# Technical Analysis and the London Stock Exchange: Testing Trading Rules Using the FT30

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This paper investigates the predictive ability of various simple technical trading rules by analysing daily data on the London Stock Exchange FT30 index for the period 1935–1994. Assessing the statistical significance of the rules via AR–ARCH models and bootstrap techniques, it is found that the trading rules worked, in the sense of producing a return greater than a buy-and-hold strategy, for most of the sample period, at least up to the early 1980s, i.e. when the market was effectively driftless. Since then, however, the buy-and-hold strategy has clearly dominated. © 1997 John Wiley & Sons, Ltd.

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## SUMMARY

After many years of being held in almost complete contempt by academics, technical analysis has enjoyed somewhat of a renaissance recently in the eyes of both practitioners and financial econometricians. The latter's interest has been rekindled by the fact that technical trading rules require some form of nonlinearity in prices to be successful—and nonlinearity is being increasingly found in financial time series—and by empirical studies which find that trading rules can outperform statistical models in predicting exchange rates and stock prices. This paper examines the predictive ability of two types of trading rule, the moving average oscillator and trading range break-out, in the London Stock Exchange by analysing daily data on the FT30 index for the period 1935–1994. It is found that, for the twenty year sub-periods 1935–1954 and 1955–1974, trading strategies based on these rules would have produced a considerably greater return than a simple buy-and-hold strategy, and these results are statistically reliable, having been assessed using a computer intensive simulation procedure known as bootstrapping. The most recent twenty year period, however, is very different, for it provides no evidence whatsoever that trading rules have provided any useful signals for predicting price movements. When this period is examined in more detail, it is found that the performance of the trading rules began to deteriorate badly in the early 1980s, when the FT30 started to increase substantially after many years of being virtually driftless over reasonable lengths of time. These driftless periods were also ones in which returns were more predictable, implying that the market was less efficient. The conclusion that trading rules can predict stock prices, and are thus profitable, only in periods when the market is inefficient, appears inescapable. The results are also compared to earlier findings on the New York Stock Exchange and, in terms of the periods over which trading rules are effective, the two markets appear to behave similarly. However, the 'break-down' period from the early 1980s has yet to be analysed using these techniques for New York, which would thus be a very interesting exercise to undertake.

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## 1. INTRODUCTION

After many years of being held in almost complete contempt by academics (see, for example, Malkiel, 1981), technical analysis (often termed chartism) has enjoyed somewhat of a renaissance recently in the eyes of both practitioners and financial econometricians. The latter's interest has been rekindled by Neftçi's (1991) demonstration that technical trading rules require some form of nonlinearity in prices to be successful—and nonlinearity is being increasingly found in financial time series—and by empirical studies, such as those of Allen and Taylor (1990), Taylor and Allen (1992) and Sweeney (1988), which find that trading rules can outperform statistical models in predicting exchange rates and stock prices.

The impetus for the present paper was provided by Brock *et al.* (1992), who reported strong evidence to suggest that two trading rules, the moving average and trading range break, help to predict daily changes in the Dow Jones Industrial Average over a period of ninety years, and that the returns generated by these rules were not consistent with what might be expected if returns followed a typical stochastic process, such as an AR(1), a GARCH-M or an exponential-GARCH. Moreover, they found that buy signals consistently generated higher returns than sell signals and that the returns following buy signals were less volatile than the returns following sell signals, these latter returns being negative.

These are findings of potential importance, and it is obviously of interest to see whether similar results hold for other major stock markets. We therefore examine here the predictive ability of trading rules in the most important of the European stock markets, the London Stock Exchange, by analysing daily data on the FT30 index for the sixty year period from 1935 to 1994.

## 2. DATA AND TECHNICAL TRADING RULES

The data used here are daily closing values on the *Financial Times–Institute of Actuaries 30* (FT30) index from 1 July 1935 to 31 January 1994, a total of 15 003 observations. Following Brock *et al.* (1992), two trading rules are examined. The first is the *moving average oscillator*, which involves two moving averages (MAs) of the level of the index: $x_t$, a 'short' moving average of order $n$,

$$s_t(n) = \frac{1}{n}\sum_{i=0}^{n-1} x_{t-i}$$

and a 'long' moving average of order $m(m > n)$

$$l_t(m) = \frac{1}{m}\sum_{i=0}^{m-1} x_{t-i}$$

In its simplest form, this rule generates a buy (sell) signal when $s_t(n)$ rises above (falls below) $l_t(m)$ and when this happens, a 'trend' is said to be initiated. The most popular MA rule is the 1–200, which sets $n = 1$ (so that $s_t(n)$ is just the current level of the index, $x_t$) and $m = 200$. We also investigate the 1–50, 1–150, 5–150 and 2–200 MA rules. These rules are often modified by introducing a band around the MA, which reduces the number of buy and sell signals by eliminating 'whiplash' signals that occur when $s_t(n)$ and $l_t(m)$ are close to each other. We examine the MA rules both with and without a one per cent band, i.e. a buy (sell) signal is generated when $s_t(n)$ is above (below) $l_t(m)$ by more than one per cent. If $s_t(n)$ is inside the band, no signal is generated. This rule attempts to simulate a strategy where traders go long as $s_t(n)$ moves above $l_t(m)$ and short when it moves below: with a band of zero all days are classified as either buys or sells.

The second trading rule that we analyse is the *trading range break-out* (TRB). With this rule, a buy signal is generated when the price penetrates a resistance level, defined as a local maximum. A sell signal, on the other hand, is generated when the price penetrates a support level, defined as a local minimum. Thus, if

$$\mathrm{res}_t(m) = \max(x_{t-1}, \ldots, x_{t-m})$$

and

$$\mathrm{sup}_t(m) = \min(x_{t-1}, \ldots, x_{t-m})$$

then a buy signal is generated if $x_t > \mathrm{res}_t(m)$ and a sell signal is generated if $x_t < \mathrm{sup}_t(m)$. As with the MA rules, $m$ was set at 50, 150 and 200, and the TRB rules were implemented both with and without a one per cent band.

