

# Time-variable and nonlinear phenomenon of stock market

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**ABSTRACT:** This paper started from moving average method. After finding that the physical meaning of moving average is somehow not clear, this paper modified the moving average and proposed a new model called volume weighted moving average (VWMA).

The VWMA model has been applied to mainland China's stock market. After following the market for ten years, it is tentatively concluded that the stock market is a time-variable and nonlinear system. The relation between the whole market average and the daily average is time-variable and nonlinear.

**KEY WORDS:** VWMA, time-variable and nonlinear

# Time-variable and nonlinear phenomenon of stock market

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This paper started from moving average(MA) of stock market technical analysis. After finding that the physical meaning of MA is not clear, I modified the MA method and proposed a new model.

I have applied this new model in the mainland China's stock market for ten years long. From the result, I have found some strange phenomenon. Tentatively I thought it is a kind of time-variable and nonlinear phenomenon. I would like to share the result with other people. I wish this will lead more attentions and discussions so that to help us understand the nature of the stock market much better.

This paper is divided into five parts. The first part is the background introduction. Starting from the MA method, I introduce the new idea. The second part is the model description. The third part is the model application. I would like to introduce how to apply the model in the complex market. The fourth part is the result. I chose two typical results. The fifth part is the tentative conclusion.

## 1. literature review

Among the technical analysis methods of stock market, the moving average is very common. Taking the close price of certain days and making a simple arithmetic average, the moving average can be obtained.

$$\text{Moving average (MA)} = \frac{\sum_{i=1}^n P_i}{n}. \quad (1)$$

Where, n represents the number of days. It can be 5, 10 or even longer like 120 etc.  $P_i$  is the close price.

In the real stock market there is a turnover rate, that is, the daily volume divides by the whole quantity of outstanding stock. I have found that sometimes some stocks are very volatile in the stock market. The volume is very big and the turnover rate is also very big. For example, the accumulation of three-day turnover rate can reach 100% for one stock. From my feeling this stock has almost changed ownership thoroughly in the three days. I feel that the average price after trading is only related with the trading status of the three days. In this case, the physical meaning of 5-day or 10-day above moving average is not clear. It would be meaningless.

Calculating average from the physical meaning would be like this. For a single stock there is a quantity of outstanding stock. After trading in the stock market, the knock down price of every share may be the same or may not be the same. If there are m kinds of knock down price  $P_i$  for a stock, i is an integer from 1 to m. The volume

knock down at  $P_i$  is  $V_i$ . The average price is

$$\text{Average price} = \frac{\sum_{i=1}^m P_i \cdot V_i}{\sum_{i=1}^m V_i} . \quad (2)$$

Where, the denominator equals to the whole quantity of outstanding stock.

It can be seen from the formula (2) that the average price is related with volume. Since the market information is very limited, no one can know exactly the volume of a stock knocking down at every price. Therefore the real average price can not be reached.

Because of this, I am thinking whether it is possible to set up a model to get a close estimation of the real average price.

## 2. model description

To closely estimate the real average price, I have set up a new model. I call it volume-weighted moving average. I would like to use VWMA as the abbreviation.

At first, I would like to make a hypothesis. That is : in a certain period, there is no overlapping in the daily volume.

The way to calculate VWMA is as follows.

For a single stock, there is a quantity of the outstanding stock. Take the whole or part of the quantity as the target volume  $tvol$  for the volume accumulation. From the daily volume  $dv$  and daily turnover  $dt$ , the daily average price is  $da=dt/dv$ .

To calculate one day's VWMA value, starting to count from this day to the past. Accumulate every day's volume. If the volume accumulation is less than  $tvol$ , take one more previous day's volume to accumulate. Until the  $n$  day, the volume

accumulation is bigger than or equal to  $tvol$ . That is  $\sum_{i=1}^n dv_i \geq tvol$ .

Take a part  $dvp_n$  from the volume of the most previous  $n$  day.

$$dvp_n = dv_n - \left( \sum_{i=1}^n dv_i - tvol \right) . \quad (3)$$

VWMA can be calculated.

$$\text{VWMA} = \frac{\sum_{i=1}^{n-1} dv_i \cdot da_i + dvp_n \cdot da_n}{\sum_{i=1}^{n-1} dv_i + dvp_n} . \quad (4)$$

Where,  $dv_i$  is daily volume and  $da_i$  is daily average.

