Can Commodity Futures be Profitably Traded with Quantitative Market Timing Strategies?

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Abstract

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JEL Classification: *G12, G14*

Keywords: *Commodity, Futures, Technical Analysis, Quantitative, Market Timing*

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Abstract

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1. Introduction

We consider whether quantitative trading rules can be profitably applied to commodity futures trading. While this question has been considered in the past, we aim to provide the most comprehensive examination to date. We study a larger universe of technical trading rules, focus on more recent data and address the issue of data snooping bias using robust statistical techniques.

Commodity futures have been traded for long time. However, it is only recently that researchers have begun discussing the merits of including them in conventional portfolios. Gorton and Rouwnhorst (2006) show that commodity futures are very effective at providing diversification for both stock and bond portfolios. Vrugt, Bauer, Molenaar, and Steenkamp (2004) suggest this diversification can be achieved while losing no or less than proportional return. There are several possible explanations for these strong diversification benefits. Gorton and Rouwnhorst (2006) propose one explanation is the strong performance of commodities in periods of unexpected inflation compared to the weak performance of stocks and bonds in these periods, while Hiller, Draper, and Faff (2006) suggest precious metal commodities may be seen as safe destinations for funds during periods of stock high market volatility.

Erb and Harvey (2006) suggest out that out-performance is not assured by just adding commodity futures to a portfolio, which implies that consideration needs to be given to the value that can be added by active management. It is therefore interesting that recent studies have shown that commodity futures can be successfully traded with a variety of strategies. Basu, Oomen, and Stremme (2006) show that the Commitment of Traders Report published by the Commodity Futures Trading Commission (CFTC), which summaries the positions taken by different participants in the market, contains information that can be exploited by an active manager. Vrugt, Bauer, Molenaar, and Steenkamp (2004) show variables related to the business cycle, monetary policy, and market sentiment can all be used to generate profitable trading signals for commodity futures. Miffre and Rallis (2007) show that Jegadeesh and Titman (1993) momentum strategies generate returns of over 9% a year when applied to commodity futures, while Wang and Yu (2004) find that short-term contrarian strategies, similar to those of Lehmann (1990) and Lo and MacKinlay (1990), produce abnormal returns on commodity futures.

Futures markets are more attractive for pursing active trading strategies than stock markets for several reasons. Any active trading strategy incurs higher transaction costs than a buy-and-hold approach. Indeed, it is transactions costs that often make the difference between a trading strategy being economically significant or not. For instance, Bessembinder and Chan (1998) show that the profits attributed to technical trading rules applied to the Dow Jones Industrial Average documented by Brock, Lakonishok and LeBaron (1992) are not higher than reasonable estimates of the transaction costs incurred in implementing them. Transaction costs (spreads plus commissions) are a lot lower in futures markets than stock markets. Locke and Venkatesh (1997) estimate futures markets transaction costs to be in the 0.0004% to 0.033% range, while Lesmond, Ogden, and Trzcinka (1999) estimate that equity market transaction costs range from 1.2% for large decile U.S. firms to 10.3% for their small decile counterparts.

The ability to short-sell is a key component of most active trading strategies. Lesmond, Schill, and Zhou (2004) show that the profits to equity market momentum trading strategies are predominately earned from short-sales of small illiquid stocks which is difficult, if not impossible, in reality. In contrast, short-selling is easily done in futures markets.

The first paper to consider technical trading rules on commodity futures data appears to be Donchian (1960) who considered Channel Trading Rules on Copper futures data. Since this paper, several authors have documented profitability that exceeds reasonable estimates of transaction costs. Irwin, Zulauf, Gerlow, and Tinker (1997) find that a Channel Trading System generates statistically significant mean returns ranging 5.1%-26.6% in Soybeans, Soybean Oil, and Soybean Meal futures during the 1984-1988 period, while Lukac, Brorsen, and Irwin (1988) find that several technical trading systems, such as Moving Average and Channel Break-out systems, yield statistically significant portfolio returns ranging from 3.8%-5.6% in 12 futures markets (including agriculturals and metals) during the 1978-1984 period.[1] Surveys of market participants and journalists (e.g., Lui and Mole, 1998; Oberlechner, 2001) continue to find that these individuals place a lot of emphasis on technical analysis for shorter forecasting horizons

We extend this literature by considering 7,846 trading rule specifications from five rule families (Filter Rules, Moving Average Rules, Support and Resistance Rules, Channel Breakouts, and On Balance Volume Rules). We apply these rules to the 15 commodities considered by Wang and Yu (2004). The commodity series include Cocoa, Coffee, Cotton, Crude Oil, Feeder Cattle, Gold, Heating Oil, Live Cattle, Oats, Platinum, Silver, Soyabeans, Soya Oil, Sugar, and Wheat. Our data covers the 1/1/1984 – 31/12/2005 period. We study the entire series and two equal sub-periods. We focus on this later

[1] The interested reader should refer to Park and Irwin (2004) for an excellent review of early technical analysis studies.

period separately because Olson (2004) shows that the profits to technical analysis in the currency market have been eroded over time.