Table 1. Summary statistics for daily returns.

| | 1935–1994 | 1935–1954 | 1955–1974 | 1975–1994 |
|---|---|---|---|---|
| Mean | 0.00022 | 0.00013 | −0.00000 | 0.00053 |
| Std. dev. | 0.01004 | 0.00604 | 0.01024 | 0.01269 |
| Skewness | −0.144 | −0.434 | −0.189 | −0.102 |
| Kurtosis | 14.53 | 20.11 | 13.38 | 10.38 |
| $\rho(1)$ | 0.098 | 0.344 | 0.095 | 0.044 |
| $\rho(2)$ | 0.014 | 0.186 | −0.018 | −0.004 |
| $\rho(3)$ | 0.013 | 0.051 | −0.016 | 0.023 |
| $\rho(4)$ | 0.014 | −0.004 | −0.024 | 0.038 |
| $\rho(5)$ | 0.011 | −0.000 | −0.001 | 0.019 |
| $\rho^2(1)$ | 0.420 | 0.292 | 0.389 | 0.433 |
| $\rho^2(2)$ | 0.192 | 0.155 | 0.090 | 0.227 |
| $\rho^2(3)$ | 0.184 | 0.310 | 0.071 | 0.208 |
| $\rho^2(4)$ | 0.175 | 0.187 | 0.076 | 0.201 |
| $\rho^2(5)$ | 0.165 | 0.126 | 0.059 | 0.183 |
| Std. error | 0.008 | 0.014 | 0.014 | 0.014 |

Results are presented for the full sample and for three nonoverlapping subperiods. Returns are measured as log differences of the level of the index: $r_t = \ln(x_t/x_{t-1})$. $\rho(i)$ is the estimated autocorrelation at lag $i$ of $r_t$; $\rho^2(i)$ is the estimated autocorrelation at lag $i$ of $r_t^2$. Std. error refers to the Bartlett standard error.

## 3. EMPIRICAL RESULTS

Table 1 contains summary statistics for daily returns for the complete sample and for three nonoverlapping subsamples of 5000 observations each, which closely correspond to the periods 1935–1954, 1955–1974 and 1975–1994. (We refer to these subsamples in this manner from now on.) Returns are strongly leptokurtic (fat tailed) and negatively skewed in all periods. However, both the mean return and volatility are considerably larger in the 1975–1994 period than in the two earlier periods. These increases have been accompanied by a serious weakening in the linear autocorrelation structure of returns, although not in the nonlinear autocorrelation structure, as measured by the autocorrelation coefficients of the squared returns (see, for example, Maravall, 1983, for a justification for the use of the autocorrelations of the squared observations as a general test for nonlinearity). This is an important finding for, as we have noted above, the presence of nonlinearity is a necessary condition for trading rules to have potential predictive power.

The results of trading strategies based on the MA rules for the complete sixty year sample and for the three subperiods are reported in tables 2–5. The columns labelled 'Buy' and 'Sell' present the mean returns obtained during buy and sell periods, respectively: a buy period, for example, being defined as the period after a buy signal up to the next sell signal. The column labelled 'Buy–Sell' presents the difference between these two means. The $t$-statistics accompanying these statistics are computed using the formulae given by Brock *et al.* (1992, footnote 9). For the complete sample results of table 2, the differences between the mean daily buy and sell returns are significantly positive for all rules. The introduction of the one per cent band increases the spread between the buy and sell returns, although the difference decreases as the lengths of the MAs increase. The number of buy signals generated by each rule always exceeds the number of sell signals, by between forty-five and seventy-five per cent, which is consistent with an upward trending market. The mean buy returns are all positive with an average daily return for the ten tests of 0.053 per cent, which is about fifteen per cent at an annual rate, and which compares with an unconditional mean daily return of 0.022 per cent from table 1. However, only for the two 1–50 rules do the $t$-statistics reject the null hypothesis that the buy returns equal the unconditional returns at the 0.05 level using a two-sided test. The results are

 

Table 2. Results for MA rules: complete sample, 1935–1994.

| Rule | $N$(buy) | $N$(Sell) | Buy | Sell | Buy > 0 | Sell > 0 | Buy−Sell |
|---|---|---|---|---|---|---|---|
| 1, 50, 0 | 8850 | 6102 | 0.715 | −0.375 | 0.519 | 0.468 | 1.090 |
| | | | (3.30) | (4.22) | | | (6.52) |
| 1, 50, 0.01 | 7272 | 4768 | 0.779 | −0.503 | 0.521 | 0.464 | 1.282 |
| | | | (3.55) | (4.62) | | | (6.85) |
| 1, 150, 0 | 9184 | 5668 | 0.490 | −0.100 | 0.511 | 0.468 | 0.590 |
| | | | (1.68) | (2.32) | | | (3.47) |
| 1, 150, 0.01 | 8315 | 4904 | 0.526 | −0.146 | 0.510 | 0.473 | 0.672 |
| | | | (1.89) | (2.48) | | | (3.70) |
| 5, 150, 0 | 9187 | 5665 | 0.423 | −0.008 | 0.506 | 0.485 | 0.415 |
| | | | (1.18) | (1.63) | | | (2.44) |
| 5, 150, 0.01 | 8280 | 4890 | 0.444 | −0.003 | 0.505 | 0.482 | 0.447 |
| | | | (1.30) | (1.61) | | | (2.46) |
| 1, 200, 0 | 9296 | 5506 | 0.485 | −0.106 | 0.512 | 0.475 | 0.591 |
| | | | (1.65) | (2.33) | | | (3.44) |
| 1, 200, 0.01 | 8642 | 4952 | 0.488 | −0.120 | 0.511 | 0.474 | 0.608 |
| | | | (1.63) | (2.33) | | | (3.38) |
| 2, 200, 0 | 9276 | 5526 | 0.459 | −0.060 | 0.511 | 0.477 | 0.519 |
| | | | (1.45) | (2.04) | | | (3.03) |
| 2, 200, 0.01 | 8653 | 4945 | 0.463 | −0.057 | 0.510 | 0.478 | 0.520 |
| | | | (1.45) | (1.95) | | | (2.89) |
| Average | | | 0.527 | −0.148 | | | 0.675 |

Rules are identified as ($n$, $m$, $b$), where $b$ is the band, either 0 or 0.01. '$N$(Buy)' and '$N$(Sell)' are the number of buy and sell signals generated by the rule. 'Buy > 0' and 'Sell > 0' are the fraction of buy and sell returns greater than zero. Numbers in parentheses are standard $t$-statistics testing the difference between the mean buy return and the unconditional mean return, between the mean sell return and the unconditional mean return and between buy−sell and zero. The last row reports averages across all ten rules. The mean returns are scaled by a factor of 1000 for easier interpretation.

stronger for the sells. All sell mean returns are negative with an average daily return for the ten tests of −0.015 per cent, about four per cent at an annual rate, and all but two of the $t$-statistics are significantly different from zero. The 'Buy > 0' and 'Sell > 0' columns present the fraction of buy and sell returns that are greater than zero. The buy fraction is consistently greater than fifty per cent, while that for sells is considerably less, being in the region of forty-six to forty-eight per cent. Under the null hypothesis that technical trading rules do not produce useful signals, these fractions should be the same: a binomial test shows that these differences are highly significant and the null of equality can be rejected.