From formula (3),  $\sum_{i=1}^{n-1} dv_i + dvp_n = tvol$ .

As mentioned above, if a stock is very volatile, the accumulation of three-day

turnover rate can reach 100%. The average is only related with the three-day trading status after using the model.

Drawing VWMA value on the candlesticks can get the VWMA line. Based on different value of  $tvol$ , different kinds of VWMA line can be drawn. It is the same as 5-day, 10-day moving average line.

From formula (4) it can be seen that if there is an ideal case, that is, every day's volume is equal, the formula (4) would be changed into the same form of formula (1). Therefore, moving average is a special case of my model. This shows that my model is more versatile.

### 3. model application

I have applied the model in mainland China's stock market. From 1997 I have followed the market for ten years long. Next I would like to introduce how to use the model in the complex stock market.

The mainland China's stock market is formed by two stock exchanges, one in Shanghai, the other in Shenzhen. The total stock number of the two exchanges is about 300 in 1997. Right now it is around 1300.

Before the year 2005 in China, the shares of big shareholders and sponsors can not be traded in the market. Only the shares issued to the public can be traded in the market. This part is the outstanding stock.

When VWMA method is used, I only consider the outstanding stock. I have a thinking of how to choose the quantity of the outstanding stock as the target volume for the volume accumulation. If taking the whole part of the outstanding stock, the VWMA result would be too slow to follow the daily price. If taking a small part of the outstanding stock, the VWMA result would respond too fast. Since different target volume will generate different VWMA value, I would like to choose the Fibonacci parameter to get a good experiment result. I take the 0.382 of the outstanding stock as the target volume for the volume accumulation. The resulting VWMA is close to the average of the part that is most recently traded and occupying 38.2% of the outstanding stock.

For a single stock, I can use the VWMA method directly. The result of VWMA can be drawn on the candlesticks to do further analysis. The next question is how to apply VWMA method to the whole market.

Usually there is the Index for the whole market. I don't think the VWMA method can be applied directly to the Index, because the Index can not be treated as a single stock. Still I would like to think from average point of view. Some Indexes are related with quantity of stock. Some others are not. To show the average better, I would like to take the quantity of stock into consideration. From VWMA method, the VWMA value of a single stock can be calculated. From many single VWMA values, the VWMA value of the whole market can be obtained.

$$\text{Market}_{VWMA} = \frac{\sum_{i=1}^k VWMA_i \cdot Ovol_i}{\sum_{i=1}^k Ovol_i} \quad (5)$$

Where,  $VWMA_i$  is the VWMA value of a single stock. The  $i$  is an integer from 1 to  $k$ . The  $k$  represents the whole stock number of the market.  $Ovol_i$  is the quantity of a single outstanding stock.

In the same way, the market daily average price can be calculated.

$$\text{Market}_{\text{daily}} = \frac{\sum_{i=1}^k da_i \cdot Ovol_i}{\sum_{i=1}^k Ovol_i} \quad (6)$$

Where  $da_i$  is the daily average of a single stock. As illustrated previously,  $da_i = dt_i / dv_i$ .

Drawing the  $\text{Market}_{\text{daily}}$  and  $\text{Market}_{VWMA}$  in a same chart, the further analysis can be made for the whole market.

In the above application, I realize that the market itself is continuous unless some special things happen. The bonus, dividend, bonus stock and issuing new shares will be considered to keep the continuity of the market.

In China, the bonus and dividend is usually very little. So I don't take these two into account. The trading data will not be changed.

For the bonus stock, since the market would ex-rights automatically, the trading data will be changed according to bonus stock. For example, if the bonus stock ratio is ten shares gifting three new shares, the price before the ex-rights day will be divided by 1.3, and volume will be multiplied by 1.3. Daily turnover will keep the same.

