Classifying Market States with WARS

Lixiang Shen[1] and Francis E. H. Tay[2]
Department of Mechanical and Production Engineering, National University of Singapore
10 Kent Ridge Crescent, Singapore 119260
{[1]engp8633, [2]mpetayeh}@nus.edu.sg

Abstract. In this paper, a new indicator - *WARS (Weighted Accumulated Reconstruction Series)* at classifying the state of financial market, either trending state or mean-reverting state, was presented. Originated from the computation of Entropy, this new indicator was found to be able to reflect the market behavior accurately and easily. The algorithm of generating *WARS* and its meaning related to Entropy were introduced and some comparison results between *WARS* and the *Daily Profit Curve* were listed. As a new indicator, *WARS* also can be used to build a trading system - to provide buy, sell and hold signals. Through the application on S&P 500 index, it was verified to be effective and was a promising indicator.

1 Introduction

One of the basic tenets put forth by Charles Dow in the Dow Theory [1] is that security prices do trend. Trends are often measured and identified by "trendlines" and they represent the consistent change in prices (i.e., a change in investor expectations). In the Fig. 1 and Fig. 2, rising trend and falling trend were illustrated.

Fig. 1. Rising Trend

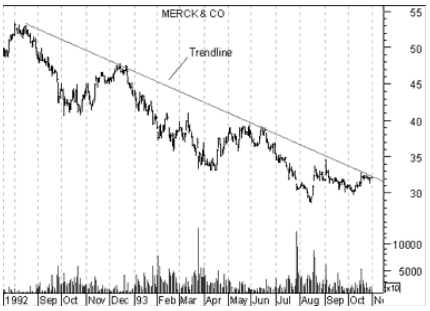

Fig. 2. Falling Trend

A principle of technical analysis is that once a trend has been formed, it will remain intact until broken [2]. The goal of technical analysis is to analyze the current trend using trendlines and then either invest with the current trend until the trendline is broken, or wait for the trendline to be broken and then invest with the new (opposite) trend. For trading, it is very important to know the current market state – either in the rising trend or in the falling trend. So our work was focussed on searching for indicators that can reflect the fluctuation of price or index in the financial markets. An indicator, called *Weighted Accumulated Reconstruction Series* (*WARS*), has been constructed and found to have interesting characteristics. It can

reflect the trend of the changes in price. The indicator was able to make use of more information contained in the data than moving average and therefore may be able to better reflect the state of the price or index.

2 Weighted Accumulated Reconstruction Series (*WARS*)

The idea of generating *Weighted Accumulated Reconstruction Series (WARS)* came from the computation of Entropy. The concept of Entropy was first proposed by Shannon [3] in the Information Theory as a measure of the complexity of a system. Up to now, this concept has been applied in the economic domain to measure the production flexibility [4], customer requirements [5], and processing cost of administrating the production facility [6]. In the capital market, a derivative of information entropy - Kolmogorov Entropy, was applied to measure how chaotic a system is based on the analysis of real-time price or index [7, 8, 9, 10, 11, 12]. By calculation of Kolmogorov Entropy, the predictability of the price changes or returns is studied. Kapur and Kesavan [13] even used the Kullback's Minimum Cross-Entropy Principle to minimise the risk in portfolio analysis.

The Shannon Entropy, represented by *Ent(S)*, of a system is defined as:

$$Ent(S) = -\sum_{i=1}^{k} P(C_i, S)\log(P(C_i, S)) \ . \qquad (1)$$

where C_i presents the *i*th event in system S, i = 1, 2, …, k;

$P(C_i,S)$ is the *a priori* probability of event C_i's occurrence in *S*.

From the above definition in Eq. 1, the distribution of the system must be known before the System Entropy is calculated. But in practice, usually the distribution of the system may not be known in advance. The easiest way to solve this problem is to accumulate this series and it will follow the exponential function for a positive series. Following this idea, the algorithm to construct the new indicator is formulated in.