These results are strikingly similar to those reported by Brock *et al.* (1992, table II), who emphasized the difficulty in explaining them with an equilibrium model that predicts negative returns over such a large fraction of trading days. Moreover, they reported that these patterns remained the same for subperiods of their data. Tables 3–5 report our findings for the three subperiods investigated here. For the two earlier subperiods, 1935–1954 and 1955–1974, very similar results to those of the complete sample are obtained. The results for the most recent period, 1975–1994, however, are radically different. Only for the 1–50 rules are the buy−sell statistics significant, while none of the mean buy and sell returns are significantly different from the unconditional mean return, both being, on average, positive. The 'Buy > 0' and 'Sell > 0' fractions are almost identical, so that there is no evidence that trading rules provide any useful signals for predicting price movements over the last 20 years!

Results for the TRB rule are presented in tables 6 to 9, which are presented in the same format as tables 2 to 5, except that 10-day cumulative returns are reported. One noticeable difference between the rules is that the TRB rule generates far fewer signals than the MA rule, with the one per cent

 

Table 3. Results for MA rules: sample, 1935– 1954.

| Rule | $N$(Buy) | $N$(Sell) | Buy | Sell | Buy > 0 | Sell > 0 | Buy−Sell |
|---|---|---|---|---|---|---|---|
| 1, 50, 0 | 3040 | 1908 | 0.613 | −0.588 | 0.520 | 0.440 | 1.202 |
| | | | (3.33) | (4.53) | | | (6.80) |
| 1, 50, 0.01 | 2341 | 1403 | 0.745 | −0.803 | 0.532 | 0.426 | 1.548 |
| | | | (3.93) | (5.20) | | | (7.58) |
| 1, 150, 0 | 3023 | 1826 | 0.392 | 0.297 | 0.510 | 0.453 | 0.689 |
| | | | (1.85) | (2.59) | | | (3.85) |
| 1, 50, 0.01 | 2634 | 1511 | 0.450 | −0.448 | 0.510 | 0.443 | 0.898 |
| | | | (2.17) | (3.27) | | | (4.62) |
| 5, 150, 0 | 3023 | 1826 | 0.297 | −0.140 | 0.500 | 0.470 | 0.436 |
| | | | (1.17) | (1.64) | | | (2.44) |
| 5, 150, 0.01 | 2622 | 1503 | 0.307 | −0.267 | 0.498 | 0.460 | 0.575 |
| | | | (1.19) | (2.24) | | | (2.94) |
| 1, 200, 0 | 3023 | 1776 | 0.379 | −0.290 | 0.509 | 0.456 | 0.668 |
| | | | (1.77) | (2.51) | | | (3.70) |
| 1, 200, 0.01 | 2747 | 1546 | 0.427 | −0.323 | 0.510 | 0.455 | 0.750 |
| | | | (2.05) | (2.57) | | | (3.91) |
| 2, 200, 0 | 3012 | 1787 | 0.370 | −0.271 | 0.508 | 0.459 | 0.641 |
| | | | (1.70) | (2.40) | | | (3.56) |
| 2, 200, 0.01 | 2748 | 1539 | 0.371 | −0.280 | 0.506 | 0.460 | 0.651 |
| | | | (1.66) | (2.32) | | | (3.39) |
| Average | | | 0.435 | −0.371 | | | 0.806 |

Rules are identified as ($n$, $m$, $b$), where $b$ is the band, either 0 or 0.01. '$N$(Buy)' and '$N$(Sell)' are the number of buy and sell signals generated by the rule. 'Buy > 0' and 'Sell > 0' are the fraction of buy and sell returns greater than zero. Numbers in parentheses are standard $t$-statistics testing the difference between the mean buy return and the unconditional mean return, between the mean sell return and the unconditional mean return and between buy−sell and zero. The last row reports averages across all ten rules. The mean returns are scaled by a factor of 1000 for easier interpretation.

band eliminating a far higher proportion of whiplash signals. Nevertheless, the overall conclusion is consistent with the MA rules: without going into too much detail, the TRB rules show predictability in the earlier years of the sample, but no predictability whatsoever since 1975.

## 4. BOOTSTRAPPING THE RULES

These results are certainly intriguing, implying as they do that trading rules produced some measure of predictability up to the mid-1970s, but none afterwards. However, this conclusion is based on inference from $t$-statistics that assume normal, stationary (constant mean and variance), and time independent return distributions. As we have seen from table 1, these assumptions certainly do not characterize the returns from the FT30 index! We are thus left with the suspicion that these conclusions might be a consequence of using invalid significance tests—the predictability of the earlier years may be an illusion as, indeed, might the unpredictability of the post-1975 period.

Brock *et al.* (1992) employ bootstrap methodology to address these problems: Efron and Tibshirani (1993) provide a detailed exposition of this very useful computer intensive statistical technique. Informally, this methodology compares the returns conditional on buy (sell) signals using the the raw FT30 data with the conditional returns from a simulated comparison series. The trading rules classify each day as either a buy ($b_t$), a sell ($s_t$) or, if a band is used, neutral ($n_t$). If the $h$ day return is defined as

$$r_t^h = \ln(x_{t+h}) - \ln(x_t)$$

then the expected $h$ day return conditional on a buy signal at $t$ can be defined as

$$q_{\mathrm{b}} = E(r_t^h | b_t)$$

 

Table 4. Results for MA rules: sample, 1955– 1974.