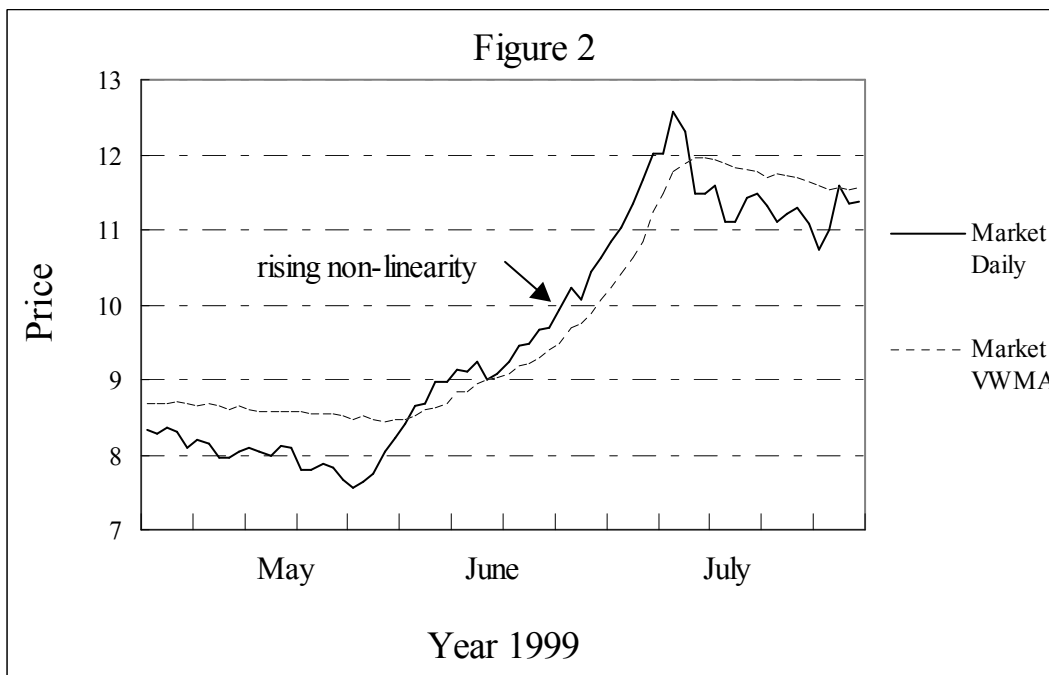
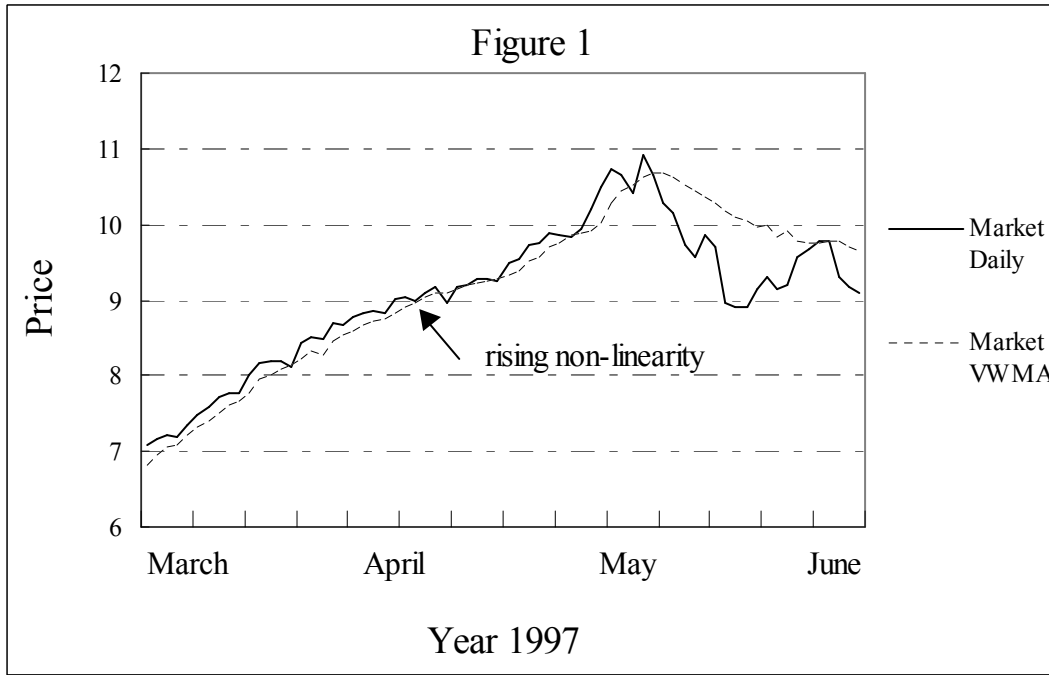
When new shares are issued to the public shareholders at a certain price with a ratio, I would treat it differently according to the offering price. If the offering price is lower than the market price a lot, most shareholders would like to buy according to the ratio. The price before the ex-rights day will be adjusted according to the offering price and the ratio. The daily volume will be enlarged according to the ratio. The daily turnover will also be adjusted accordingly. If the offering price is close to the market price, according to my observation, most shareholders will give up the rights. The trading data before the ex-rights day will not be changed.