Unlike the previous commodity futures technical analysis literature, we utilise a variety of tests to examine the statistically significance of the trading rules profits. We use the Brock, Lakonishok and LeBaron (1992) (hereafter BLL) approach which involves fitting null models to the data, generating random bootstrapped series and comparing the profits generated from running the rules on the original commodity series to the profits generated the random series. We also use the bootstrapping technique (Sullivan, Timmerman, and White (1999), hereafter STW) which adjusts for data snooping bias.

We find that the best trading rule for each commodity series typically produces profits that are statistically significant at the 5% level. However, the trading rules we consider do not generate profits on 14 of the 15 commodity series after an adjustment is made for data snooping bias. This underscores the importance of conducting a robust adjustment for data snooping bias. A short-term Moving Average rule generates statistically significant profits (after data snooping bias adjustment) for the Oats series and this profitability appears to be in excess of reasonable estimates of transactions costs, however it is not robust to our sub-period analysis. Rather, the profitability disappears in the most recent sub-period. While we cannot rule out the possibility that technical trading rules can compliment some other trading strategy, we do conclusively show that they are not profitable when used in isolation, despite their wide following.

The rest of the paper is organized as follows. Section 2 contains a description of the technical trading rules we test. Our data and bootstrapping methodologies are described in

Section 3. We present and discuss our results in Section 4, while Section 5 concludes the paper.

2. Technical Trading Rules Tested

We consider the profitability of the 7,846 technical trading rules adopted by STW (1999) on the U.S. equity market. The rules come from five rule families: Filter Rules, Moving Average Rules, Support and Resistance Rules, Channel Break-outs, and On-balance Volume Rules. The interested reader should refer to the appendix of STW (1999) for a full description of each rule applied.

The simplest Filter Rules we consider involve buying (short-selling) after price increases (decreases) by x% and selling (buying) when price decreases (increases) by x% from a subsequent high (low). Following STW (1999), we consider two alternative definitions of subsequent highs and lows. The first is the highest (lowest) closing price achieved while holding a particular long (short) position. The second definition involves a most recent closing price that is less (greater) than the e previous closing prices. Rules that allow a neutral position are also considered. Under these rules a long (short) position is closed when price decreases (increases) y percent from the previous high (low). The final variation we consider involves holding a position for a prespecified number of periods, c, regardless of other signals generated during this time.

Moving Average rules are mechanical trading rules that attempt to capture trends. These generate a buy (sell) signal when the price moves above (below) the longer moving average. Variations of Moving Average rules we consider include those that generate a buy (sell) signal when a short moving average (e.g., 10 days) moves above (below) a longer moving average (e.g., 200 days). In accordance with STW (1999), we also consider the impact of applying two filters. The first filter requires the shorter moving average to exceed the longer moving average by a fixed multiplicative amount, *b*. The second requires a buy or sell signal to remain valid for a prespecified number of periods, *d*, before the signal is acted upon. We also consider holding a position for a prespecified number of periods, *c*.

Support and Resistance or "Trading Range Break" rules are the third rule family we consider. These rules aim to profit from the technical analysis principle that trends typically begin when price breaks out of a fixed trading band. Support and Resistance rules involve buying (short-selling) when the closing price rises above (falls below) the maximum (minimum) price over the previous *n* periods. The most recent closing price that is greater (less than) the *e* previous closing price can also be set as the extreme price level that triggers a buy or a sell. Positions can be held for prespecified number of periods, *c*, and we also impose a fixed percentage band filter, *b*, and a time delay filter, *d*.

Our fourth family of rules are Channel Breakouts. We follow STW (1999) in that the Channel Breakout rules we test involve buying (selling) when the closing price moves above (below) the channel. A channel is said to occur when the high over the previous *n* periods is within *x* percent of the low over the previous *n* periods. Positions are held for a fixed number of periods, *c*. We also investigate a sub-set of Channel Breakout rules which involve, a fixed band, *b*, being applied to the channel as a filter.

Our last rule family is On-Balance Volume (OBV) Averages. The OBV indicator is computed by keeping a running total of the indicator each period and adding (subtracting) the entire amount of daily volume when the closing price increases (decreases). In accordance with STW (1999), we apply a moving average of n periods to the OBV indicator and apply trading rules similar to the Moving Average rules, except the variable of interest is OBV rather than price. The interested reader should refer to the STW (1999) paper for a more in-depth description of the trading rules we apply.