Step 1: Normalize every value of this series between -1 to 1 (to remove amplitude effect off the series)

$$x_i = x_i / \max(|x_i|); \qquad (i = 1, 2, \ldots, Win\_length) \qquad (2)$$

Step 2: Subtract the first value of a series (to keep all the intervals at the same beginning, the origin of coordinates).

$$x_i = x_i - x_1; \qquad (i = 1, 2, \ldots, Win\_length) \qquad (3)$$

Step 3: Subtract the mean value from the whole series.

$$x_i = x_i - Mean\_x; \qquad (i = 1, 2, \ldots, Win\_length) \qquad (4)$$

where: $Mean\_x = \frac{1}{n}\sum_i x_i$

Step 4: Reconstruct a new series (*WARS*) by means of weighted accumulating the original one.

$$Weight_j = \frac{1+2+\cdots+j}{1+2+\cdots+Win\_length}. \qquad (j = 1, 2, \ldots, Win\_length) \qquad (5)$$

$$y_1 = \frac{1}{1+2+\cdots+n} x_1 ;$$

…

$$y_n = \frac{1}{1+2+\cdots+n}x_1 + \frac{1+2}{1+2+\cdots+n}x_2 + \cdots + \frac{1+2+\cdots+n}{1+2+\cdots+n}x_n \,. \quad (6)$$

In this process, the more recent points have more contribution to *WARS*.

Step 5: Calculate the area of this interval and get its absolute value.

$$Area = |y_1 + y_2 + \cdots + y_n| \,. \quad (7)$$

The trending and mean-reverting states were distinguished according to the area value. If the area value is greater than 0, then market is in a trending state, else the market is in a mean-reverting state.

In Figure 3, three curves representing up-trending, down-trending and mean-reverting series were drawn. After *weighted accumulated reconstruction*, the corresponding three curves were drawn in Figure 4.

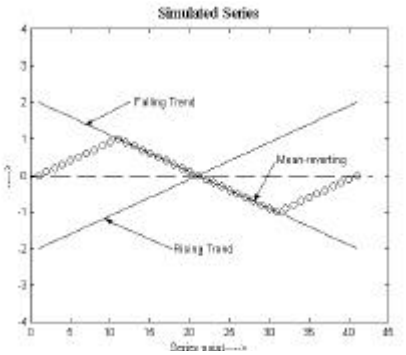

Fig. 3. The illustration of Accumulated Reconstruction Series

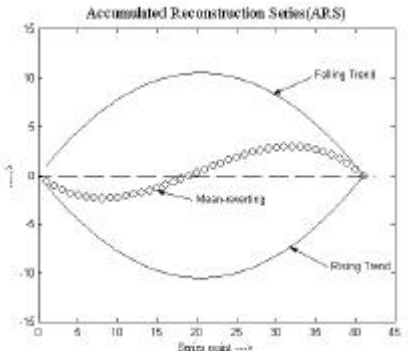

Fig. 4. The illustration of Accumulated Reconstruction Series

During the process of generating *WARS*, the original series was rolled and the *area* of every interval was calculated iteratively. For instance, if there are 10 points in a series; and *Win_length* is chosen as 4. From the 1st point to the 4th point the first area value is calculated. From the 2nd point to the 5th point the second area value is obtained. This process is repeated and eventually six points are obtained to construct *WARS*. The length of *WARS* equals to the length of original series less *Win_length*.

3 Comparison of *WARS* and *Daily Profit Curve*s

For a large company, usually a certain strategy will be adopted to direct its operation in the financial market. Further, the *equity curve* of a period will be used to evaluate the pros and cons of this strategy [14]. If the *equity curve* goes up, the company is making a profit and vice versa. The generation of the *equity curve* will not be introduced in this paper. This was taken to be a given information. For the testing of the new indicator, 15 historical futures data supplied by Man-Drapeau Research Pte Ltd (Singapore) were selected. The *WARS* was generated from the *daily close price*. For the convenience of comparison of the above two curves, the *equity curve* was first changed to *daily profit curve* by using the following method:

$$y_i = x_i - x_{i-1}. \quad (i = 1, 2, \ldots, n) \quad (8)$$

Then the *moving average curve* [15] was calculated for both *WARS* and *Daily Profit Curve*. The correlation coefficient of *WARS* and the *Daily Profit Curve* was calculated to evaluate their similarity.