When a new stock is listed in the market, I will increase the  $k$  by 1 in formula (5) and also add new VWMA value and  $Ovol$ . With the number of listed stock increases, the  $k$  value will also be increased.

#### 4. result

I have applied the model in China stock market for ten years since 1997. Since the VWMA model is a new method, I can not be sure of what kind of result can be seen from the beginning. I follow the market and observe. From the ten-year observation, I can tentatively determine that I have seen two nonlinear phenomenon.

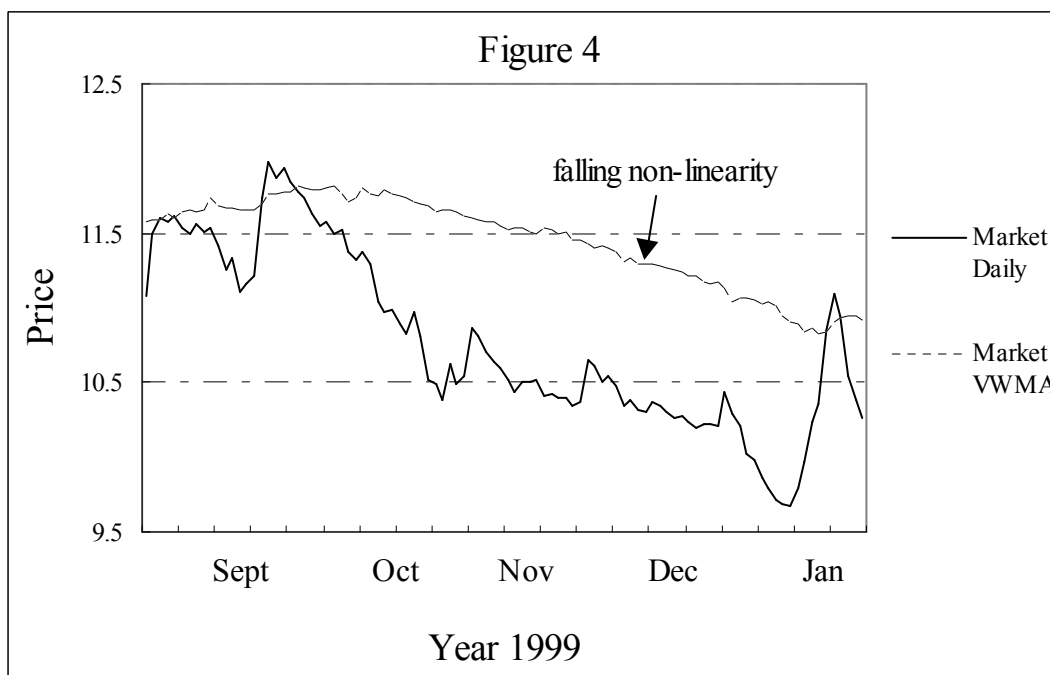
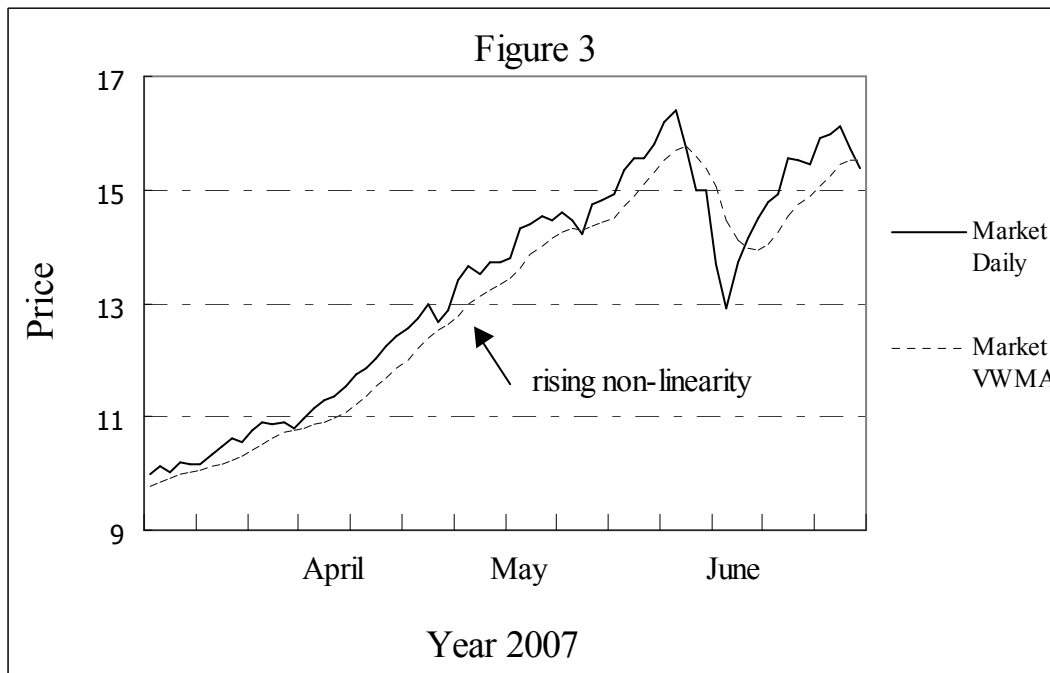
I choose six cases with  $\text{Market}_{\text{daily}}$  and  $\text{Market}_{VWMA}$  drawing together. Figure1-Figure3 are the rising cases. Figure4-Figure6 are the falling cases. Figure1 is from March to June of 1997. Figure2 is from April to July of 1999. Figure3 is from March to June of 2007. Figure4 is from August to December of 1999. Figure5 is from June to September of 2001. Figure6 is from April to September of 2004.