3. Data and Methodology

3.1. Data

We analyze daily data on settlement prices and trading volume for the fifteen commodities considered by Wang and Yu (2004).[2] The commodity series include Cocoa, Coffee, Cotton, Crude Oil, Feeder Cattle, Gold, Heating Oil, Live Cattle, Oats, Platinum, Silver, Soyabeans, Soya Oil, Sugar, and Wheat. Wang and Yu (2004) choose this broad range of series due to their economic importance and market liquidity. Each commodity series covers the 1/1/1984 – 31/12/2005 interval with the exception of silver, which starts on 30/8/1988. In line with Wang and Yu (2004), we use Datastream continuous price series, which represent the price for the most actively traded contract.

Consistent with past research (e.g. Bessembinder, 1992; Miffre and Rallis, 2007) we measure daily returns as the log of the difference in price relatives, although it is important to note this is a conservative estimate of the gains made by someone applying our technical

[2] We are unable to source a corn series for an extended period so we include an oats series instead.

trading strategy. Miffre and Rallis (2007) highlight that aside from the initial margins, no cash payment is made when the position is opened. Initial margin is deposited but this is returned to the trader when an investment is closed. Had futures returns been measured relative to the margins, the trading rule profits we document would be larger. In this regard, our definition of return is conservative (see Miffre and Rallis, 2007, for more detail on this point).

We present the summary statistics for each commodity series in Table 1. We examine the distribution characteristics using the following statistics: mean, standard deviation, skewness, kurtosis, and the autocorrelation characteristics using the Ljung-Box-Pierce (Q-stats) test at lags of 6, 12 and 24 days, along with the estimated autocorrelation at lags of 1 to 4 days. Nine of the 15 commodity series have positive mean daily returns, with Platinum has the largest mean daily return while Cocoa has the smallest. Sugar, Heating Oil, and Coffee are the most volatile series. Statistically significant (at the 1% level) skewness is prevalent in each commodity series. However, there is an almost even split between positive (7 commodities) and negative skewness (8 commodites). Statistically significant (at the 1% level) kurtosis is present in returns in all commodity series, which indicates the presence of fat tails in each of the return distributions.

Turning to the time series properties of the samples, we observe that there is evidence of positive (negative) autocorrelation at one lag in four (two) of the series. Negative autocorrelation at two lags, three lags, and four lags is prevalent in six, two, and one of the series respectively. However, the Ljung-Box test indicates that positive autocorrelation is more prevalent at long lags.

[Insert Table 1 About Here]

3.2. Methodology

Tests of the profitability of technical trading rules in commodity futures markets (e.g., Stevenson and Bear, 1970) usually rely on the assumption that returns are stationary, independent, and normally distributed. However, Lukac and Brorsen (1990) find that technical trading returns on commodities are positively skewed and leptokurtic so these tests may not be valid. We apply two more appropriate test procedures. The first is the BLL (1992) bootstrapping methodology, while the second is the Reality Check bootstrapping technique of STW (1999) that accounts for data-snooping bias. We describe each of these tests in more detail below.

We begin by applying the bootstrap methodology that BLL (1992) adopted. We fit a null model to that data and generate the parameters of this model. We then randomly resample the residuals 500 times. We use each series of resampled residuals and the model parameters to generate random price series which have the same times-series properties as the original series. Earlier work (e.g. BLL, 1992) shows that bootstrap results are invariant to the choice of null model so we follow the established precedent in the literature (e.g. Kwon and Kish, 2002) and focus on the GARCH-M null model. The GARCH-M model we apply is presented in equations 1 to 3 (see BLL, 1992 for a detailed description of this model):

$$r_t = \alpha + \gamma\sigma_t^2 + \beta\varepsilon_{t-1} + \varepsilon_t \qquad (1)$$

$$\sigma_t^2 = \alpha_0 + \alpha_1\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2 \qquad (2)$$

$$\varepsilon_t = \sigma_t z_t \qquad z_t \sim N(0,1) \qquad (3)$$

The BLL (1992) bootstrap methodology involves comparing the conditional buy and sell returns generated by a trading rule on the original commodity series with the conditional buy or sell returns generated from the same trading rule on a random simulated series. We follow BLL (1992) and define the buy (sell) return as the mean return per period for all the periods where the rule is long (short). The difference between the two means is the buy-sell return. The proportion of times the buy-sell profit for the rule is greater on the 500 random series than the original series is the buy-sell p-value. If, for a given rule, 24 of the 500 random series have a buy-sell profit greater than that on the original series the p-value will be 0.048.

Our second test of profitability is the so-called While Reality Check bootstrap, introduced by White (2000). This bootstrap-based test evaluates whether the profitability of the best trading rule is statistically significant *after* adjusting for data-snooping bias which is introduced by selecting the rule from a wide universe of rules. When there is a large universe of rules some will be profitable due to randomness so explicitly adjusting for data-snooping is critical. The White Reality Check accounts for this by adjusting down the statistical significance of profitable trading rules if they are drawn from a large universe of unprofitable rules. This is in contrast to the BLL (1992) approach where each rule is evaluated in isolation.

