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A Study on Market Efficiency Using Data from Shanghai Stock Exchange and Shenzhen Stock Exchange

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Abstract

This paper studies market efficiency from weak form aspect using data of Shanghai Stock Exchange composite index (SSEC) and Shenzhen Stock Exchange composite index (SZSEC) under expected return theory. Some classical methods are used to examine the features of stock returns and a little evidence against mutually independency, random walk of returns, and sub-martingale of stock prices is found. A notion of a new simple statistical test based on information set for judgement of market efficiency is proposed. Through hypothesis tests, evidence indicating inefficient markets around 2008, 2011 and 2018 under expected return theory is found. It is a new finding that SZSEC is more sensitive to information and therefore may be more appealing to investors than SSEC. Moreover, there is an another new finding that when market extends in size the degree of whole market efficiency declines. From the relationship between market efficiency and volatility, volatility is not a very good criterion for market efficiency but some rough rules can be concluded to help investors make their decisions on what time to conduct their own strategies. Finally, the results suggest that it is the time to think about strategies.

Keywords: stock market, market efficiency hypothesis, random walk, investment strategy, hypothesis test
JEL Classification: C12, G12, G14

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1.Introduction

Up till now, there are a great number of studies on efficient capital markets. However, for people who started studying problems of efficient capital markets, the first problem they encountered was how to define the word "efficient". One famous paper, Fama (1970), which summarized important theory and empirical work on efficient capital markets, has been playing a significant role in development of market efficiency. This famous paper perfectly summarized studies before 1970 giving the other economists a detailed reference which was useful for keeping on doing deeper research. It said that "A market in which prices always fully reflect available information is called efficient". However, it was unable to make any progress if the theory about efficient markets was stated only in simple words but not in mathematical or statistical forms. Transforming the simple words into mathematical or statistical form, or more specifically, into concrete and verifiable models is not only important but also quite difficult. It may have been the next difficulty during that time after the definition of 'efficient'. In order to do hypothesis tests in details, we need more specific descriptions and have to make some rational, sometimes maybe irrational, assumptions on efficient market theories in the process of modeling and optimization. Fortunately, it had already been solved to some extent by economists. Fama (1970) summarized "Expected return theories" or called "Fair game models", which had been assumed in available work at that time, as the model describing that the expected value of price of one security at time t+1 based on information at time t is equal to the value of price at time t multiplying the expected return at time t+1 based on the information at time t plus 1. The details of this model will be reviewed in the methodology part. Under this theory, two aspects of assumption had been developed. First, that is random walk hypothesis: assuming returns are mutually independent. Lots of studies doing research with various stock return data form different countries tested random walk feature of stock returns. Second, that is sub-martingale hypothesis. Researches on sub-martingale model are another important parts of empirical studies on market efficiency theories, which assumes that simply stock price is rising constantly.

In fact, the theories we talked about above can be classified into weak form tests. Literatures and studies on market efficiency theories can be divided into three categories in terms of what information set the tests are based on: weak form tests, only using historical prices and returns as information set, semi-form tests, also including available public information such as stock split, information from company monthly magazines, and strong form tests, also including monopoly in information within some special investors or brokers. What this paper concerns about is whether market is efficient only under historical information, that is, weak form tests.

A major work on semi-form tests of market efficiency is, Fama, Fisher, Jensen and Roll (1969). It examined the reaction of stock price when new information reached at market. It solved two related questions as it said at the beginning of the paper:
(1)Is there normally some "unusual" behavior in the rates of return on a split security in the months surrounding the split?
(2)If splits are associated with "unusual" behavior of security returns, to what extent can this be accounted for by relationships between splits and changes in other more fundamental variables?