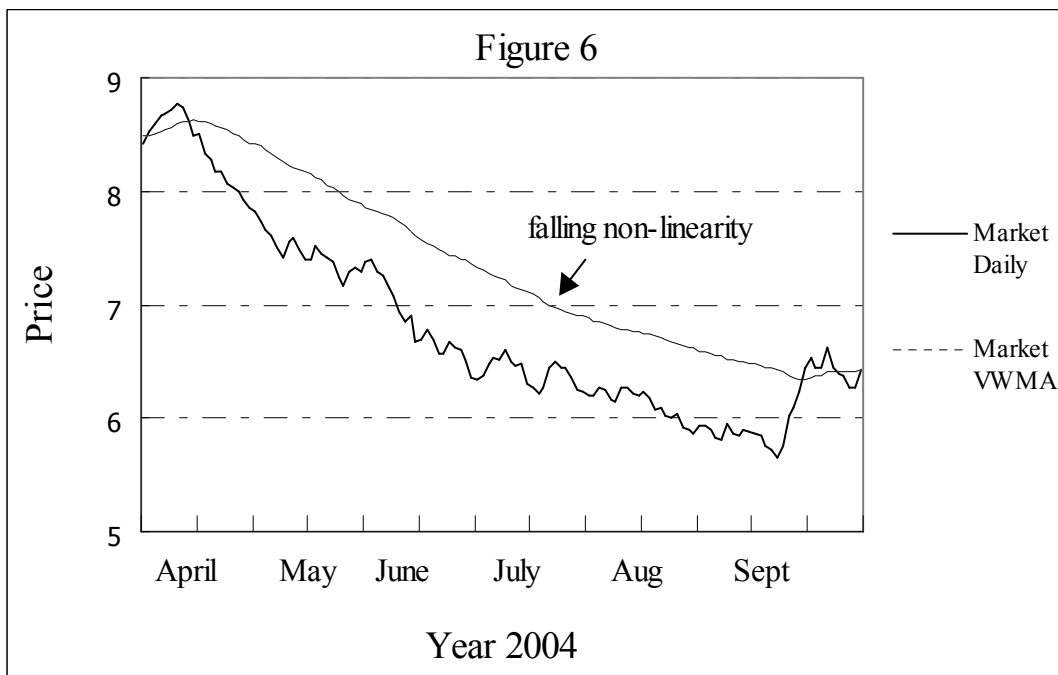
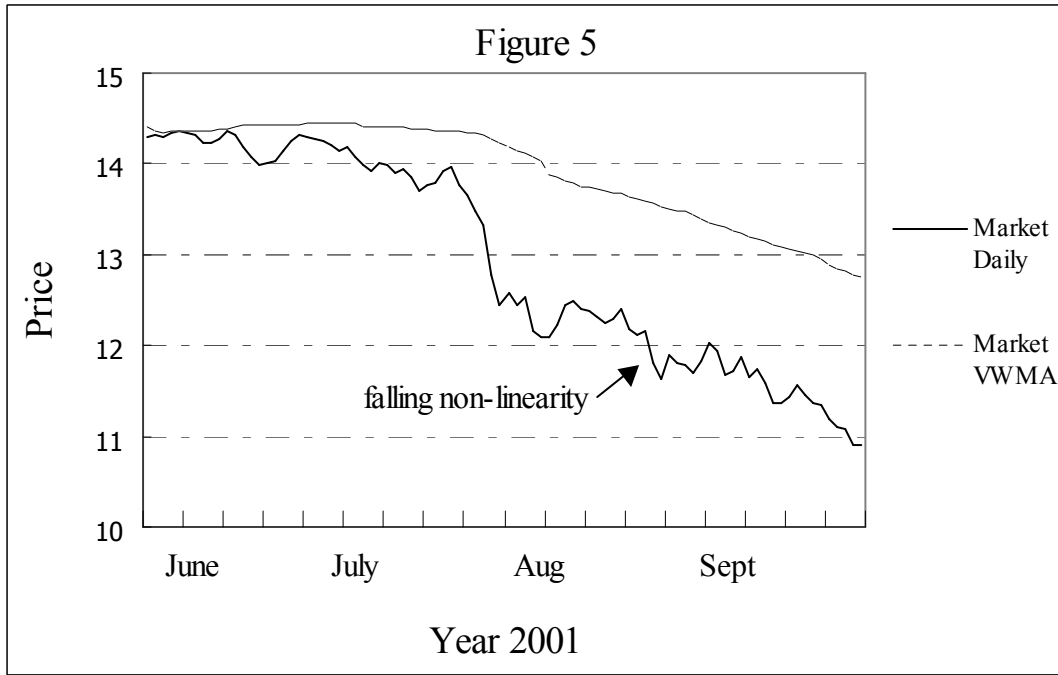
From Figure1-Figure3, when  $Market_{daily}$  rises very fast, volume also enlarges and  $Market_{VWMA}$  rises also very fast. Although the slope are different, the common characteristic is that the two lines move very close appearing nearly parallel. The closing of the two lines can be recognized as the rising non-linearity.

It is the same thing for the falling cases. From Figure4-Figure6, after  $Market_{daily}$  falls very fast, it will bend to fall slowly. Since the volume is less comparing to the rising situation,  $Market_{VWMA}$  also drops very slowly. Although the slope are different, the common characteristic is that the two lines move almost parallel with a certain distance. The parallel with a certain distance can be recognized as the falling

non-linearity. In other words, after the price falls, it will drop further, but the falling trend will be slow.