Specifically, we follow STW (1999), and let $f_{k,t}$ $(k = 1,...,M)$ be the period t return from the k-th trading rule (out of a universe of M rules), relative to the benchmark (which is the commodity return at time t). The performance statistic of interest is the mean period relative return from the k-th rule, $\bar{f}_k = \sum_{t=1}^{T} f_{k,t} / T$, where T is the number of periods in the sample.

Like STW (1999), our null hypothesis is that the performance of the best trading rule, drawn from the universe of M rules, is no better than the benchmark performance, i.e.,

$$H_0 : \max_{k=1,\dots,M} \bar{f}_k \leq 0 \qquad (4)$$

STW (1999) then use the stationary bootstrap of Politis and Romano (1994) on the M values of $\bar{f}_k$ to test the null hypothesis.[3] To do this, each time-series of relative returns, f_k $(k = 1,\dots,M)$, is resampled (with replacement) B times, i.e., for each of the M rules, we resample the time-series of relative returns B times. Note that for each of the M rules, the same B bootstrapped time-series are used. Following STW (1999), we set B = 500. For the k-th rule, this generates B means, which we denote $\bar{f}^*_{k,b}$ $(b = 1,\dots,B)$, from the B resampled time-series, where

$$\bar{f}^*_{k,b} = \sum_{t=1}^{T} f^*_{k,t,b} / T \,, \quad (b = 1,\dots,B)\,. \qquad (5)$$

The test two statistics employed in the test are:

$$\overline{V}_M = \max_{k=1,\dots,M} [\sqrt{T}\,\bar{f}_k] \qquad (6)$$

and

$$\overline{V}^*_{M,b} = \max_{k=1,\dots,M} [\sqrt{T}\,(\bar{f}^*_{k,b} - \bar{f}_k)] \quad , \quad (b = 1,\dots,B). \qquad (7)$$

To generate the test statistic, $\overline{V}_M$ is compared to the quantiles of the $\overline{V}^*_{M,b}$ distribution, i.e., we compare the maximum mean relative return from the M rules run on the original series,

[3] We refer the reader to Appendix C of STW (1999) for the details. As per STW (1999), we set the probability parameter to 0.1.

with the maximum mean across the *M* rules from each of the 500 bootstraps. In this way, the test evaluates the performance of the best rule with reference to the performance of the whole universe. In the context of our analysis, the White Reality Check bootstrap test allows us to compute a data-snooping adjusted p-value for the best rule in each of the file rule families, in relation to the universe of 7,846 rules from which they are drawn.

4. Results

Our results provide strong evidence that the large universe of technical trading rules we consider are not profitable when applied to 14 of the 15 commodity futures contracts we examine. There is evidence that certain rules generate profits, but the statistical significance of these profits disappears once data snooping bias is accounted for. We find the best Moving Average trading rule generates profits on the Oats series that are statistically significant after data snooping bias has been accounted for. These profits are in excess of reasonable estimates of transactions costs. However, this profitability is not evident in data for the 1995 – 2005 sub-period. Overall, we conclude that while we cannot rule out the possibility that technical trading rules add value by complimenting some other commodity trading strategy we can conclude that they do not consistently add value in their own right.

Table 2 contains bootstrap results for the entire 1984 – 2005 period (with the exception of Silver which starts in 1988). The p-value count columns document the number of rules that are statistically significant out of the total universe of 7,846 rules. For rule to be statistically significant at the 1% (5%) level, there would have to be 5 (25) or fewer instances of the rule generating more profit on bootstrapped series than the original series.

The remaining columns contain results relating to the STW (1999) bootstrap technique. The nominal p-value is the Reality Check p-value for the best rule, unadjusted for data-snooping. The STW (1999) p-value is the data-snooping adjusted p-value, after accounting for the fact the rule is drawn from a wider universe of 7,846 rules. The remaining columns contain other results relating to the best trading rule for each commodity series.

It is clear that from the BLL (1992) results that there is at least one rule that generates statistically significant on each of the fifteen commodity series. Coffee and Cotton have the fewest rules generating statistically significant profits at the 5% level while Live Cattle has the most. The pre-data snooping adjustment results for the STW (1999) bootstrapping procedure are similar to their BLL (1992) counterparts for eight commodities in that there is evidence of the best performing rule being statistically significant at the 5% level. For the remaining eight commodity series there is no evidence of even the best performing rule generating statistically significant profits at the 5% level. Despite these differences across the two alternative bootstrapping techniques prior to data snooping, the results are very clear once data snooping bias is accounted for.

[Insert Table 2 About Here]

After adjustment for data snooping bias the statistical significance of the best performing rule on each of the series other than Oats disappears. The difference between the nominal and STW (1999) p-values is considerable for each commodity (other than Oats) which gives an indication of the size of the potential data snooping problem. Anyone testing a few rules in isolation could incorrectly conclude that technical analysis does have value, when it fact any profitability can be attributed to data snooping bias.