Fama, Fisher, Jensen and Roll (1969) first regressed return of individual stock returns on market portfolio to get rid of influence of general market condition. Then they calculated average regression residual for month m preceding split month, which was defined as month 0, and cumulative average residual in month m. They divided the two kinds of residual to four based on increased dividends or decreased dividends after splits. They considered that unusually high returns on splitting shares in the months immediately preceding a split reflected the market's anticipation of increases in dividends and concluded that when the information effects of dividend changes were taken into account the apparent price effects of the split would vanish and on the average the market's judgments concerning the information implications of a split were fully reflected in the price of a share at least by the end of the split month but most probably almost immediately after the announcement date of split. Thus the result supported the idea that the market was efficient.

In the meanwhile, there is another type of definition on the word “efficient”, or more specific definition than the word “fully reflect”. Malkiel (2003) treated the definition that such markets do not allow investors to earn above-average returns without accepting above-average risks as the definition of an efficient market. What was also new in this paper is that it said a believe about stock prices at least partially predictable was gradually held by economists after the start of the twenty-first century. The efficient market hypothesis is associated with the idea of random walk, which suggests new information is immediately reflected in stock prices and therefore price changes are unpredictable. Anyone could do as well as the experts in the field of stock. Before twenty-first century, the answer was yes. However, just as Malkiel (2003) summarized, future stock prices were somewhat predictable on the basis of past stock price patterns. Many studies reviewed in the next paragraph indeed confirm this view. Although positive serial correlations of stock returns over periods of days, negative serial correlations of stock returns over longer holding periods, or any other predictable weekday patterns existed, Malkiel (2003) concluded there was no sufficient evidence for inefficiency that would enable investors to make excess returns. Except for Fama (1970) and Malkiel (2003), Akintoye (2008) also reviewed efficient market hypothesis including theory of behavioral finance.

There are lots of findings on stock prices or returns. Early in Fama (1965), random walk theory in stock prices was briefly discussed. Stevenson and Bear (1970) focused on random walk model on commodity future prices and found that the random walk did held. Fama and French (1988) said that the autocorrelation in returns was weak for the daily and weekly holding periods but stronger for long-horizon returns. Liu and He (1991) tested random walk hypothesis using five pairs of weekly nominal exchange rate series. The hypothesis was rejected at five percent significance level. Ding, Granger and Engle (1993) investigated ‘long memory’ property of stock market returns. They found that there was more correlation between absolute returns than returns themselves and that the power transformation of the absolute return |rt|^d also had quite high autocorrelation for long lags. They called this property ‘long memory’ and this property was strongest when d was around 1. Solnik, Boucrelle and Fur (1996) found that international correlations increased in period of high market volatility. Pan, Chan and Fok (1997) found little evidence against random walk of four currency futures prices except Japanese yen. Chen and Yeh (1997) confirmed short-term nonlinear regularities existing in TAISE and S&P but the search costs of discovering them might have been so high that the market was still efficient. Porta, Lakonishok, Shleifer and Vishny (1997) confirmed the view that expectational errors about earrings prospects influenced the superior to value stocks. Although increases in portfolio returns existed from using technical rules, as Bessembinder and Chan (1998) studied, this could not be seen as a single of market inefficiency because of elimination of these increases as costs were under consideration. Ojah and Karemera (1999) found evidence supporting random walks and weak-form efficiency in major American emerging equity markets and investors could not make profitable trading schemes using historical information. In the same year, Karemera, Ojah and Cole (1999) also found the same results as Ojah and Karemera (1999) in fifteen emerging markets.

Smith, Jefferis and Ryoo (2002) studies random walk model for four types of stock market in Africa. Only the South African market followed the model. Worthington and Higgs (2004) tested random walks and weak-form market efficiency for sixteen developed markets and four emerging markets. They found that the emerging markets were not consistent with random walk model except Hungary while the results for developed markets were mixed: some was consistent with random walk while some were not. Özdemir (2008) studied the efficient market hypothesis for Istanbul Stock Exchange National (ISEN) 100 price index. They used ADF unit root test, runs test and variance-ratio test. The ISEN 100 index was characterized by a unit root with two structural breaks. They split the sample into three sub-periods according to the trend shifts and tested efficient market hypothesis for different periods. They concluded that ISE was a weak form efficient market. Magnus (2008) examined Databank Stock Index for test of weak-form efficient market hypothesis of Ghana Stock Exchange and concluded that the market was inefficient because of rejection of random walk model. Chen (2009) examined random walks for Pacific Basin foreign exchange markets and found some markets were not weak-form efficient. Onali and Goddard (2009) confirmed serial correlation and non-Normality in the Mibtel, the principal Italian stock market index, and that the markets had long-memory.

