + u_{t+1}$$

- $r_0 = 0 \Rightarrow$ prices follow a random walk without drift

  $r_0 \neq 0 \Rightarrow$ prices follow a random walk with drift

Pictures of Efficient Markets

- According to the International Fisher Effect,

$$E\left(\tilde{S}_{t+1}\right) = \frac{\left(1+i_{\$}\right)}{\left(1+i_{£}\right)} \times S_t$$

- If the IFE is augmented with an error term *u*,

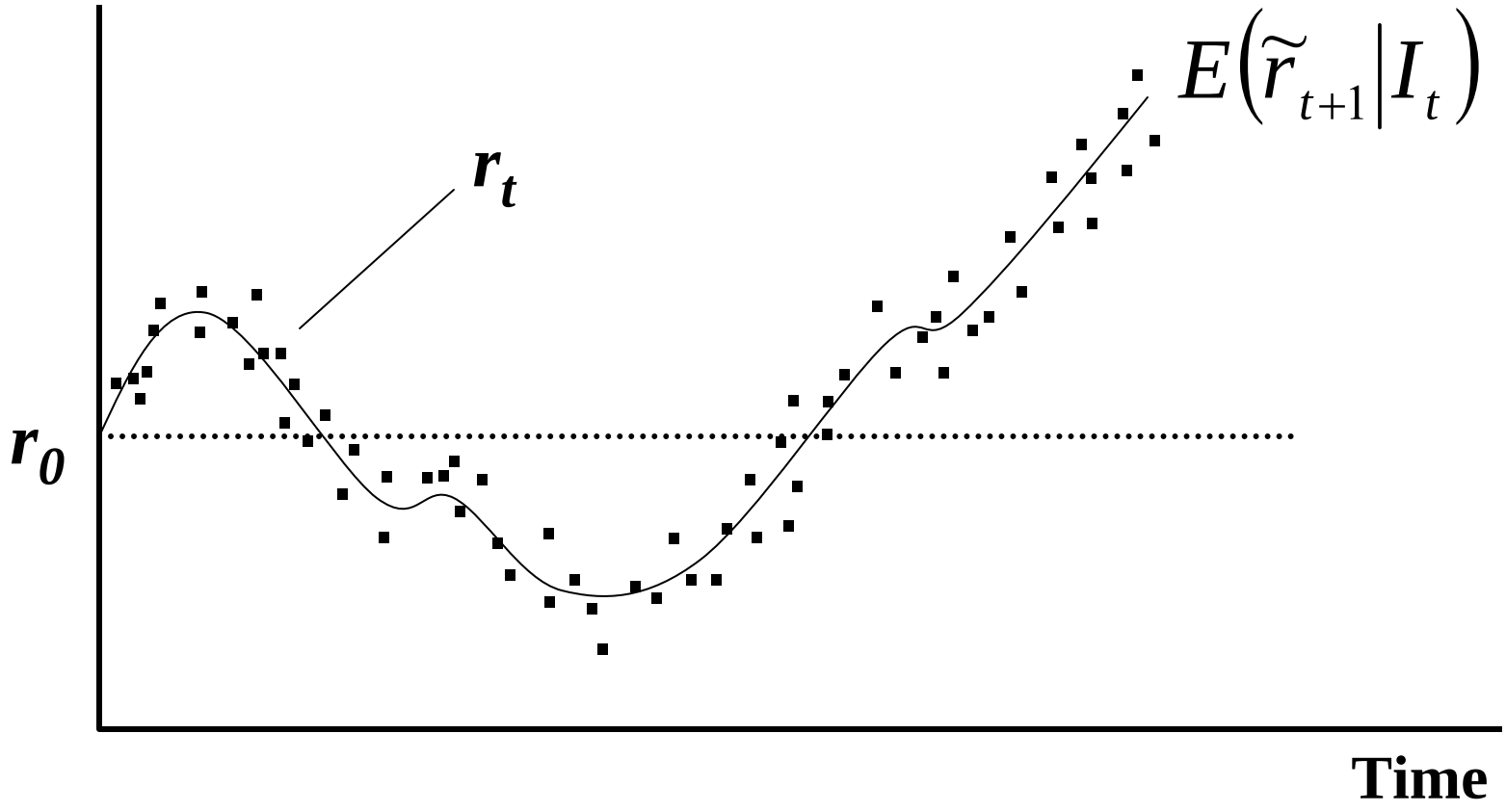
$$S_{t+1} = S_t \times e^{\left[\left(i_{\$} - i_{£}\right) + u_{t+1}\right]}$$

$$\Rightarrow \quad \ln(S_{t+1}) - \ln(S_t) = (i_{\$} - i_{£}) + u_{t+1}$$

- Here, the spot exchange rate follows a random walk with drift equal to the interest differential.

Pictures of Efficient Markets

When the equilibrium expected return wanders substantially ...



Pictures of Efficient Markets

- When the equilibrium expected return wanders substantially over time, efficient market behavior continues to require that actual returns oscillate randomly about expected returns.
- The equilibrium return on a security can wander substantially when a business cycle exists.
  - » Equilibrium return on invested capital changes with time
- The monetary model of the exchange rate can also present cases in which the equilibrium spot exchange rate wanders substantially.
  - » And so equilibrium change in the exchange rate might wander over time, or be correlated (as in overshooting).

Empirical Evidence on Exchange Market Efficiency

- Rather than test whether prices or returns conform to their equilibrium expected values, empirical studies have preferred to test for the availability of unusual or risk-adjusted profit opportunities.
- In the case of certainty or risk-free investments, the equilibrium expected return is zero.
- In the case of uncertainty or risky investments, the equilibrium expected return is some positive level of profit.

Market Efficiency
with Certainty and Risk-Free Investment

- The major testing ground for market efficiency in the case of certainty has been the analysis of covered interest arbitrage.
- Various explanations
  - » transaction costs,
  - » non-comparable risk in securities,
  - » exchange controls,
  - » political risk, and
  - » taxes

  have been shown to account for most all observed parity deviations, suggesting that covered interest arbitrage profit opportunities are more apparent than real.

Market Efficiency
with Uncertainty and Risky Investment

- There are basically two techniques for bearing exchange risk:
  - » Spot speculation and forward speculation
  - » In equilibrium, the returns on each type are identical
  - » Investor choice is driven by cost, convenience, regulation
- The primary test for spot market efficiency has been to compute the profitability of various technical trading strategies, such as the *filter* and *moving average crossover rules*.
- Studies suggest that most technical models resulted in profitable trading strategies even after adjusting for transaction costs.

Technical, Trend-Following Rules

- Technical analysis in FX is based to a great extent on assumed persistence in exchange rate movements
  - » Persistence $\Rightarrow$ positive correlation of changes
  - » Trend identification through filter rule, moving average cross-over rule, other rules
- Because exchange rate history is public information, should not be useful for designing a profitable trading strategy. $(i - i^*)$ should offset $E(\Delta S_{t+n})$
- Note well: Market efficiency does not preclude patterns in exchange rates. Market efficiency precludes the existence of exploiting any knowledge of patterns for earning unusual profits.