The best performing trading rule on the Oats series is the Moving Average rule involving price and a two-day moving average of price. This rule generates statistically significant (at the 1% level) profits after data snooping bias has been accounted for. These profits also appear to be economically significant. Even though the trading rule generates many trading signals (average days per trade is only 2.85), the average return per trade is 0.403%. This suggests that profits are available after transactions costs even if we assume that one-way transaction costs are at the upper extreme of the Locke and Venkatesh (1997) estimated range of 0.0004% to 0.033%. The proportion of winning trades to total trades for oats (41%) indicates that technical trading rules can generate profits overall even if more losing than winning trades are generated.

No one rule performs best on each of the commodity series. Rather, rules form each of the rule families are represented across each of the 15 series. While the short-term Moving Average rule generates the largest profits for the Oats series, a relatively long-term Support and Resistance rule generates the largest profits on the Gold series. This rule only signals 4 trades, or which all are profitable. It generates an average return per trade of 34.9% but this is not statistically significant (either before or after data snooping adjustment) as the average daily return is only 0.024%.

We consider the robustness of these results by breaking each data series in half. Table 3 contains bootstrap results for the 1984 – 1994 period (except for silver which is 1998 – 1996). Given this consistency between the BLL (1992) and STW (1999) bootstrap results for the entire period we only present the more common STW (1999) results. The nominal p-value results indicate that, on average, the best performing rule on commodity series is more statistically significant in the early period than the entire period. Nine of the 15 nominal p-values are lower (more statistically significant) in the 1984 – 1994 period. Similarly, the average daily return is higher for the best rules on 10 of the 15 series in the early period.

Despite the evidence of more profitability to trading rules in the earlier period, the overall conclusions about their profitability made earlier still stand. There is strong evidence that the best performing trading rule generates statistically significant profits in the majority of series before data snooping is accounted for, but this profitability disappears in all but the Oats series once data snooping bias is adjusted for. The Moving Average rule involving price and a two-day moving average of price is again the most profitable rule on the Oats series. The proportion of all trades that turn out to be winning trades is similar (41%) to the entire series, while the average return per trade is slightly higher (0.473%).

[Insert Table 3 About Here]

Results for the second sub-period (1995 – 2005, except for silver which is 1989 – 2005) are presented in Table 4. Consistent with the entire period and first sub-period results, there is no evidence that the best performing trading rule produces profits that are statistically significant once data snooping bias is adjusted for the majority of commodity series. This also applies to Oats, which was previously able to be traded profitably using a short-term Moving Average rule. The fact that the best performing rule on the Oats series in this period is a Filter Rule and even this is not profitable after data snooping adjustment indicates that profitability of the Moving Average rule is not robust to different sub-periods.

Similar to Gold in the entire period, the best performing rule on Heating Oil in the second sub-period generates profits in excess of 30% per trade. Despite the large size of these profits, they are not statistically significant before or after data snooping adjustment due to the small number of trades generated (7) and the corresponding low average return per day. A comparison of the average return per trade figures for the first and second sub-periods indicates there is some evidence of a decline in profitability over time. Nine of the 15 commodity series have a best rule which yield lower profits in the second period.

[Insert Table 4 About Here]

We complete our analysis by considering whether there are major differences between the profits generated by the long and short signals generated by the best trading rule for the entire period.[4] It is possible that a rule generates particularly profitable long (short) signals but the lack of profitability in short (long) signals offsets this profitability. If this is the case then an investor may choose to act on the long (short) signals but ignore the short (long) signals.

The results presented in Table 5 indicate there is some evidence that the average daily return is higher for long trades than short trades. This is evident in 11 of the 15 commodity series. This is unsurprising as while commodity futures, as measured by the Reuters-CRB index, experienced considerable volatility over the 1984 - 2005 period we study, they did increase 27%. This indicates that, on average, there was more upward than downward movement. Although there is evidence of superior performance for long trades, the difference between the profits generated by long and short trades is generally small. The

[4] Equivalent results for each sub-period are very similar so are not reported in order to conserve space. The interested reader should contact the authors for these results.

differences in average daily return per day are all 0.03% or less, which suggests an investor applying these technical trading rules is unlikely to be able to consistently add meaningful incremental profit by following the long signals of a rule and ignoring the short signals.

[Insert Table 5 About Here]

In summary, our results demonstrate that technical trading rules cannot be used to profitably trade the 15 commodity series we consider. While there is evidence of the best performing rule on the oats series generating profits that are statistically significant after data snooping adjustment and economically significant over the entire 1984 – 2005 period, this rule is not profitable in the more recent 1995 – 2005 sub-period. The majority of commodity series have a trading rule that generates profitable trades but the statistical significance of this profitability disappears once data snooping bias is accounted for.