| Rule | $N$(Buy) | $N$(Sell) | Buy | Sell | Buy > 0 | Sell > 0 | Buy−Sell |
|---|---|---|---|---|---|---|---|
| 1, 50, 0 | 2763 | 2186 | 0.525 | −0.524 | 0.531 | 0.463 | 1.049 |
| | | | (1.92) | (2.23) | | | (3.59) |
| 1, 50, 0.01 | 2293 | 1765 | 0.473 | −0.701 | 0.530 | 0.459 | 1.173 |
| | | | (1.60) | (2.69) | | | (3.63) |
| 1, 150, 0 | 2675 | 2174 | 0.463 | −0.462 | 0.523 | 0.471 | 0.924 |
| | | | (1.69) | (1.94) | | | (3.14) |
| 1, 150, 0.01 | 2433 | 1936 | 0.465 | −0.490 | 0.521 | 0.467 | 0.955 |
| | | | (1.64) | (1.96) | | | (3.07) |
| 5, 150, 0 | 2675 | 2174 | 0.426 | −0.417 | 0.520 | 0.475 | 0.843 |
| | | | (1.54) | (1.77) | | | (2.86) |
| 5, 150, 0.01 | 2436 | 1928 | 0.454 | −0.442 | 0.518 | 0.472 | 0.896 |
| | | | (1.60) | (1.79) | | | (2.88) |
| 1, 200, 0 | 2632 | 2167 | 0.499 | −0.488 | 0.526 | 0.468 | 0.988 |
| | | | (1.80) | (2.05) | | | (3.34) |
| 1, 200, 0.01 | 2442 | 2013 | 0.519 | −0.509 | 0.524 | 0.465 | 1.028 |
| | | | (1.83) | (2.08) | | | (3.35) |
| 2, 200, 0 | 2637 | 2162 | 0.466 | −0.450 | 0.524 | 0.470 | 0.915 |
| | | | (1.66) | (1.91) | | | (3.09) |
| 2, 200, 0.01 | 2453 | 2016 | 0.476 | −0.479 | 0.523 | 0.468 | 0.955 |
| | | | (1.67) | (1.97) | | | (3.11) |
| Average | | | 0.477 | −0.496 | | | 0.973 |

Rules are identified as ($n$, $m$, $b$), where $b$ is the band, either 0 or 0.01. '$N$(Buy)' and '$N$(Sell)' are the number of buy and sell signals generated by the rule. 'Buy > 0' and 'Sell > 0' are the fraction of buy and sell returns greater than zero. Numbers in parentheses are standard $t$-statistics testing the difference between the mean buy return and the unconditional mean return, between the mean sell return and the unconditional mean return and between buy−sell and zero. The last row reports averages across all ten rules. The mean returns are scaled by a factor of 1000 for easier interpretation.

with $q_s$ defined analogously. The conditional standard deviations may then be defined as

$$\sigma_b = (E[(r_t^h - q_b)^2 | b_t])^{1/2}$$

and, analogously, $\sigma_s$. These conditional expectations are estimated using appropriate sample means calculated from the FT30 returns and compared to expectations estimated in a similar way from simulated models.

A decision has to be made as to what model(s) should be used to simulate the comparison series. Two features of the autocorrelations reported in table 1 inform our decision. First, it is clear that the correlation structure of returns is not constant across the whole sample, so it would be inappropriate to fit a single model to the entire data set. Second, the returns exhibit autocorrelation in both levels and squares, so that ARMA models with GARCH disturbances are the natural class to focus attention upon. Using the three subperiods used above, we fitted AR–ARCH models to the returns, the estimated models being shown in table 10. For all three samples an ARCH(3) process was required to fit the conditional variance $h_t$. For the two earlier periods the conditional mean return was adequately fitted by AR(2) processes, albeit with rather different estimates, whereas the final period required an AR(1) with intercept, a reflection of the pronounced (stochastic) trend in the index during these years. Extensions such as GARCH conditional variance equations and including $h_t$ as a regressor in the the conditional mean equation (GARCH-in-mean) were investigated, but were unsuccessful. The models presented in table 10 do, nevertheless, provide satisfactory statistical fits.

The bootstrap simulations are performed by resampling, with replacement, the residuals from the fitted models and, using these scrambled residuals and the estimated parameters, generating new return series from the models, from which the

 

Table 5. Results for MA rules: sample, 1975–1994.

| Rule | $N$(Buy) | $N$(Sell) | Buy | Sell | Buy > 0 | Sell > 0 | Buy−Sell |
|---|---|---|---|---|---|---|---|
| 1, 50, 0 | 3024 | 1925 | 1.021 | 0.068 | 0.507 | 0.499 | 0.953 |
| | | | (1.26) | (1.74) | | | (2.60) |
| 1, 50, 0.01 | 2623 | 1524 | 1.098 | 0.043 | 0.505 | 0.501 | 1.054 |
| | | | (1.45) | (1.66) | | | (2.60) |
| 1, 150, 0 | 3285 | 1564 | 0.499 | 0.475 | 0.501 | 0.504 | 0.024 |
| | | | (0.02) | (0.06) | | | (0.07) |
| 1, 150, 0.01 | 3069 | 1364 | 0.531 | 0.503 | 0.499 | 0.512 | 0.028 |
| | | | (0.13) | (0.02) | | | (0.07) |
| 5, 150, 0 | 3290 | 1559 | 0.440 | 0.600 | 0.498 | 0.511 | −0.160 |
| | | | (0.21) | (0.31) | | | (0.44) |
| 5, 150, 0.01 | 3046 | 1368 | 0.459 | 0.711 | 0.499 | 0.518 | −0.252 |
| | | | (0.13) | (0.60) | | | (0.66) |
| 1, 200, 0 | 3366 | 1433 | 0.504 | 0.567 | 0.502 | 0.505 | −0.063 |
| | | | (0.07) | (0.13) | | | (0.17) |
| 1, 200, 0.01 | 3193 | 1267 | 0.472 | 0.585 | 0.502 | 0.508 | −0.113 |
| | | | (0.19) | (0.18) | | | (0.30) |
| 2, 200, 0 | 3354 | 1445 | 0.475 | 0.636 | 0.501 | 0.508 | −0.161 |
| | | | (0.18) | (0.33) | | | (0.45) |
| 2, 200, 0.01 | 3189 | 1262 | 0.491 | 0.722 | 0.502 | 0.511 | −0.230 |
| | | | (0.11) | (0.55) | | | (0.60) |
| Average | | | 0.591 | 0.491 | | | 0.100 |

Rules are identified as ($n$, $m$, $b$), where $b$ is the band, either 0 or 0.01. '$N$(Buy)' and '$N$(Sell)' are the number of buy and sell signals generated by the rule. 'Buy > 0' and 'Sell > 0' are the fraction of buy and sell returns greater than zero. Numbers in parentheses are standard $t$-statistics testing the difference between the mean buy return and the unconditional mean return, between the mean sell return and the unconditional mean return and between buy−sell and zero. The last row reports averages across all ten rules. The mean returns are scaled by a factor of 1000 for easier interpretation.