At first when I see the two phenomenon, I find that it is not easy to understand. If the moving average method is used in Figure1-Figure3, the MA(moving average) line will also bend and rise. But the VWMA rises more quickly. If the MA method is used in Figure4-Figure6, when  $Market_{daily}$  drops slowly, MA line will move gradually close to  $Market_{daily}$ . This means MA line drops somehow fast. But the VWMA line drops slowly keeping a certain distance from  $Market_{daily}$ .



After some thinking, I find that the two kinds of non-linearity can be somehow understood by the common sense of the stock market. In the stock market there is a common sense, that is, when price rises, usually volume is big, when price falls, usually volume is small. Therefore when price rises, volume will increase. It can be considered that there is a big ownership changing in the market. Then the average price will be close to the current market price. After using VWMA method, it can be seen that the VWMA value also rises up very fast. This is the rising non-linearity. When price drops, volume becomes smaller. This means that the ownership changing in the market is less so that there is not a big change with the average price. After

using VWMA method, the VWMA value drops also very slowly. It can be seen from the chart that the  $Market_{daily}$  and  $Market_{VWMA}$  move almost parallel. This is the falling non-linearity.

In this paper I only choose six cases to explain the result. Since the market itself is very complex, the random is very big in rising or falling. Sometimes, market rebounds and drops again without rising further, or market drops and rises without dropping further. In this case the nonlinear effect cannot be observed. Sometimes, the market rises and moves up further, or drops and moves down further. But the lasting period is short. In this case, the nonlinear effect is not obvious. This paper only chooses six cases to illustrate the result. There are many similar cases in stock market.

The above mentioned nonlinear phenomenon is acquired from the whole market. To a single stock, the VWMA value can be drawn on the candlesticks. Since the random of a single stock is very big, the nonlinear characterization is not obvious.

When I am using VWMA method, I notice that the number of days choosing is varying, because the number of days is chosen by the volume accumulation. When volume is bigger, the number of days is less. While the volume is less, the number of days is bigger. Therefore, the number of days is varying. I think this can be recognized as time-variable. In other words, time choosing is variable. I think it can be somehow understood by the instinct of the market. When volume is big, the time to change the ownership of 38.2% outstanding stock is less. When volume is less, the time is longer.

## 5. tentative conclusion

I have got the tentative conclusion of time-variable and nonlinear after combining the above results. This tentative conclusion is acquired basing on the model calculation. There is an unreasonable hypothesis of the method. That is there is no overlapping in daily volume. Obviously the market itself is not like this. Therefore the result based on the model is only a close estimation.

Then the next question is whether the real situation of the market is the same like the above-mentioned. Since the average of formula (2) is objectively existed, if there is a method to calculate average price using formula (2) and (5) and draw on a chart, the question is whether the same result can be acquired.

Since the aim of using the model calculation is to closely get the real average of the market, in other words, the reality of the market would be close to the result based on the model calculation. From this I would like to deduce that the market itself is time-variable and nonlinear. I feel that this can be somehow understood by the common sense of the market. When price goes up, usually volume becomes bigger. The time to reach a certain amount of ownership changing is less. Less time means the average price would be close to the current market price. When price goes down, usually volume becomes smaller. The time to reach a certain amount of ownership changing is longer. Longer time means the average price would change slowly keeping a certain distance from the current market price. A certain distance means almost parallel running.

Combining all the above-mentioned, my feeling is that from the real average

point of view, the stock market is a kind of time-variable and nonlinear system. As a system, there are two objectively existed variables in stock market. One is the average of the whole market. The other is the daily average. My conclusion is that the relation between the two variables is time-variable and nonlinear. Or it can be somehow understood like this: the characteristic of a time-variable and nonlinear system is that when price goes up, volume is big; when price goes down, volume is small. This conclusion is based on induction method but not deductive method.

This is only my guess. The real verification will be a very difficult task according to formula (2), because every share of the stock market should be counted.

I would like to share my experience with other experts. I hope this paper will lead more discussions and improvements so that we can understand the nature of the stock market much better.

In the end, I would like to draw an exaggerated picture Figure7 to represent the time-variable and nonlinear phenomenon of the stock market.