5. Conclusions

We re-consider whether quantitative trading rules can be profitably applied to commodity futures trading. Compared to previous work, we study a larger universe of technical trading rules, focus on more recent data and address the issue of data snooping bias using robust statistical techniques. Commodity futures have been trading for long time, but it is only recently that debate has begun about the merits of including commodity futures in mainstream portfolios. Recent work has shown commodities can be very effective at providing diversification for both stock and bond portfolios, which may be due to their strong performance in periods of unexpected inflation or due to safe haven qualities of precious metal commodities.

Futures markets have several features that make them a more attractive market for active trading strategies than stock markets. In particular, transaction costs are lower and it is easier to short-sell. It is therefore interesting that recent studies have shown that commodity futures can be successfully traded with a variety of strategies, including using information on market positions from the Commodity Futures Trading Commission, medium-term momentum strategies and short-term contrarian strategies.

We extend this literature by considering 7,846 trading rule specifications from five rule families (Filter Rules, Moving Average Rules, Support and Resistance Rules, Channel Breakouts, and On Balance Volume Rules). We apply these rules to the 15 major commodity series over the 1/1/1984 – 31/12/2005 period. We study the entire series and two equal sub-periods. Unlike the previous commodity futures technical analysis literature, we apply a suite of tests to test the statistically significance of the trading rules profits. These are the Brock, Lakonishok and LeBaron (1992) approach of fitting null models to the data, generating random series and comparing the results from running the rules on the original series to those from running on the randomly generated bootstrapped series, and bootstrapping technique of Sullivan, Timmerman, and White (1999) which adjusts for data snooping bias.

We find that the best trading rule for each commodity series typically produces profits that are statistically significant at the 5% level. However, the trading rules we consider do not generate profits on 14 of the 15 commodity series after an adjustment is made for data snooping bias. This underscores the importance of conducting a robust adjustment for data snooping bias. A short-term moving average rule generates statistically significant profits (after data snooping bias adjustment) for the Oats series. This profitability appears to be in excess of reasonable estimates of transactions costs, however it is not robust to our sub-period analysis. Rather, the profitability disappears in the most recent sub-period. While we cannot rule out the possibility that technical trading rules can compliment some other trading strategy, we do conclusively show that they are not profitable when used in isolation, despite their wide following.

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Table 1
Summary Statistics

	N	Mean (%)	Std. (%)	Skew.	Kurt.	ρ (1)	ρ (2)	ρ (3)	ρ (4)	Q(6)	Q(12)	Q(24)
Cocoa	11480	-0.0105	1.9040	0.1545**	6.2546**	0.0011	-0.0245	0.0075	-0.0074	0.4719	4.5600	17.5873
Coffee	11480	-0.0045	2.4306	0.2137**	10.8884**	-0.0026	-0.0330*	0.0364**	0.0024**	0.4641**	22.1726**	31.3498**
Cotton	11480	-0.0061	1.8993	-11.2831**	437.3499**	0.0172	-0.0281*	-0.0109	0.0167	0.4753	8.6335	12.7815
Crude Oil	11480	0.0126	2.3711	-1.1412**	22.7825**	-0.0099	-0.0517**	-0.0434**	0.0188	0.4658**	34.3410**	47.1361**
Feeder Cattle	11480	0.0089	0.8572	-0.1738**	7.1394**	0.0394**	0.0109	0.0205	-0.0027	0.4860**	27.7084**	58.4575**
Gold	11480	0.0051	0.8929	0.0524*	12.0246**	-0.0325*	-0.0247	-0.0010	0.0007	0.4847	10.5015	14.5724
Heating Oil	11480	0.0125	2.4373	-1.6611**	24.4073**	-0.0154	-0.0080	-0.0400**	-0.0034	0.4666**	23.6366**	59.3482**
Live Cattle	11480	0.0061	1.0399	-0.6999**	10.9612**	0.0367**	-0.0001	0.0155	0.0175	0.4834**	20.4507**	40.2751**
Oats	11480	0.0008	2.0151	-0.048*	9.4390**	0.0645**	-0.0216	-0.0130	-0.0173	0.4699**	36.6366**	52.7165**
Platinum	11480	0.0159	1.4006	0.3228**	18.0310**	-0.0308**	-0.0192	-0.0329	-0.0225	0.4782**	19.4358**	26.7163**
Silver	9048	0.0068	1.4265	-0.3679**	8.2722**	-0.0073	-0.0028	-0.0060	-0.0078	0.4766	1.4817	15.0351
Soybeans	11480	-0.0053	1.3695	-0.5001**	8.1828**	0.0012	0.0148	0.0124	0.0118	0.4789*	16.5106**	28.1074*
Soya oil	11480	-0.0054	1.5075	0.0939**	4.9157**	0.0118	-0.0370**	-0.0147	0.0277	0.4775**	17.4790*	21.7579*
Sugar	11480	0.0131	3.3189	10.7817**	460.4833**	-0.0117	-0.0551**	-0.0072	-0.0689**	0.4616**	46.6694**	76.5959**
Wheat	11480	-0.0012	1.5319	-0.2539**	11.3228**	0.0313*	-0.0344**	-0.0223	-0.0095	0.4775**	29.2327**	41.1632**

Table 1 contains summary statistics for each data series. The ρ columns are the autocorrelation results for the stated lags. Ljung-Box-Pierce Q autocorrelation results are also presented. * indicates statistical significance at the 5% level, ** indicates statistical significance at the 1% level.