Fig. 5. The comparison of *WARS* and *Daily Profit Curve* for SP Futures

Fig. 6. The comparison of *WARS* and *Daily Profit Curve* for IA Futures

In Figures 5 - 6, the two curves were rescaled between -1 and 1 so that they can be compared directly. The solid line curve in Figures 5 - 6 represented *WARS* while the other curve represented the *Daily Profit Curve*. In these Figures, the two curves, *WARS* and *Daily Profit Curve* were found to have similar shape. It was clear that *WARS* reflected the fluctuation of *Daily Profit Curve*. From the correlation coefficient, the value was always larger than 0.6 (sometimes almost equal to 0.95). Thus *WARS* reflected the changing of *Daily Profit Curve* quite well.

From the generation of *WARS*, its meaning in the financial market can be interpreted as follows: *WARS* was generated by using the closing price in a period. If within this period, the price changes in a trending way, either up-trending or down-trending, *WARS* will maintain its large value or it may go up. When the price fluctuates in a mean-reverting way, *WARS* will go down or remain as a small value. Indirectly, it continuously reflects the changing of price. From the view of entropy, it can be simply interpreted as follows: The market states can be represented as 1 - up-trending, 0 -mean-reverting and -1 - down-trending. When the market falls in the trending state (either 1 or -1), the entropy of market equals to 0, corresponding to large value of *WARS*, close to 1. The mean-reverting state (0) is composed of up-trending and down-trending states, when the entropy of market equals to $\log 2$ ($Ent = -(\frac{1}{2}\log\frac{1}{2} + \frac{1}{2}\log\frac{1}{2})$), corresponding to a small value of *WARS*, close to 0. It is easy to understand the above results. When the market moves in a trending way, the system is more certain than in a mean-reverting state, in which the direction of price cannot be determined, i.e. more uncertainty contained in this system.

4 Using *WARS* to Generate Trading System

Based on the previous analysis, in this section, *WARS* was used to generate a trading system. The trading system [16] was built in the following steps:

- Calculate *WARS* using historical data.

- Determine the threshold value for buying and selling action according to the value of *WARS* calculated using training data set.
- Generate the trading signals as follows:
  If value of *WARS* > threshold of buying, then buy at the next day's opening price
  If value of *WARS* < threshold of selling, then sell at the next day's opening price
  If value of *WARS* is in between the thresholds, then no action is taken - hold.

Figure 7 depicts such a trading system using S&P500 index. The time interval of data was daily. The *WARS* was calculated based on 5-day-Win_length.

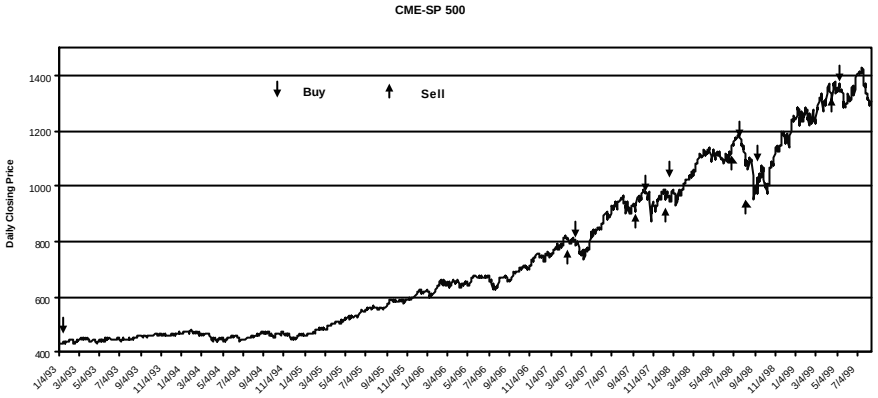

Fig. 7. Trading system generated using *WARS* on S&P 500 index

From the Figure 7, it can be seen that *WARS* gave correct trading signals at suitable time when the market changed gradually, from Jan. 1993 to Oct. 1997. But when the market changed dramatically, from Nov. 1997 to Apr. 1999, some signals given were lagging behind the change of price. This indicated that *WARS* is a reactive indictor. The trading performance was illustrated in Table 1.