Mechanics of Simple Technical Trading Rules

- Filter Rule – A one parameter rule, the filter size *f*
  - » Buy Signal: $S(t) > (1 + f)\, S(Min^*,t)$
  - » Sell Signal: $S(t) < (1 - f)\, S(Max^*,t)$

  where $S(Min^*,t)$ = most recent trough price

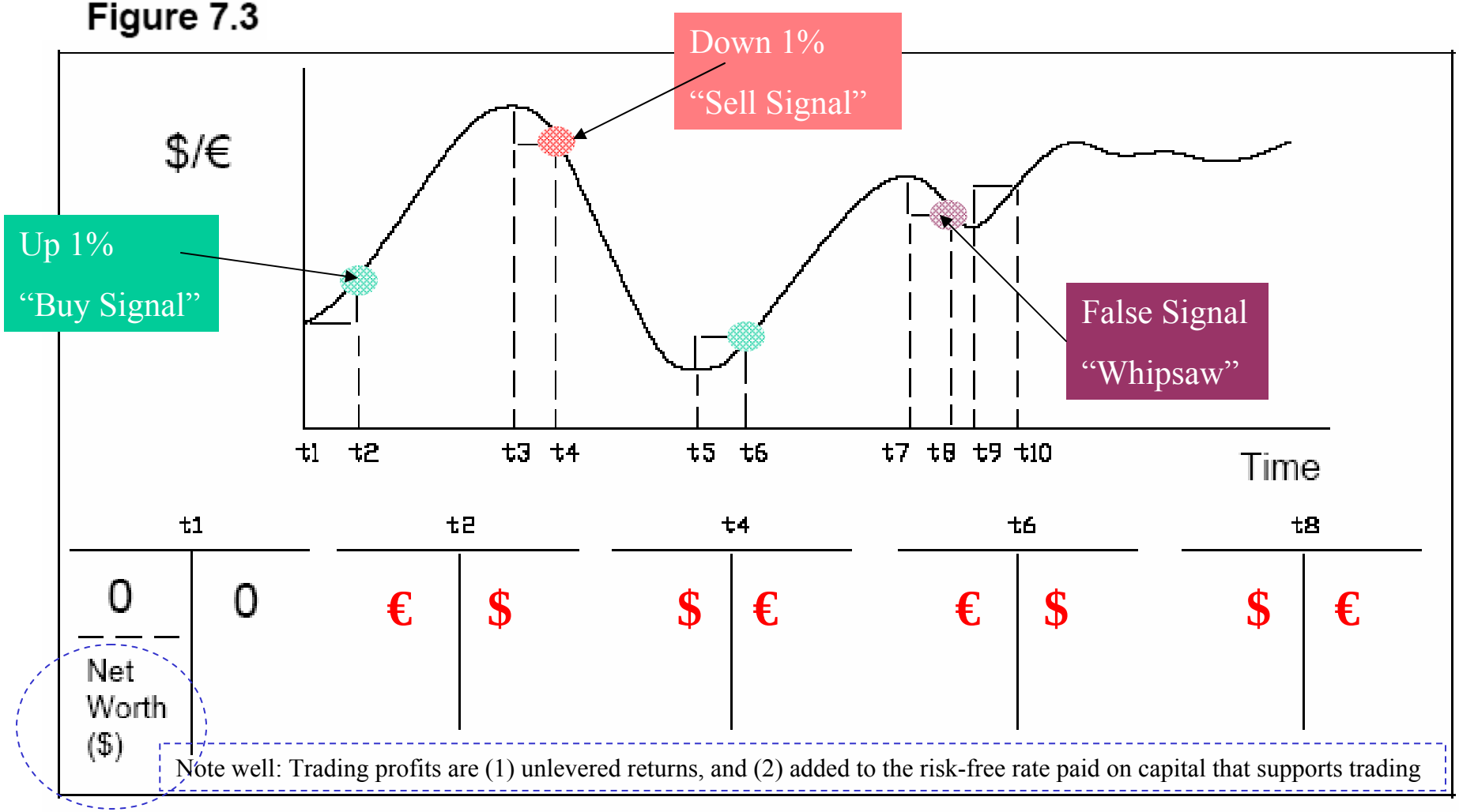
  and $S(Max^*,t)$ = most recent peak price
- Moving Average Crossover Rule – A two parameter rule
  - » Buy Signal: $MA(S,t) > MA(L,t)$
  - » Sell Signal: $MA(S,t) < MA(L,t)$

  where $MA(S,t)$ = Short-term moving average at time *t*

  and $MA(L,t)$ = Long-term moving average at time *t*
  - » Note: $MA(5,t) = [S(t-1) + S(t-2) + S(t-3) + S(t-4) + S(t-5)]/5$