Table 6. Results for TRB rules: complete sample, 1935–1994.

| Rule | $N$(Buy) | $N$(Sell) | Buy | Sell | Buy > 0 | Sell > 0 | Buy−Sell |
|---|---|---|---|---|---|---|---|
| 50, 0 | 1819 | 945 | 7.167 | −0.061 | 0.635 | 0.494 | 7.228 |
| | | | (4.93) | (2.43) | | | (5.08) |
| 50, 0.01 | 300 | 324 | 9.422 | 1.425 | 0.590 | 0.488 | 7.997 |
| | | | (3.19) | (0.70) | | | (2.81) |
| 150, 0 | 1210 | 434 | 5.973 | 0.420 | 0.633 | 0.509 | 5.553 |
| | | | (3.02) | (1.35) | | | (2.79) |
| 150, 0.01 | 175 | 181 | 3.683 | 3.285 | 0.537 | 0.530 | 0.398 |
| | | | (0.34) | (0.20) | | | (0.11) |
| 200, 0 | 1098 | 371 | 5.905 | 1.889 | 0.628 | 0.520 | 4.016 |
| | | | (2.82) | (0.47) | | | (1.88) |
| 200, 0.01 | 158 | 155 | 3.795 | 3.979 | 0.538 | 0.529 | −0.184 |
| | | | (0.36) | (0.42) | | | (0.05) |
| Average | | | 5.991 | 1.823 | | | 4.168 |

Cumulative returns are reported for fixed 10-day periods after signals. Rules are identified as ($m$, $b$), where $b$ is the band, either 0 or 0.01. '$N$(Buy)' and '$N$(Sell)' are the number of buy and sell signals generated by the rule. 'Buy > 0' and 'Sell > 0' are the fraction of buy and sell returns greater than zero. Numbers in parentheses are standard $t$-statistics testing the difference between the mean buy return and the unconditional 1-day mean return, between the mean sell return and the unconditional mean return and between buy−sell and zero. The last row reports averages across all six rules. The mean returns are scaled by a factor of 1000 for easier interpretation.

 

Table 7. Results for TRB rules: sample, 1935– 1954.

| Rule | $N$(Buy) | $N$(Sell) | Buy | Sell | Buy > 0 | Sell > 0 | Buy−Sell |
|---|---|---|---|---|---|---|---|
| 50, 0 | 722 | 329 | 7.160 | −4.341 | 0.684 | 0.456 | 11.502 |
| | | | (5.11) | (4.00) | | | (6.49) |
| 50, 0.01 | 30 | 87 | 8.169 | 0.905 | 0.700 | 0.506 | 7.264 |
| | | | (1.32) | (0.29) | | | (1.29) |
| 150, 0 | 468 | 151 | 8.597 | −2.561 | 0.718 | 0.470 | 11.158 |
| | | | (5.46) | (1.84) | | | (4.45) |
| 150, 0.01 | 15 | 54 | 16.209 | 2.919 | 0.800 | 0.519 | 13.290 |
| | | | (2.12) | (0.38) | | | (1.70) |
| 200, 0 | 425 | 121 | 9.187 | 1.557 | 0.722 | 0.504 | 7.630 |
| | | | (5.64) | (0.02) | | | (2.75) |
| 200, 0.01 | 14 | 44 | 17.957 | 9.130 | 0.857 | 0.545 | 8.827 |
| | | | (2.28) | (1.87) | | | (1.07) |
| Average | | | 11.213 | 1.268 | 9.945 | | |

Cumulative returns are reported for fixed 10-day periods after signals. Rules are identified as ($m$, $b$), where $b$ is the band, either 0 or 0.01. '$N$(Buy)' and '$N$(Sell)' are the number of buy and sell signals generated by the rule. 'Buy > 0' and 'Sell > 0' are the fraction of buy and sell returns greater than zero. Numbers in parentheses are standard $t$-statistics testing the difference between the mean buy return and the unconditional 1-day mean return, between the mean sell return and the unconditional mean return and between buy−sell and zero. The last row reports averages across all six rules. The mean returns are scaled by a factor of 1000 for easier interpretation.

various statistics reported in earlier tables may be calculated. The results from the bootstrap simulations are shown in tables 11–13. The numbers presented are the fractions of the 500 simulations that result in larger statistics than those for the observed FT30 series. These statistics include, as in tables 2–9, the mean buy, mean sell and mean buy−sell difference returns, and the conditional standard deviations $\sigma_b$ and $\sigma_s$, which are defined above. For example, for the MA(1, 50, 0) rule, table 11 shows that, for the period 1935–1954, 4.2% of the simulated series generated a mean buy return as large as that from the actual FT30 series, and this number can be thought of as a simulated '$p$-value'. On the other hand, 99.6% of the simulated series generated mean sell returns larger than the FT30

Table 8. Results for TRB rules: sample, 1955–1974.

| Rule | $N$(Buy) | $N$(Sell) | Buy | Sell | Buy > 0 | Sell > 0 | Buy−Sell |
|---|---|---|---|---|---|---|---|
| 50, 0 | 530 | 346 | 5.659 | −1.114 | 0.600 | 0.494 | 6.773 |
| | | | (3.29) | (0.93) | | | (2.93) |
| 50, 0.01 | 88 | 125 | 9.216 | −2.374 | 0.557 | 0.472 | 11.590 |
| | | | (2.39) | (0.99) | | | (2.49) |
| 150, 0 | 349 | 186 | 6.134 | 0.785 | 0.593 | 0.538 | 5.349 |
| | | | (3.04) | (0.10) | | | (1.77) |
| 150, 0.01 | 50 | 80 | 6.346 | −0.343 | 0.520 | 0.538 | 6.688 |
| | | | (1.23) | (0.23) | | | (1.12) |
| 200, 0 | 315 | 174 | 6.307 | 0.723 | 0.587 | 0.534 | 5.584 |
| | | | (2.99) | (0.08) | | | (1.77) |
| 200, 0.01 | 45 | 74 | 7.950 | −1.795 | 0.556 | 0.527 | 9.745 |
| | | | (1.49) | (0.59) | | | (1.55) |
| Average | | | 6.935 | −0.686 | | | 7.621 |

Cumulative returns are reported for fixed 10-day periods after signals. Rules are identified as ($m$, $b$), where $b$ is the band, either 0 or 0.01. '$N$(Buy)' and '$N$(Sell)' are the number of buy and sell signals generated by the rule. 'Buy > 0' and 'Sell > 0' are the fraction of buy and sell returns greater than zero. Numbers in parentheses are standard $t$-statistics testing the difference between the mean buy return and the unconditional 1-day mean return, between the mean sell return and the unconditional mean return and between buy−sell and zero. The last row reports averages across all six rules. The mean returns are scaled by a factor of 1000 for easier interpretation.