Table 2
Bootstrap Results – Full Period

	BLL p-Value Count (1%)	**BLL p-Value Count (5%)**	**Nominal p-Value**	**STW p-Value**	**Average Daily Return**	**Average Return Per Trade**	**Total No. of Trades**	**No. of Winning Trades**	**No. of Losing Trades**	**Average Days Per Trade**
Cocoa	13	111	0.032	0.628	0.047%	1.597%	170	101	69	26.06
Coffee	4	82	0.052	0.670	0.056%	1.228%	261	140	121	10.04
Cotton	26	129	0.054	0.532	0.037%	0.070%	3002	1358	1644	1.91
Crude Oil	51	193	0.068	0.784	0.070%	1.323%	304	157	147	18.73
Feeder Cattle	93	311	0.038	0.676	0.035%	0.385%	524	299	225	5.14
Gold	77	262	0.106	0.832	0.024%	34.908%	4	4	0	1401.25
Heating Oil	27	137	0.038	0.740	0.079%	0.178%	2554	975	1579	2.25
Live Cattle	325	573	0.006	0.428	0.047%	3.668%	74	53	21	51.35
Oats	77	253	0.000	0.010	0.141%	0.403%	2012	816	1196	2.85
Platinum	10	132	0.190	0.932	0.036%	4.113%	50	26	24	111.96
Silver	26	128	0.068	0.754	0.048%	1.565%	139	80	59	26.33
Soybeans	46	179	0.008	0.248	0.058%	3.442%	96	56	40	53.05
Soya oil	14	115	0.016	0.372	0.055%	0.126%	2473	926	1547	2.32
Sugar	13	100	0.132	0.806	0.068%	4.037%	96	54	42	52.96
Wheat	64	121	0.008	0.310	0.060%	0.084%	4131	1915	2216	1.38

Table 2 contains bootstrap results for the entire 1984 – 2005 period (with the exception of Silver which starts in 1988). The p-value count columns document the number of rules that are statistically significant out of the total universe of 7,846 rules. For rule to be statistically significant at the 1% (5%) level, there would have to be 5 (25) or fewer instances of the rule generating more profit on bootstrapped series than the original series. The remaining columns contain results relating to the Sullivan, Timmerman, and White (1999) (STW) bootstrap technique. The nominal p-value is the Reality Check p-value for the best rule, unadjusted for data-snooping. The STW (1999) p-value is the data-snooping adjusted p-value, after accounting for the fact the rule is drawn from a wider universe of 7,846 rules. The remaining columns contain results relating to the best trading rule for each commodity series.

Table 3
Bootstrap Results – First Sub-Period

	Nominal p-Value	**STW p-Value**	**Average Daily Return**	**Average Return Per Trade**	**Total No. of Trades**	**No. of Winning Trades**	**No. of Losing Trades**	**Average Days Per Trade**
Cocoa	0.012	0.486	0.070%	5.030%	40	26	14	50.00
Coffee	0.052	0.720	0.080%	7.676%	30	19	11	50.27
Cotton	0.066	0.466	0.063%	4.867%	37	21	16	74.92
Crude Oil	0.012	0.448	0.113%	2.234%	145	72	73	19.48
Feeder Cattle	0.052	0.742	0.035%	5.908%	17	11	6	165.12
Gold	0.044	0.716	0.034%	0.303%	320	165	155	8.93
Heating Oil	0.038	0.680	0.084%	0.188%	1282	488	794	2.24
Live Cattle	0.032	0.610	0.044%	0.507%	249	156	93	5.08
Oats	0.000	0.016	0.172%	0.473%	1045	433	612	2.75
Platinum	0.066	0.728	0.053%	3.720%	41	24	17	68.24
Silver	0.032	0.674	0.003%	1.415%	4	3	1	493.75
Soybeans	0.014	0.320	0.054%	5.337%	29	20	9	92.76
Soya oil	0.026	0.680	0.055%	26.076%	6	5	1	477.67
Sugar	0.082	0.854	0.119%	7.136%	48	28	20	52.50
Wheat	0.022	0.456	0.078%	0.189%	1187	459	728	2.42

Table 3 contains bootstrap results for the 1984 – 1994 period (except for silver which is 1988 – 1996). Each column contains results relating to the Sullivan, Timmerman, and White (1999) (STW) bootstrap technique. The nominal p-value is the Reality Check p-value for the best rule, unadjusted for data-snooping. The STW (1999) p-value is the data-snooping adjusted p-value, after accounting for the fact the rule is drawn from a wider universe of 7,846 rules. The remaining columns contain results relating to the best trading rule for each commodity series.