Mechanics of a Filter Rules in the Foreign Exchange Market

Figure 7.3

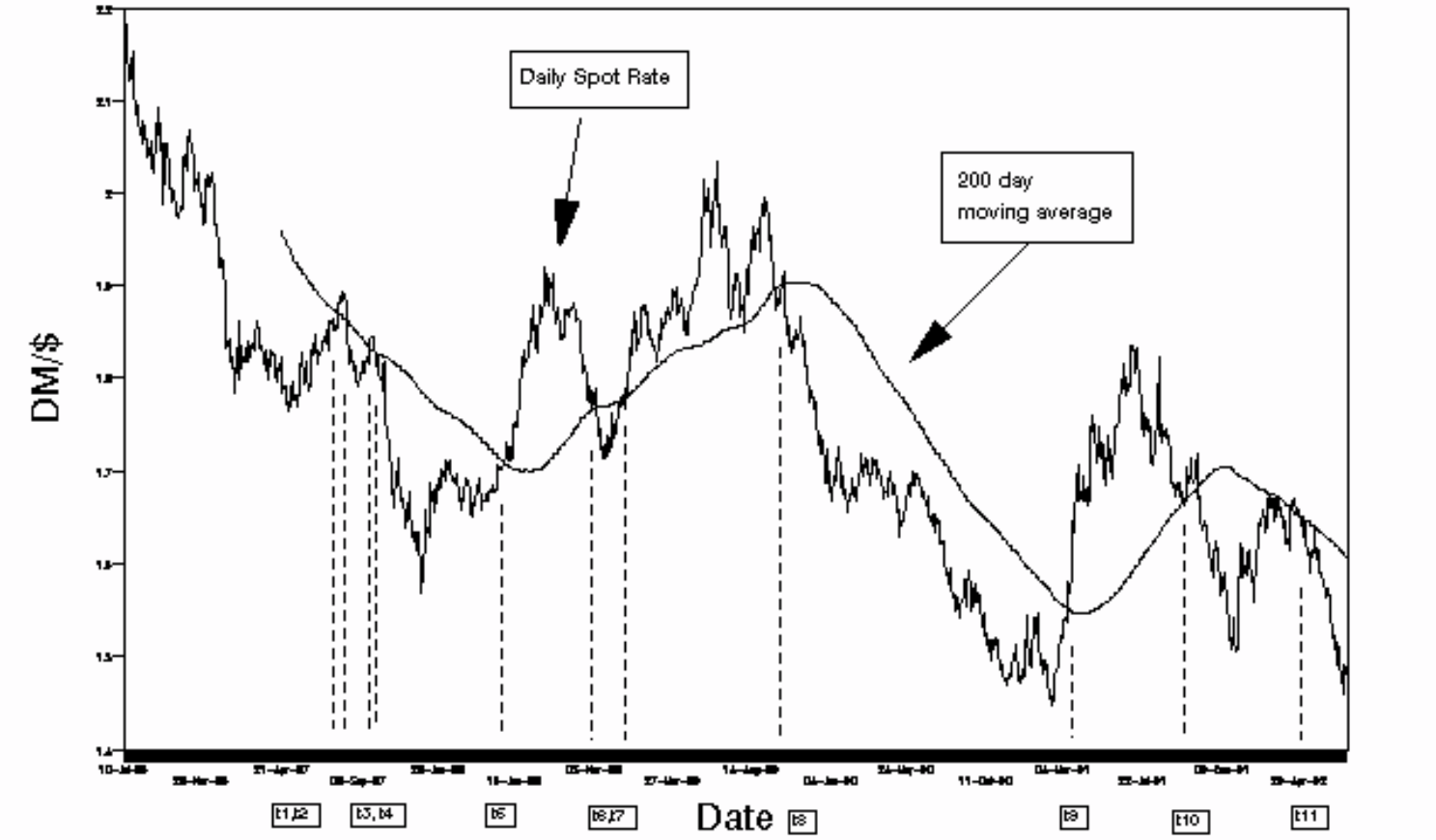


Defining Profits in Technical Trading Rules

- Profit on a long position = % Revenue - % Cost
  - » Assumption: Buy FC against USD at time *t1*; Sell FC at time *t2*
  - » % Revenue = ln [S(t2) / S(t1)]
  - » % Cost = $\sum_{t1}^{t2}(i_{t,USD} - i_{t,FC})$
- Profit on a short position = % Revenue - % Cost
  - » Assumption: Sell FC against USD at time *t3*; Buy FC at time *t4*
  - » % Revenue = ln [S(t3) / S(t4)]
  - » % Cost = $\sum_{t3}^{t4}(i_{t,FC} - i_{t,USD})$
- Null hypothesis: E(Profit) = 0 in an efficient market

Illustration of 1/200 MA Crossover Rule

DM Spot (Daily): 7/10/86 – 7/23/92



Note:A *moving average crossover rule* generates buy signals when the short-term moving average rises above the long-term moving average (at points like t_1, t_3 and t_5), and sell signals when the short-term moving average drops below the long-term moving average (at points like t_2, t_4 and t_6).

Profitability of Filter Rules and Moving Average Rules

Percent Per Annum, Sample Period, January 1976 - December 1990)

Currency Sample Size	Filter Size (in %) 0.5	1.0	2.0	3.0	4.0	5.0	Average Profit	Moving Average: Short-term (days)/Long-term(days) 1/5	5/20	1/200	Average Profit
DM (N=3786)											
Actual Profit	1.9	8.9	5.6	7.7	7.8	7.9	6.6	5.6	11.1	7.6	8.1
No. of Trades	833	411	193	99	62	41		950	212	79	
Rank in 10,000	7652	9998	9808	9975	9981	9991		9786	10000	9990	
BP (N=3786)											
Actual Profit	10.0	6.6	6.2	7.8	6.7	4.9	7.0	8.1	8.8	9.4	8.8
No. of Trades	793	432	192	108	69	53		935	192	42	
Rank in 10,000	9994	9852	9850	9961	9907	9609		9975	9987	9993	
CD (N=3785)											
Actual Profit	2.9	3.5	1.4	0.7	1.5	1.0	1.8	3.1	2.6	2.1	2.6
No. of Trades	309	119	51	28	15	11		957	190	91	
Rank in 10,000	9969	9989	9089	7845	9317	8672		9977	9917	9804	
JY (N=3533)											
Actual Profit	6.7	7.8	8.0	7.3	10.2	8.5	8.1	7.8	10.5	8.7	9.0
No. of Trades	777	412	170	98	60	44		866	190	87	
Rank in 10,000	9883	9965	9973	9945	9997	9987		9957	10000	9994	
SF (N=3786)											
Actual Profit	7.2	6.5	3.4	7.1	9.8	5.8	6.6	7.5	4.4	8.7	6.9
No. of Trades	907	541	253	127	78	64		975	213	71	
Rank in 10,000	9873	9808	9680	9872	9991	9702		9912	9235	9987	

Source: Reprinted from Richard M. Levich and Lee R. Thomas, "The Significance of Technical Trading-Rule Profits in the Foreign Exchange Markets: A Bootstrap Approach," Journal of International Money and Finance, Vol. 12, No. 5, October 1993, pp. 451-74 with kind permission of Elsevier Science Ltd, Kidlington, UK.

How to Explain Technical Trading Profits?

- Could central bank intervention in the FX market be a factor? (Silber 1991, Neely 1998)
- Past results may be an aberration. Technical trading profits may be declining. (Park and Irwin, 2005; Neely, Weller and Ulrich, 2007)
  - » But not every study agrees
- Trading profits are non-normally distributed
  - » Duration of profitable positions exceeds duration of unprofitable positions. (Schulmeister, 2005)
- Exchange rate changes may not be random. Look for non-linear relationships. (Bilson, 1990)

Moving Average Trading Rules in Currency Futures and Other Futures Markets

Table 7.5	(1) Number of Years	(2) Average Annual Returns	(3) Standard Deviation of Returns	(4) Sharpe Ratio [(2)/(3)]	(5) Average Trades per Year	(6) Average Annual Returns After Transaction Costs	(7) T-Statistic on Column 6 Returns	(8) Average Annual Returns: Buy and Roll Over	(9) Sharpe Ratio [(6)/(3)]
German Mark	12	0.0980	0.1176	0.8333	17.08	0.0937	2.72	-0.0197	0.797
3-Month Eurodollar	8	0.0034	0.0038	0.8947	16.75	0.00298	2.53	0.0036	0.785
Swiss Franc	12	0.10103	0.1311	0.7727	12.25	0.0982	2.67	-0.0268	0.749
Japanese Yen	12	0.0742	0.1112	0.6673	17.08	0.0699	2.17	0.020	0.629
British Pound	12	0.0580	0.1198	0.4841	16.58	0.0539	1.55	0.0047	0.4495
Canadian $	12	0.0253	0.0429	0.5897	25.50	0.0189	1.52	0.0148	0.441
Crude Oil	7	0.199	0.4151	0.479	31.71	0.1673	1.07	0.117	0.403
3-Month Sterling	8	0.0024	0.0054	0.4444	28.63	0.00168	0.88	-0.0046	0.312
U.S. T-Bonds	12	0.0450	0.1406	0.3201	24.42	0.0377	0.93	0.0371	0.267
Silver	11	-0.003	0.3159	-0.009	30.18	-0.0271	-0.28	-0.2224	-0.086
Gold	12	-0.0270	0.2337	-0.1155	18.92	-0.0364	-0.54	-0.121	-0.15
S&P 500	8	-0.1120	0.2195	-0.5103	15.88	-0.1152	-1.48	0.0672	-0.524

Note: All tests are on futures contracts. Calculations based on daily data. Moving average crossover rules, MA(i,j), are analyzed over all combinations i = 1, 2,... 15; j = 16, 18, 20,..., 200. Best rule in year *t* is applied in year *t+1*. Analysis of best rule is updated annually.