 

Table 9. Results for TRB Rules: sample, 1975–1994.

| Rule | $N$(Buy) | $N$(Sell) | Buy | Sell | Buy > 0 | Sell > 0 | Buy−Sell |
|---|---|---|---|---|---|---|---|
| 50, 0 | 565 | 255 | 8.720 | 6.435 | 0.607 | 0.541 | 2.285 |
| | | | (1.10) | (0.06) | | | (0.70) |
| 50, 0.01 | 181 | 103 | 9.911 | 5.937 | 0.591 | 0.485 | 3.975 |
| | | | (1.01) | (0.15) | | | (0.74) |
| 150, 0 | 366 | 83 | 3.939 | 2.159 | 0.574 | 0.518 | 1.779 |
| | | | (0.50) | (0.66) | | | (0.38) |
| 150, 0.01 | 98 | 38 | 2.596 | 6.493 | 0.520 | 0.526 | −3.898 |
| | | | (0.61) | (0.24) | | | (0.53) |
| 200, 0 | 332 | 62 | 3.922 | 2.307 | 0.566 | 0.516 | 1.615 |
| | | | (0.66) | (0.63) | | | (0.31) |
| 200, 0.01 | 89 | 28 | 3.167 | 4.651 | 0.506 | 0.500 | −1.484 |
| | | | (0.54) | (0.10) | | | (0.18) |
| Average | | | 5.259 | 4.664 | | | 0.595 |

Cumulative returns are reported for fixed 10-day periods after signals. Rules are identified as ($m$, $b$), where $b$ is the band, either 0 or 0.01. '$N$(Buy)' and '$N$(Sell)'" are the number of buy and sell signals generated by the rule. 'Buy > 0' and 'Sell > 0' are the fraction of buy and sell returns greater than zero. Numbers in parentheses are standard $t$-statistics testing the difference between the mean buy return and the unconditional 1-day mean return, between the mean sell return and the unconditional mean return and between buy−sell and zero. The last row reports averages across all six rules. The mean returns are scaled by a factor of 1000 for easier interpretation.

mean sell return, while none of the simulated series generated mean buy−sell differences larger than the mean difference for the FT30. These results are consistent with the traditional tests presented in the corresponding table 3. The $\sigma_b$ and $\sigma_s$ entries show that every simulated buy conditional standard deviation exceeded that of the analogous FT30 standard deviation, whereas none of the simulated sell standard deviations was larger than the corresponding value from the observed series. The buy signals therefore pick out periods where higher conditional means are accompanied by lower volatilities, in contrast to sell periods where the conditional return is lower and volatility is

Table 10. AR–ARCH models fitted to sub-periods.

1935–1954: AR(2)–ARCH(3)

$$r_t = \underset{(0.0769)}{0.4225}\, r_{t-1} + \underset{(0.0160)}{0.0626}\, r_{t-2} + \varepsilon_t \qquad \varepsilon_t = h_t^{1/2} z_t \qquad z_t \sim N(0,1)$$

$$h_t = \underset{(0.00000)}{0.00005} + \underset{(0.0229)}{0.3529}\, \varepsilon_{t-1}^2 + \underset{(0.0259)}{0.2909}\, \varepsilon_{t-2}^2 + \underset{(0.0232)}{0.2339}\, \varepsilon_{t-3}^2$$

1955–1974: AR(2)–ARCH(3)

$$r_t = \underset{(0.0170)}{0.2702}\, r_{t-1} - \underset{(0.0157)}{0.1015}\, r_{t-2} + \varepsilon_t \qquad \varepsilon_t = h_t^{1/2} z_t \qquad z_t \sim N(0,1)$$

$$h_t = \underset{(0.00000)}{0.00005} + \underset{(0.0281)}{0.3631}\, \varepsilon_{t-1}^2 + \underset{(0.0212)}{0.1676}\, \varepsilon_{t-2}^2 + \underset{(0.0176)}{0.1037}\, \varepsilon_{t-3}^2$$

1975–1994: AR(1) with intercept–ARCH(3)

$$r_t = \underset{(0.0001)}{0.0006} + \underset{(0.0156)}{0.0682}\, r_{t-1} + \varepsilon_t \qquad \varepsilon_t = h_t^{1/2} z_t \qquad z_t \sim N(0,1)$$

$$h_t = \underset{(0.00000)}{0.00010} + \underset{(0.0208)}{0.1734}\, \varepsilon_{t-1}^2 + \underset{(0.0222)}{0.2098}\, \varepsilon_{t-2}^2 + \underset{(0.0195)}{0.1414}\, \varepsilon_{t-3}^2$$

 

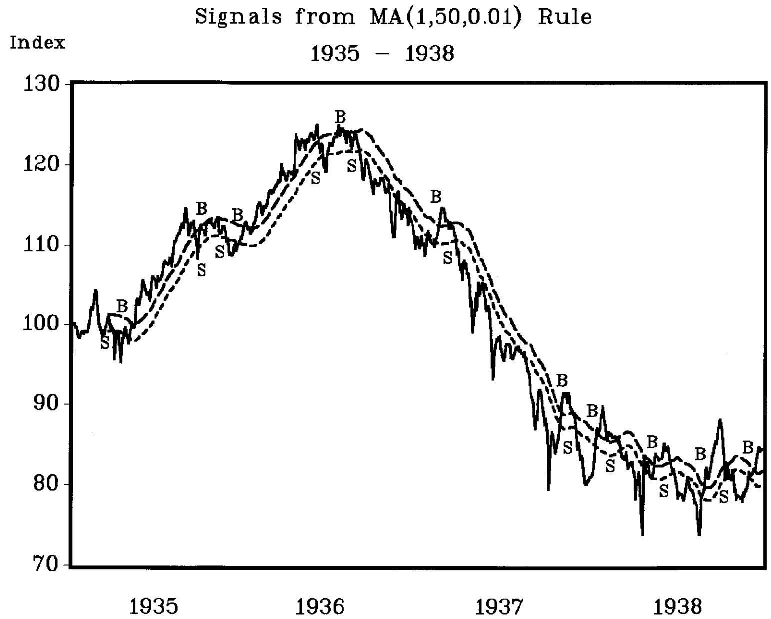

Figure 1. Signals from MA(1, 50, 0.01) rule 1935–1938.

higher. These findings are similar to those found for the Dow in the United States by Brock *et al.* (1992), who emphasize that these are not in accord with any argument that explains return predictability in terms of changing risk levels. Almost identical results are found for all the other MA rules, while the TRB rules produce similar, if not quite as conclusive, findings. Indeed, these patterns are repeated in table 12 for the 1955–1974 period.