Table 1 . Trading system performance based on the indicator *WARS* on S&P 500

Training Data Set	Testing Data Set
Training period:	Testing period:
01/04/1988 - 12/31/1992	01/01/1993 - 08/12/1999
max_*WARS*_area = 0.022152	Net_profit = 873.649963
min_*WARS*_area = -0.034170	max_win = 325.150024
threshold_buy = 0.003378	max_loss = -37.000000
threshold_sell = -0.015396	Trading_number = 14
Mean_*WARS*_area = 0.000446	Winning_Trade = 9
Std_*WARS*_area = 0.005593	Sharpe_ratio = 0.522271

There were altogether 14 trades in this index, among which 9 of them were profitable. From these results, it can be seen that this new indicator is effective in differentiating the market states and so it can be used to trace the changing market and provide the trading signals.

5 Concluding Remarks

A new indicator - *Weighted Accumulated Reconstruction Series* (*WARS*) is presented. In comparison with the *Daily Profit Curve*, *WARS* can indicate the *Daily Profit Curve* accurately and easily. In addition, *WARS* can be used to build a trading system. Through the application on S&P 500 index, it can be seen that this indicator is effective and promising. Further, *WARS* can be used to reflect the uncertainty of the market. When the magnitude of *WARS* approaches 1, the market is a strong trending state and therefore more investment can be done.

Although *WARS* is very similar in behaviour to the *Daily Profit Curve*, there are still many factors affecting the final results, such as the parameters: *Win_length* and *Moving Average Interval*. These issues will be further studied in the future

References

1. Bishop, G. W.: Charles H. Dow and the Dow theory. New York, Appleton-Century-Crofts (1960)
2. Achelis, S. B.: Technical Analysis from A to Z: covers every trading tool - from the Absolute Breadth Index to the Zig Zag. Probus Publisher, Chicago (1995)
3. Shannon, C. E. and Weaver,W.: The mathematical theory of communication. Urbana: University of Illinois Press (1949)
4. Frizelle, G. and Woodcock, E.: Measuring Complexity as an Aid to Developing Operational Strategy. International Journal of Operations and Production Management 15 (1995) 26-39
5. Johnston, R. B.: From Efficiency to Flexibility: Entropic Measures of Market Complexity and Production Flexibility. Complexity International 3 (1996)
6. Ronen, B. and Karp R.: An Information Entropy Approach to the Small-Lot Concept. IEEE Transactions on Engineering Management 41 (1994) 89-92
7. Barkoulas J. and Travlos N: Chaos in an emerging capital market? The case of the Athens Stock Exchange. Applied Financial Economics 8 (1998) 231-243
8. Mayfield E. and Mizrach B.: On Determining the Dimension of Real-Time Stock-Price Data. Journal of Business & Economic Statistics 10 (1992) 367-374
9. Frank, M. and Stengos, T.: Measuring the Strangeness of Gold and Silver Rates of Return. Review of Economic Studies 56 (1989) 553-567
10. Chen, S-H.: Elements of Information Theory: A Book Review. Journal of Economic Dynamics and Control 20 (1996) 819-824
11. Chen, S.-H and Tan, C.-W.: Measuring Randomness by Rissanen's Stochastic Complexity: Application to Financial Data. In: Dowe, D., Korb, K. and Oliver, J. (eds.): Information, Statistics and Induction in Science. World Scientific, Singapore (1996) 200-211
12. Chen, S-H and Tan, C.-W.: Estimating the Complexity Function of Financial Time Series: An Estimation Based on Predictive Stochastic Complexity. Journal of Management and Economics 3 (1999)
13. Kapur, J. and Kesavan, H.: Entropy optimization principles with applications, Boston: Academic Press (1992)
14. Hampton, J.: Risk Management: the Equity Curve Revisited. Journal of Computational Intelligence in Finance 6 (1998) 47-50
15. Webster, A. L.: Applied Statistics for Business and Economics. 2nd ed. McGraw-Hill Inc. (1995)
16. Pardo, R.: Design, Testing, and Optimization of Trading Systems. John Wiley & Sons Inc. (1992)