Source: William L. Silber, "Technical Trading: When It Works and When It Doesn't," Journal of Derivatives, Spring 1994.

Government Intervention and Technical Trading Profits

MA (1,150) Trading Rule Results, March 1, 1973 to December 31, 1996.

		$/DM	$/JY
Panel A: All observations	N	5982	5982
	100*AR	5.64	8.41
	100*std.	0.67	0.62
	t statistic	2.60	4.20
	Sharpe	0.53	0.86
	trades per year	6.84	4.49
	p-value	0.00	0.00
Panel B: Observations excluding days of U.S. intervention	N	5016	5740
	100*AR	4.54	8.01
	100*std.	0.67	0.61
	t statistic	1.91	3.98
	Sharpe	0.43	0.83
	trades per year	7.35	4.59
	p-value	0.01	0.00
	Markov *p*-value	0.12	0.17
Panel C: Observations excluding days prior to U.S. intervention	N	5015	5739
	100*AR	1.19	5.50
	100*std.	0.64	0.60
	t statistic	0.52	2.78
	Sharpe	0.12	0.58
	trades per year	7.46	4.68
	p-value	0.16	0.04
	Markov *p*-value	0.00	0.00

NOTES: N denotes the number of observations. The difference between the number of observations in panels A and B is not equal to the number of in-market interventions because some interventions occurred on days when the exchange rate was missing. 100*AR is the annual return in percentage terms, and 100*Std is the standard deviation of the series in percentage terms. The *t* statistic tests the null hypothesis that the mean excess return is zero. *P*-value is the fraction of randomly drawn returns that would have a mean at least as large as the mean return generated by the trading rule. Panel B excludes returns from *t* to *t+1* when the U.S. authorities intervene on day *t*. Panel C excludes returns from *t-1* to *t* when the U.S. authorities intervene on day *t*. The row labeled Markov *p*-value is the fraction of samples with simulated intervention series whose returns were lower than those produced by removing actual intervention series on either the day of intervention or the day prior to intervention.

- Panel B: Excludes all those trading days when US intervention takes place. Small downward impact on trading profits. T-statistics still significant.
- Panel C: Excludes all those trading days *prior to* the day of US intervention. Larger downward impact on trading profits. T-statistic on $/DM no longer significant, $/¥ still significant.

Interpretations:

- US central bank may be creating predictable price patterns in otherwise efficient markets. Their actions transfer money from authorities to technical traders
- Official intervention and predictable trends in currencies are driven by common factors – i,e, intervention tends to occur when market are trending, but it does not necessarily cause the trending behavior.

Source: Christopher J. Neely, "Technical Analysis and the Profitability of U.S. Foreign Exchange Intervention," *Review*, Federal Reserve Bank of St. Louis, July/August 1998, pp. 3-17.

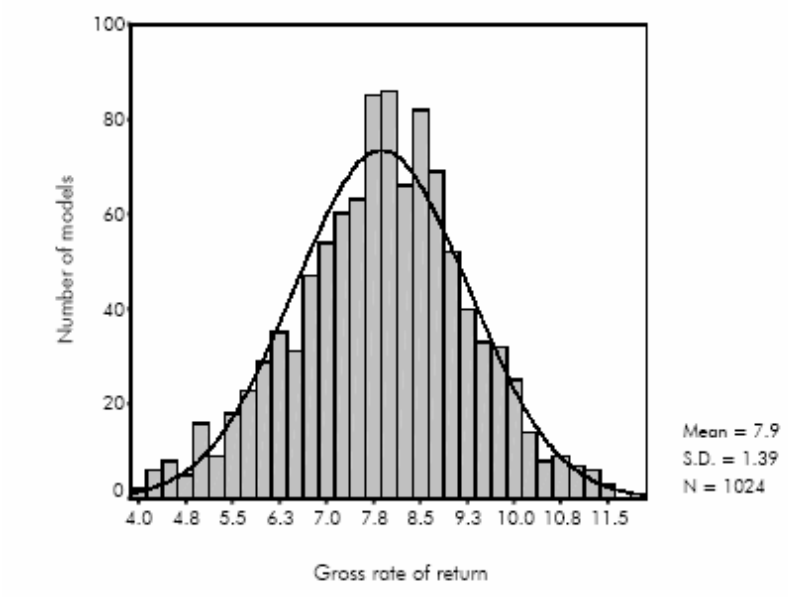
Attributes of Profitable Technical Currency Trading

- Schulmeister (2005) examines 1,024 moving average and momentum model on DM (Euro) vs. USD using daily data, 1973-99, and out of sample, 2000-04.
  - » Each model profitable over the entire sample period, 91.7% remained profitable in 2000-04.
  - » The number of profitable trades is lower than the number of unprofitable trades.
  - » The average return per day during profitable positions is smaller than the average loss per day during unprofitable positions.
  - » Profitable positions last 3 to 5 times longer than unprofitable positions. Hence, the overall profitability of technical currency trading is exclusively due to the exploitation of persistent exchange rate trends.
  - » The profitability of technical trading has been significantly lower since the late 1980s as compared to the first 15 years of the floating rate period.

Attributes of Profitable Technical Currency Trading

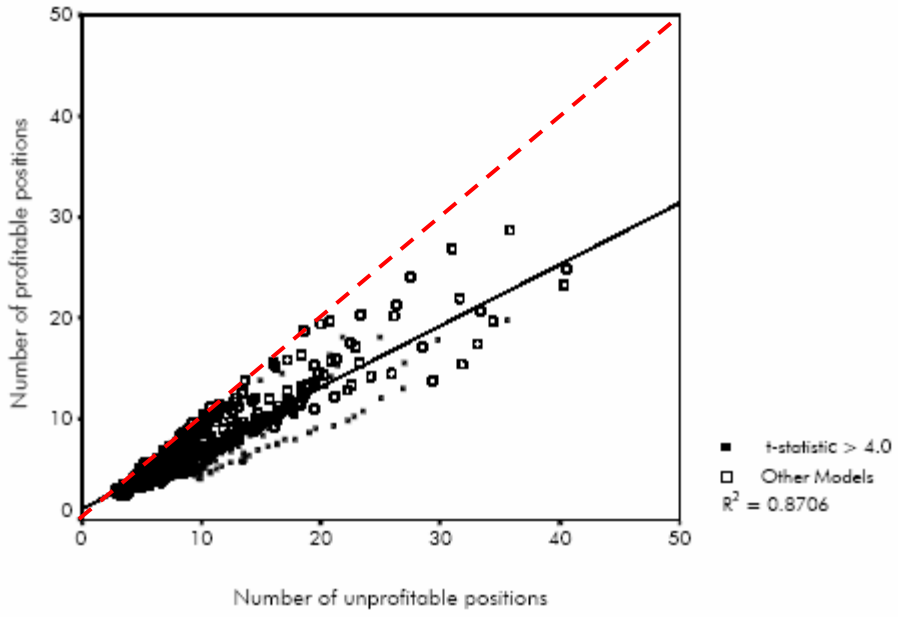
Distribution of 1024 trading systems by the gross rate of return, DM/dollar trading 1973-99

- The mean return for all rules was 7.9% p.a.