They are not, however, repeated for the 1975–1994 period. Here no clear pattern emerges, with the entries changing quite dramatically across different rules. We interpret this as being consistent with the test statistics reported in tables 5 and 9: trading rules do not appear to have any significant predictive content and hence it is difficult to maintain the view that the rules could be used profitably during this period.

## 5. DISCUSSION

A direct way of assessing the profitability of trading rules is to compare them with a simple buy-and-hold strategy. We do this in figures 2 and 3 for the MA(1, 50, 0.01) rule for the periods 1935–1954 and 1975–1994 respectively. Cumulated profits are calculated in the following way. We take $x_t$ to be the 'price' of the index on day $t$, $t = 1, 2, \ldots, T$. For the buy-and-hold strategy, cumulated profit at $t$ is simply given by $x_t - x_1$, on the assumption that the index was 'bought' for $x_1$ on day 1. The MA rule gives a sequence of buy and sell signals, as shown for a representative segment of the FT30 in figure 1. We denote the sequence of signals as $j = 1, 2, \ldots, J$, with odd $j$ denoting buys and even $j$ sells: the signal prices are then denoted $x(j)$ (by convention, $x(1) = x_1$ is a buy and $x(J) = x_T$ is a sell). Cumulated profits after $j$ signals from the MA rule is then given by

$$\sum_{k=2}^{j}(-1)^{k-1}(x(k-1) - x(k))$$

This obviously abstracts from transaction costs, dividends and interest earned on profits when 'out of the market'. Nevertheless, the paths of cumulated profits for the two periods are quite striking. For the period 1935–1954, buy-and-hold profits cumulate to 93.5, whereas the MA trading rule amasses profits of 195.4. Indeed, the buy-and-hold strategy only makes a profit in the final two years of the period when the FT30 increases substantially. The MA rule, on the other hand, consistently shows a profit even during the many years in which there was a 'non-trending' market.

For the period from 1975, the profitability of the two strategies is reversed: the profit from buy-and-hold is 2446.4, compared to the MA trading rule profit of only 1598.6. However, we can see from

 

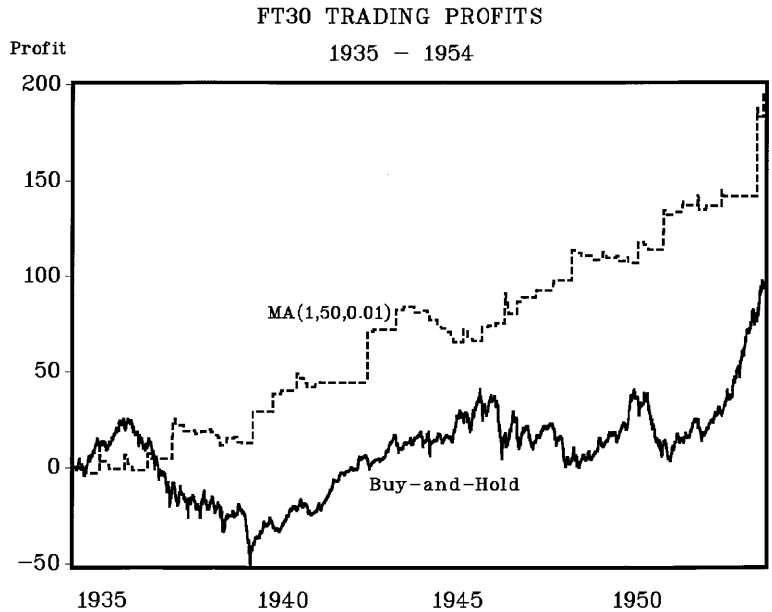


Figure 2. FT30 trading profits 1935–1954.

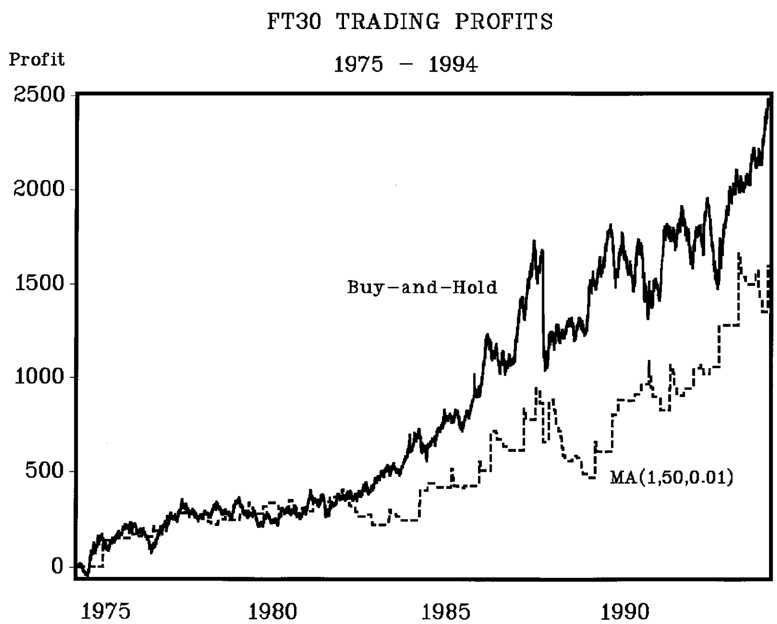


Figure 3. FT30 trading profits 1975–1994.

figure 3 that the performance of the two strategies was very similar in the early years of the period when the market was growing relatively modestly. It is only when the market trend begins to dominate that the trading rule performs poorly: in particular, it misses out on the acceleration of prices in the early 1980s. The exponential growth observed in the FT30 in this period might suggest that a moving average rule based on the logarithms of $x_t$ (or, equivalently, a moving *geometric* average of $x_t$ itself) would be more appropriate. This was, in fact, tried, but gave an almost identical set of signals to the conventional moving (arithmetic) average.