Table 4
Bootstrap Results – Second Sub-Period

	Nominal p-Value	STW p-Value	Average Daily Return	Average Return Per Trade	Total No. of Trades	No. of Winning Trades	No. of Losing Trades	Average Days Per Trade
Cocoa	0.060	0.774	0.065%	1.211%	153	81	72	10.32
Coffee	0.022	0.434	0.130%	4.089%	91	57	34	27.15
Cotton	0.022	0.444	0.079%	2.622%	86	53	33	27.03
Crude Oil	0.118	0.970	0.079%	0.822%	276	102	174	10.38
Feeder Cattle	0.036	0.782	0.025%	7.068%	10	4	6	266.80
Gold	0.084	0.772	0.041%	1.325%	88	56	32	27.68
Heating Oil	0.186	0.932	0.082%	33.498%	7	6	1	373.71
Live Cattle	0.028	0.674	0.053%	4.506%	34	29	5	50.00
Oats	0.020	0.528	0.114%	0.151%	2160	958	1202	1.31
Platinum	0.346	0.984	0.043%	3.393%	36	17	19	75.42
Silver	0.072	0.822	0.081%	2.558%	74	47	27	25.14
Soybeans	0.050	0.660	0.062%	3.724%	48	29	19	54.60
Soya oil	0.014	0.274	0.078%	0.188%	1179	472	707	2.43
Sugar	0.010	0.554	0.102%	9.474%	31	16	15	88.10
Wheat	0.000	0.212	0.108%	0.143%	2163	1058	1105	1.31

Table 4 contains bootstrap results for the 1995 – 2005 period (except for silver which is 1997 – 2005). Each column contains results relating to the Sullivan, Timmerman, and White (1999) (STW) bootstrap technique. The nominal p-value is the Reality Check p-value for the best rule, unadjusted for data-snooping. The STW (1999) p-value is the data-snooping adjusted p-value, after accounting for the fact the rule is drawn from a wider universe of 7,846 rules. The remaining columns contain results relating to the best trading rule for each commodity series.

Table 5
Bootstrap Results for Long and Short Trades – Entire Period

	Average Daily Return	**Average Return Per Trade**	**Total No. of Trades**	**No. of Winning Trades**	**No. of Losing Trades**	**Average Days Per Trade**
			Panel A: Long Trades			
Cocoa	0.06%	1.620%	88	53	35	26.20
Coffee	0.11%	1.125%	140	70	70	10.07
Cotton	0.03%	0.059%	1501	691	810	1.97
Crude Oil	0.08%	1.548%	152	87	65	20.49
Feeder Cattle	0.09%	0.473%	250	144	106	5.14
Gold	0.04%	44.866%	2	2	0	1192.50
Heating Oil	0.09%	0.207%	1277	520	757	2.32
Live Cattle	0.07%	3.624%	36	26	10	51.39
Oats	0.14%	0.407%	1006	397	609	2.90
Platinum	0.05%	6.207%	25	13	12	112.92
Silver	0.06%	1.655%	80	43	37	26.25
Soybeans	0.06%	3.274%	44	27	17	52.11
Soya oil	0.05%	0.113%	1236	468	768	2.31
Sugar	0.08%	4.333%	49	30	19	51.71
Wheat	0.06%	0.084%	2066	938	1128	1.39
			Panel B: Short Trades			
Cocoa	0.06%	1.572%	82	48	34	25.91
Coffee	0.13%	1.347%	121	70	51	10.00
Cotton	0.04%	0.081%	1501	667	834	1.84
Crude Oil	0.06%	1.097%	152	70	82	16.97
Feeder Cattle	0.06%	0.305%	274	155	119	5.15
Gold	0.02%	24.950%	2	2	0	1610.00
Heating Oil	0.07%	0.148%	1277	455	822	2.17
Live Cattle	0.07%	3.711%	38	27	11	51.32
Oats	0.14%	0.398%	1006	419	587	2.81
Platinum	0.02%	2.020%	25	13	12	111.00
Silver	0.05%	1.442%	59	37	22	26.44
Soybeans	0.07%	3.584%	52	29	23	53.85
Soya oil	0.06%	0.139%	1237	458	779	2.33
Sugar	0.07%	3.728%	47	24	23	54.26
Wheat	0.06%	0.083%	2065	977	1088	1.37

Table 5 contains bootstrap results for long and short trades for the entire 1984 – 2005 period (with the exception of Silver which starts in 1988). Each column contains results for to the best trading rule for each commodity series.