Frequency of profitable and unprofitable positions, DM/dollar trading 1973-99

- Almost all rules experienced more unprofitable than profitable positions.

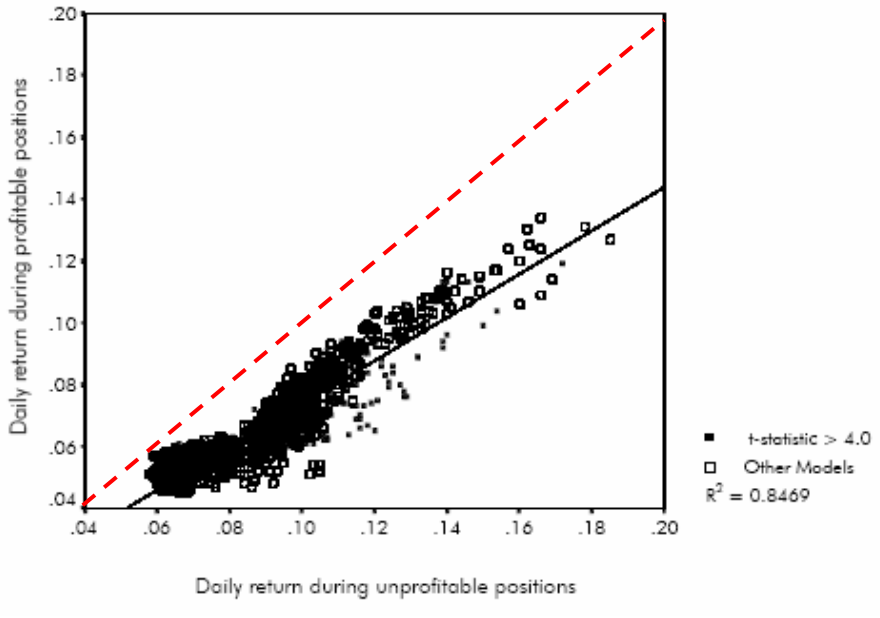


Source: Schulmeister (2005)

Attributes of Profitable Technical Currency Trading

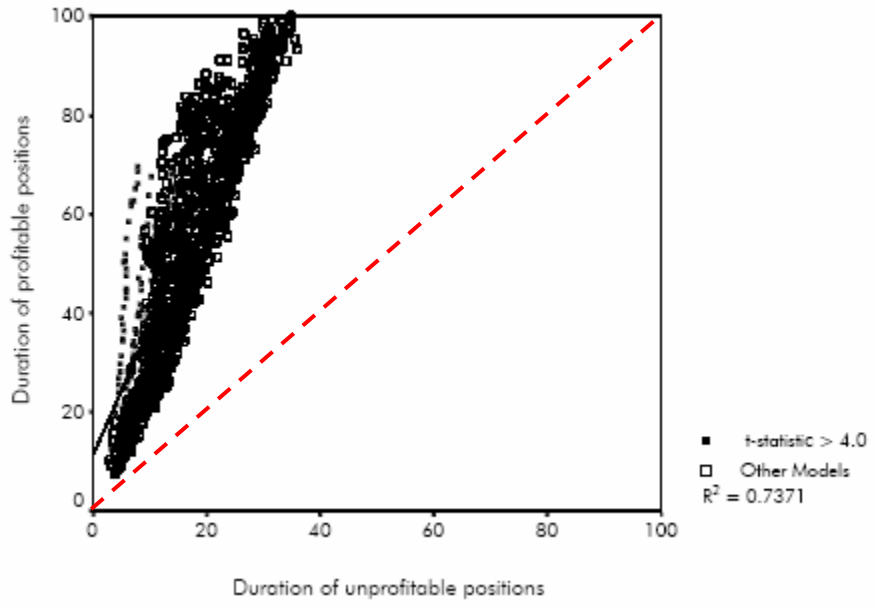
Average daily return during profitable and unprofitable positions, DM/dollar trading 1973-99

- Per day profits generally < per day losses



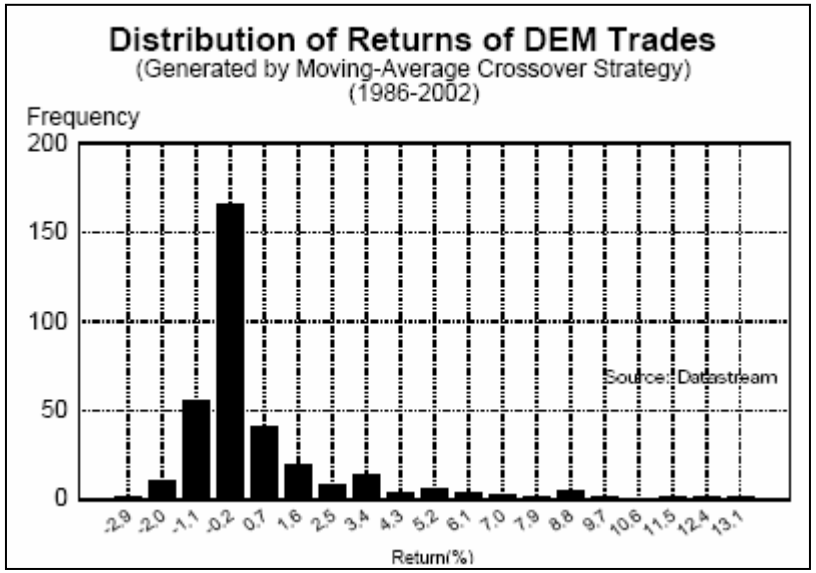
Average duration of profitable and unprofitable positions, DM/dollar trading 1973-99

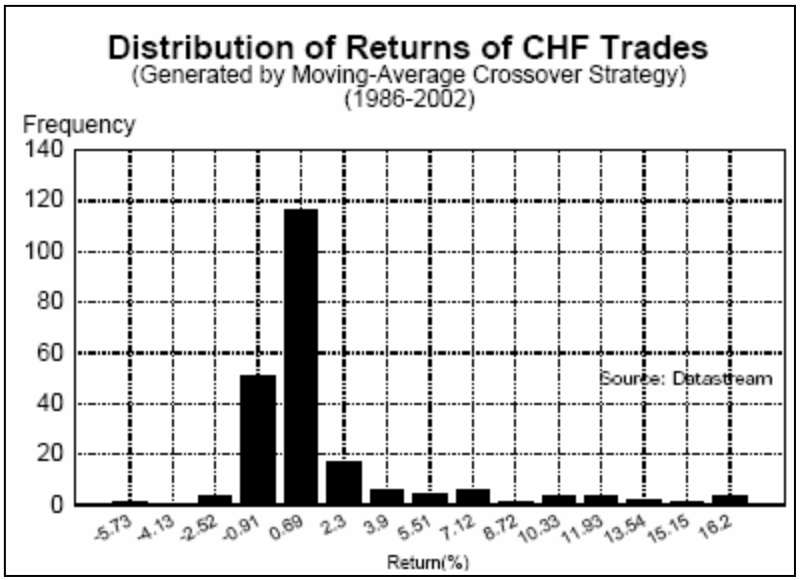
- However, profitable positions generally last 3-4 times longer than unprofitable positions.