 

Table 11. Simulation tests from AR–ARCH bootstraps: sample, 1935–1954.

| Rule | Result | | Buy | $\sigma_b$ | Sell | $\sigma_s$ | Buy−Sell |
|---|---|---|---|---|---|---|---|
| 1, 50, 0 | MA | % > FT30 | 4.2 | 100 | 99.6 | 0 | 0 |
| | TRB | | 6.0 | 35.0 | 88.4 | 0 | 3.8 |
| 1, 50, 0.01 | MA | % > FT30 | 2.0 | 100 | 99.6 | 0 | 0 |
| | TRB | | 26.8 | 9.2 | 42.0 | 0 | 35.4 |
| 1, 150, 0 | MA | % > FT30 | 19.8 | 100 | 95.2 | 0 | 3.4 |
| | TRB | | 4.8 | 61.2 | 67.6 | 0 | 9.4 |
| 1, 150, 0.1 | MA | % > FT30 | 11.2 | 100 | 98.8 | 0 | 0 |
| | TRB | | 11.0 | 43.6 | 33.6 | 0 | 21.6 |
| 1, 200, 0 | MA | % > FT30 | 17.6 | 100 | 93.4 | 0 | 4.2 |
| | TRB | | 2.8 | 81.0 | 44.4 | 0 | 21.6 |
| 1, 200, 0.01 | MA | % > FT30 | 12.2 | 100 | 95.2 | 0 | 1.8 |
| | TRB | | 12.8 | 47.8 | 12.2 | 0 | 38.8 |

Returns are simulated 500 times using the estimated parameters and resampled, with replacement, residuals. % > FT30 denotes the fraction of simulations generating a mean or standard deviation larger than those from the actual FT30 series.

Table 12. Simulation tests from AR–ARCH bootstraps: sample, 1955–1974.

| Rule | Result | | Buy | $\sigma_b$ | Sell | $\sigma_s$ | Buy−Sell |
|---|---|---|---|---|---|---|---|
| 1, 50, 0 | MA | % > FT30 | 0.6 | 100 | 99.8 | 3.8 | 0 |
| | TRB | | 5.6 | 96.6 | 84.0 | 1.6 | 5.4 |
| 1, 50, 0.01 | MA | % > FT30 | 2.8 | 100 | 100 | 1.4 | 0 |
| | TRB | | 5.0 | 77.6 | 85.2 | 0.6 | 2.8 |
| 1, 150, 0 | MA | % > FT30 | 3.4 | 100 | 98.8 | 9.4 | 0 |
| | TRB | | 7.8 | 97.4 | 64.2 | 0.8 | 13.8 |
| 1, 150, 0.1 | MA | % > FT30 | 6.2 | 100 | 99.0 | 3.8 | 0 |
| | TRB | | 16.8 | 66.8 | 72.8 | 1.0 | 13.8 |
| 1, 200, 0 | MA | % > FT30 | 6.6 | 100 | 99.6 | 14.8 | 0 |
| | TRB | | 8.4 | 94.0 | 64.0 | 0.4 | 12 |
| 1, 200, 0.01 | MA | % > FT30 | 3.0 | 100 | 98.8 | 7.8 | 0 |
| | TRB | | 10.6 | 58.0 | 77.0 | 0.6 | 7.6 |

Returns are simulated 500 times using the estimated parameters and resampled, with replacement, residuals. % > FT30 denotes the fraction of simulations generating a mean or standard deviation larger than those from the actual FT30 series.

Table 13. Simulation tests from AR–ARCH bootstraps: sample, 1975–1994.

| Rule | | Result | Buy | $\sigma_b$ | Sell | $\sigma_s$ | Buy−Sell |
|---|---|---|---|---|---|---|---|
| | MA | | 13.6 | 62.6 | 97.8 | 42.2 | 1.2 |
| 1, 50, 0 | | % > FT30 | | | | | |
| | TRB | | 36.2 | 69.0 | 54.6 | 11.6 | 39.2 |
| | MA | | 7.4 | 40.8 | 97.8 | 8.4 | 0.4 |
| 1, 50, 0.01 | | % > FT30 | | | | | |
| | TRB | | 27.4 | 1.4 | 53.6 | 0.6 | 34.2 |
| | MA | | 63.2 | 100 | 62.2 | 0.2 | 46.2 |
| 1, 150, 0 | | % > FT30 | | | | | |
| | TRB | | 66.6 | 89.4 | 68.4 | 1.8 | 41.0 |
| | MA | | 56.0 | 99.4 | 56.2 | 0 | 46.6 |
| 1, 150, 0.1 | | % > FT30 | | | | | |
| | TRB | | 73.2 | 29.8 | 51.0 | 0 | 61.8 |
| | MA | | 64.4 | 99.6 | 52.6 | 0 | 54.8 |
| 1, 200, 0 | | % > FT30 | | | | | |
| | TRB | | 67.8 | 76.6 | 59.6 | 5.0 | 48.8 |
| | MA | | 70.2 | 100 | 52.8 | 0 | 57.6 |
| 1, 200, 0.01 | | % > FT30 | | | | | |
| | TRB | | 66.2 | 31.4 | 52.2 | 0.6 | 54.6 |

Returns are simulated 500 times using the estimated parameters and resampled, with replacement, residuals. % > FT30 denotes the fraction of simulations generating a mean or standard deviation larger than those from the actual FT30 series.

It would therefore seem to be the case that trading rules 'worked' when the market was driftless (see the return models fitted in table 10, which did not have significant constants for the two earlier periods). These were years when, it might be argued, the market was less efficient, in the sense of being more predictable, both linearly and nonlinearly: the $R^2$ of the AR–ARCH model fitted to the 1935–1954 data is 0.145, while that of the model fitted to the 1975–1994 data is only 0.005.

The results for the first forty years of our sample are thus consistent, in almost every respect, with those of Brock *et al.* (1992) for the Dow in New York. It is in the last of our sub-samples that the performance of the trading rules deteriorates badly. Indeed, it could be argued from figure 3 that it is only from the early 1980s that a buy-and- hold strategy begins clearly to dominate. This, in fact, might not be inconsistent with the behaviour of the Dow. The sample of Brock *et al.* ended in 1986 and their final subperiod began in 1962, so they were not in a position to be able to isolate any 'structural shift' that might have taken place around 1982. An analysis of the recent behaviour of the New York Stock Exchange along these lines would thus be an interesting exercise to undertake.

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