Source: Schulmeister (2005)

Distribution of Returns from Moving-Average Trading Rules





"… the overwhelming majority of recommended trades resulted in either small gains or small losses. However, … the distribution of returns is skewed heavily to the right in most cases. … These highly skewed return distributions raise the question whether conventional measures of risk such as standard deviation, Sharpe ratios, and information ratios accurately convey the asymmetric risks facing technically oriented investors, particularly over short horizons."

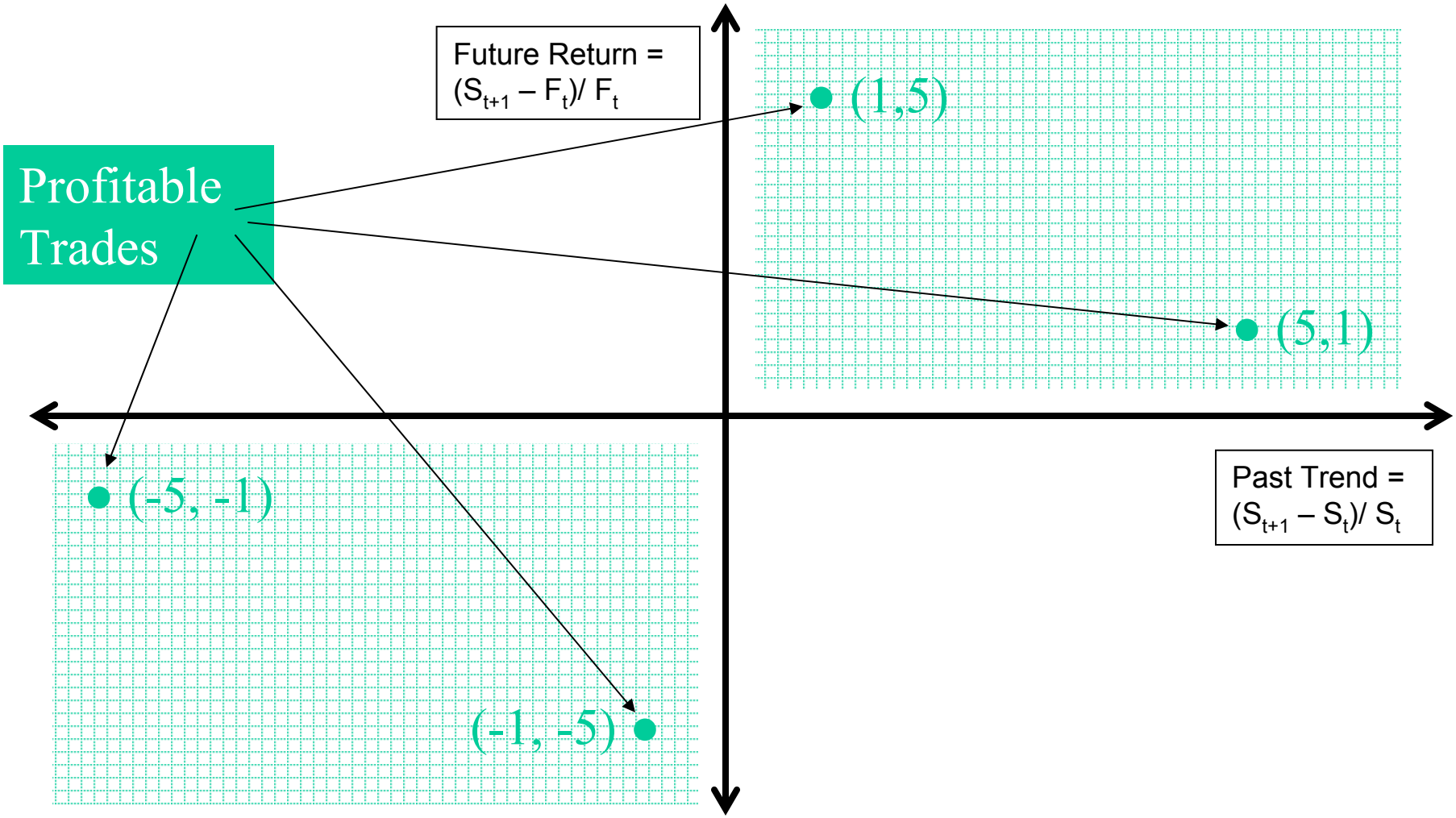
Source: Deutsche Bank Guide to Exchange-Rate Determination, May 2002, p. 18.

Another Puzzle:

Why do some see trends and others do not?

- Many economists believe that exchange rates evolve as a random walk, and many careful econometric studies support the random walk view.
- However, surveys show that foreign exchange traders and speculators rely on trend-following models to gauge near-term movements.
- Why do market professionals observe patterns in exchange rate when econometricians have difficulty finding them?
- Could it be that trend-following rules rely on a very loose relationship between the future and the past, rather than a precise, linear relation?

Are Past Trend and Future Returns Related?



Linear Regressions of Future Trend and Past Trend in Spot Exchange Rates

$$\ln [Spot_t/Spot_{t-1}] = \beta_0 + \beta_1 \ln [Spot_{t-1}/Spot_{t-2}] + \varepsilon_t$$

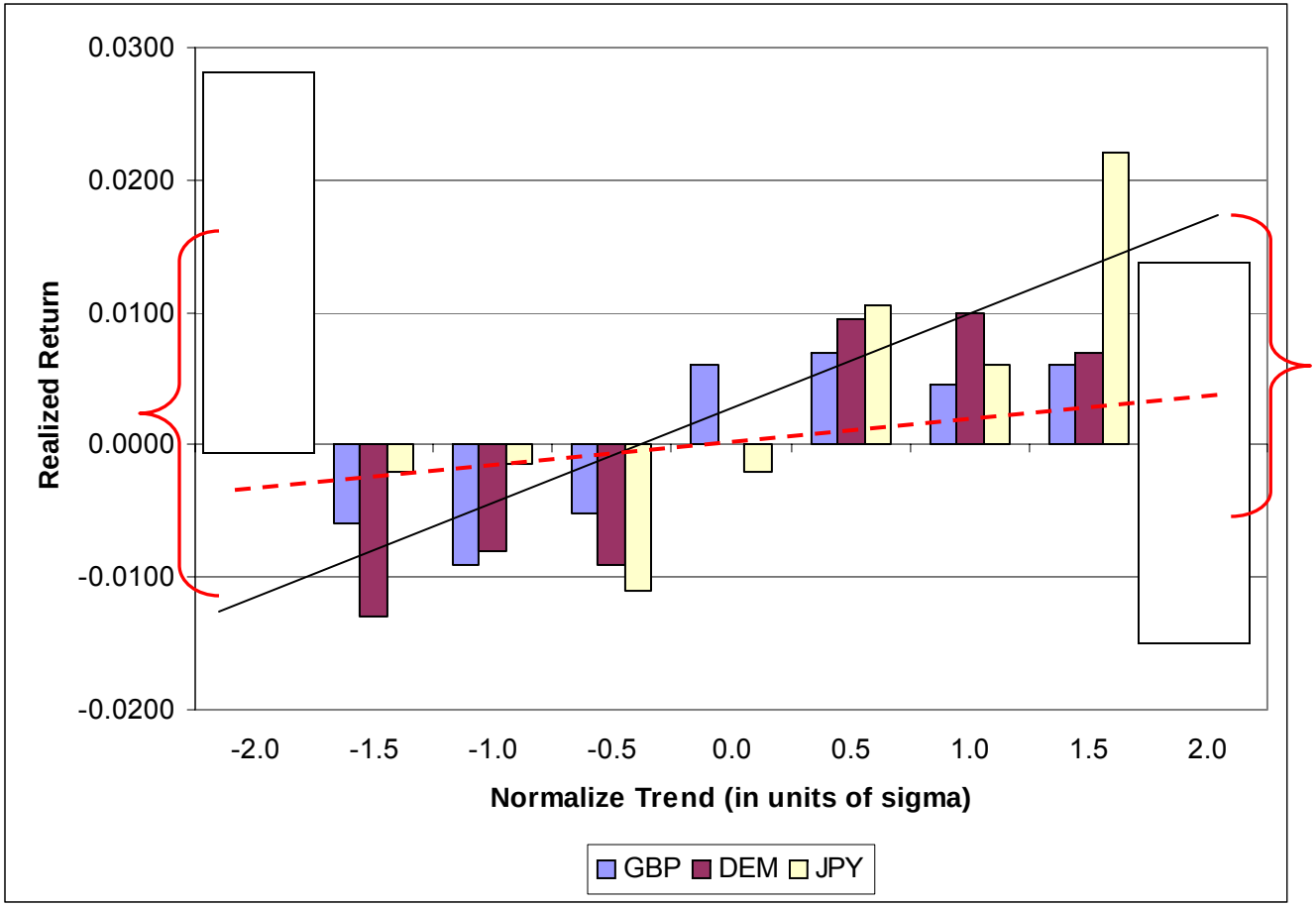
Currency	Interval	N	β_1 (t-ratio)	R^2	F (probability)	D-W	Normality	Heteroscedasticity
DM	1-week	938	0.0378 (1.16)	0.001	1.34 (.248)	2.00	.000	.000
	1-month	216	-0.0073 (0.10)	0.000	0.01 (.915)	2.00	.008	.839
	1-quarter	72	0.0918 (0.76)	0.008	0.57 (.453)	1.90	.538	.735
UK	1-week	938	0.0310 (0.95)	0.001	0.90 (.342)	2.00	.000	.022
	1-month	216	0.1077 (1.59)	0.012	2.51 (.114)	2.01	.003	.147
	1-quarter	72	0.1984 (1.61)	0.036	2.59 (.112)	1.84	.683	.724
JY	1-week	938	0.0729 (2.23)	0.005	4.99 (.026)	2.01	.000	.006
	1-month	216	0.0633 (0.93)	0.004	0.86 (.354)	2.00	.115	.077
	1-quarter	72	0.1364 (1.15)	0.018	1.31 (.256)	1.97	.328	.472
CD	1-week	938	0.0474 (1.45)	0.002	2.11 (.147)	2.00	.000	.065
	1-month	216	-0.0680 (1.00)	0.005	0.99 (.321)	2.01	.000	.811
	1-quarter	72	0.1030 (0.86)	0.011	0.75 (.391)	1.99	.529	.225
SF	1-week	938	0.0139 (0.42)	0.000	0.18 (.671)	2.00	.000	.005
	1-month	216	0.0421 (0.62)	0.002	0.38 (.536)	2.01	.003	.292
	1-quarter	72	0.0364 (0.30)	0.001	0.09 (.765)	1.90	.922	.882

Notes:
1. Sample periods are January 3, 1975 - December 31, 1992 for weekly data; 1975:M1 - 1992:M12 for monthly data; and 1975:Q1 - 1992:Q4 for quarterly data
2. Regressions are estimated using OLS in MICROFIT version 3.0 software. Sample observations are non-overlapping.
3. Normality test is based on skewness and kurtosis of residuals. Statistic reports probability that residuals are normally distributed.
4. Heteroscedasticity test is based on a regression of squared residuals on squared fitted values. Statistic reports probability that residuals are homoscedastic.
5. T-ratio for β_1 in JY, 1-week interval is 1.89 using White's heteroscedastic-consistent estimate of the standard error. The p-value on β_1 is 0.059 with this adjustment.

Linear Regressions of Future Trend and Past Trend in Spot Exchange Rates

- "The dismal R^2 and t-statistics from these regressions could certainly lead a regression analyst to the conclusion that exchange rates evolve as a random walk and that 'technical' studies that purport to prove otherwise must be based on flawed methodology, or worse."
- A problem with regression analysis is that it assumes a proportional relationship. For example, if the exchange rate has gone up by 10%, we would predict a larger movement in the future that if the exchange rate had changed by only 5%
- In contrast, suppose we posit a "block function" such that if
  $\Delta S_t > 0$ then $\Delta S_{t+1} > 0$, but not by a proportional amount.
- This better captures the imprecise predictions of trend following rules.

Past Trends and Future Returns for Three Currencies (Figure 8.8)



Data are monthly over the period April 1975 – April 1991. Past trend is measured by the change in the spot rate over a three-month period normalized by dividing by the standard deviation (about 6 percent). Future return is measure by the one-month return on a long forward contract position. Source: John F.O. Bilson, "Technical Currency Trading," in Lee Thomas (ed.), *The Currency Hedging Debate*, 1990.

A Dummy Variable Approach to Representing the Trend Relationship

- Suppose that we use a dummy variable (=+1) to represent the trend within a particular interval, and then estimate the relationship between past trend and realized return for all currencies (DEM, GBP and JPY) using a seemingly unrelated regression approach

Present Trend ($\Delta St/\sigma$)	Coefficient	T-Statistic
$\Delta St/\sigma < -1.75$	1.16	1.62
$-1.75 < \Delta St/\sigma < -1.25$	-0.31	0.64
$-1.25 < \Delta St/\sigma < -0.75$	-0.69	1.80
$-0.75 < \Delta St/\sigma < -0.25$	-0.80	2.50
$-0.25 < \Delta St/\sigma < +0.25$	-0.14	0.42
$+0.25 < \Delta St/\sigma < +0.75$	0.97	3.08
$+0.75 < \Delta St/\sigma < +1.25$	0.81	2.19
$+1.25 < \Delta St/\sigma < +1.75$	0.95	2.07
$+1.75 < \Delta St/\sigma$	-0.26	0.52

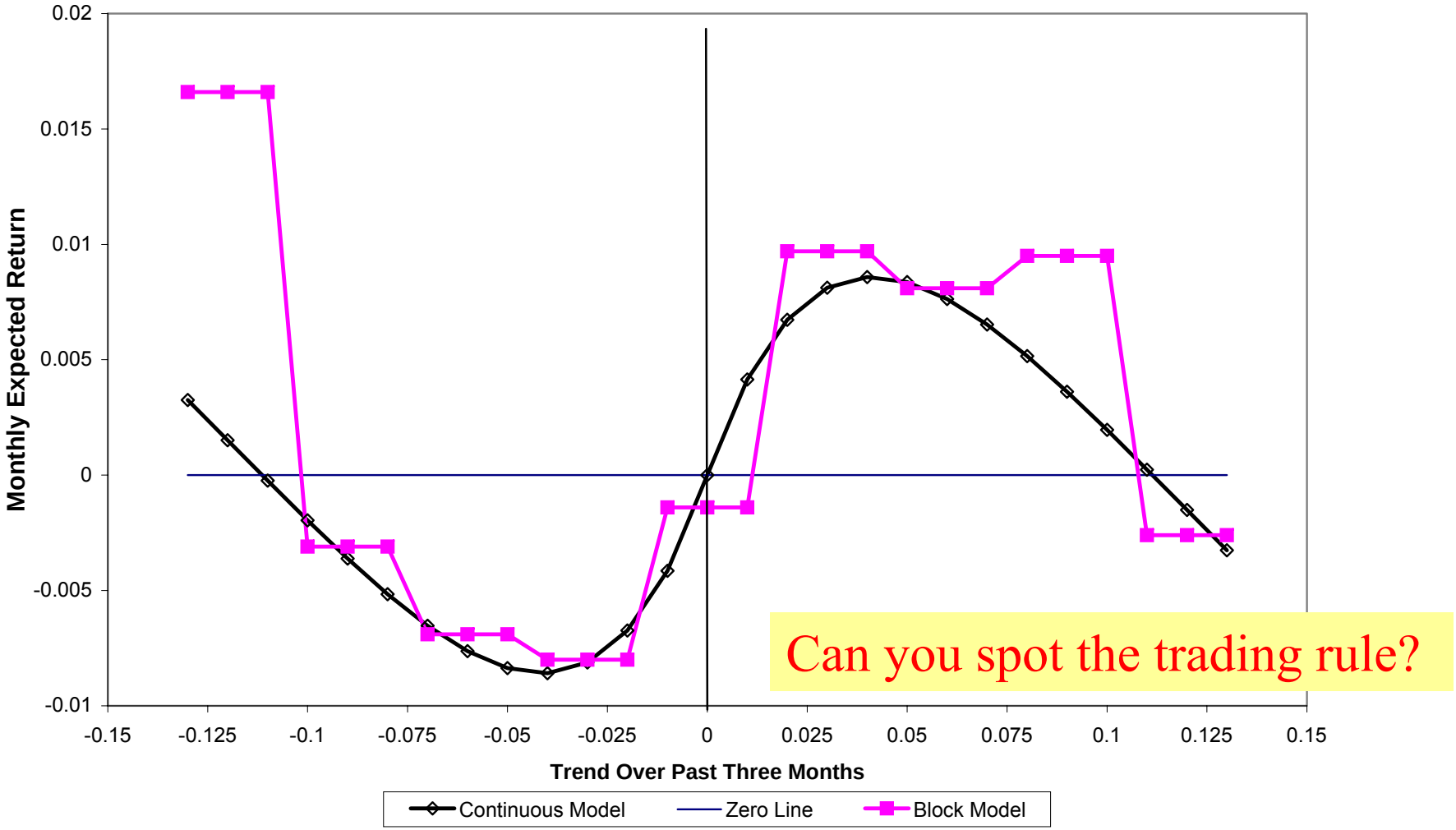
A Dummy Variable Approach to Representing the Trend Relationship

When these dummy variables are combined to form the following "Trend" variables:

Trend 1:	$\Delta S_t > 0$	d = +1
	$\Delta S_t = 0$	d = 0
	$\Delta S_t < 0$	d = -1
Trend 2:	$\Delta S_t/\sigma > +0.25$	d = +1
	$-0.25 \leq \Delta S_t/\sigma \leq +0.25$	d = 0
	$\Delta S_t/\sigma < -0.25$	d = -1
Trend 3:	$1.75 \leq \Delta S_t/\sigma \leq +0.25$	d = +1
	$-0.25 \leq \Delta S_t/\sigma \leq +0.25$	d = 0
	$-1.75 \leq \Delta S_t/\sigma \leq -0.25$	d = -1

each “Trend” variable is positively and significantly related to the future exchange rate return.

Modeling Expected Returns as a Function of Past Trend



Can you spot the trading rule?

Market Efficiency
with Uncertainty and Risky Investment

- Tests of forward market efficiency generally focus on the relationship between the *current* n-period forward rate, $F_{t,n}$, the *expected* future spot rate, $E(S_{t+n}|I_t)$, and the *actual* future spot rate, S_{t+n}.
- The *simple efficiency hypothesis* (no currency risk premium hypothesis) includes :
  1. rational expectations: $E(S_{t+n}|I_t) = S_{t+n}$
  2. forward rate pricing: $F_{t,n} = E(S_{t+n}|I_t)$

Market Efficiency
with Uncertainty and Risky Investment

- The *general efficiency hypothesis* includes :
  - ① rational expectations: $E(S_{t+n}|I_t) = S_{t+n}$
  - ② forward rate pricing: $F_{t,n} = E(S_{t+n}|I_t) + RP_{t,n}$

    where $RP_{t,n}$ represents the currency risk premium at time t for maturity n.
- Empirical evidence we reviewed earlier shows that the forward rate is a biased predictor of the future spot rate, over short horizons.
- This implies we can outperform forward rate.
- Drawing a conclusion about market efficiency is still problematic because of the ambiguity regarding a currency risk premium.

Summary

- The theory of market efficiency is difficult to test
  - » Theory rests on a joint hypothesis (1) an equilibrium benchmark, (2) setting prices to conform to the benchmark.
  - » Empirical tests also difficult to conduct: Prone to data mining, need post-sample evidence, not simply in-sample.
- Market efficiency presents puzzles
  - » Some see random behavior, others see trends
  - » Theory does not support technical trading, yet profit seeking traders frequently utilize or rely on technical models
- Resolution of puzzles may be found in
  - » Behavioral finance theories, FX market microstructure, improved FX trading risk measures, or pricing currency risk