Borges (2010) tested the weak-form market efficiency of indexes of France, Germany, UK, Greece, Portugal and Spain with serial correlation test, runs test, augmented Dicket-Fuller test and multiple variance ration test. They found convincing evidence that monthly prices and returns followed random walks but daily returns were not normally distributed with negatively skewness and kurtosis over three. Hamid, Suleman, Shah and Akash (2010) also conducted a test on weak-form market efficiency and found that monthly prices did not follow random walks in all countries of the Asian-Pacific region. Enowbi, Guidi and Mlambo (2010) tested several emerging African stock markets and found week effects with negative Monday and positive Friday effects. AI-Jafari (2011) focused on Kuwait stock exchange and found evidence against efficient market and therefore they thought investors could make profitable returns by using historical information. NWOSA and OSENI (2011) found evidence revealing the Nigeria stock market inefficiency as well. Sewell (2012) made a specific study on Dow Jones Industrial Average log returns by using daily, weekly, monthly and annual data. He found that first-order autocorrelation was small but positive for all time periods. However, autocorrection close to 0 was consistent with an efficient market for daily and weekly returns while standard runs test was rejected for daily returns but not rejected for the others. He also concluded that no evidence supporting long memory in returns was found. Nisar and Hanif (2012) examined the weak-form market efficiency on four major stock exchanges of South Asia including, India, Pakistan, Bangladesh and Sri Lanka with four statistical tests, runs test, serial correlation, unit root and variance ratio test. They concluded that none of the four major stock markets of South-Asia followed random walk. Therefore they thought all these markets were not weak-form efficient markets. Afego (2012) found evidence indicating inefficient Nigerian stock market as well. Mbululu, Auret and Chiliba (2013) rejected random walk hypothesis using data of daily nominal United States dollar/Zambian kwacha. Degutis and Novickyte (2014) thinks that investors could not earn an excess profits although stock market anomalies exist. Titan (2015) reviewed the growing body of empirical research on efficient market hypothesis. It said there were many opposite views regarding efficient market hypothesis: some of them rejecting it while other supporting it. It stressed the truth that testing for market efficiency was difficult and new theoretical model had to be developed. Rossi (2015) summarized studies on calendar anomalies of markets, such as January effect, Day-of-the-week effect and Turn-of-the-month effect and said that the evidence against efficient market hypothesis had grown. Malafeyev, Awashi and S.Kambekar (2017) studied Bombay Stock Exchange and Shanghai Stock Exchange Composite Index. They found evidence against weak-form market efficiency as well.

Many papers have focused on the weak form test of an market. They tried to study different stock markets in the world with statistical tests. But just as Titan (2015) said, some found evidence against market efficiency while some did not found strong evidence against it.

This paper utilizes some classical methods to examine market efficiency hypotheses but also provides a notion of new simple statistical test for judgement of market efficiency. Moreover, this paper also works on a new question: how does market efficiency change when market extends in size.

The rest parts of this paper are arranged as follow. Part two sketches out the theory under which the researches are done and states what and how this paper does to study the market efficiency. Briefly, examine random walk hypothesis, sub-martingale hypothesis and fair game models in three situations (or based on three different information sets). Draw a comparison between market efficiency and market volatility. Part three introduces the data and analyzes summary statistics of the data. Part four shows empirical results of tests and draws some conclusions. Part five summarizes all the paper and raises some questions.

2.Methodology

The theory of market efficiency mainly means 'expected return models' or 'fair game models' (Fama(1970)), which can be described as:

$$(1) \qquad E(\dot{p}_{j,t+1} \setminus \Phi_t) = [1 + E(\dot{r}_{j,t+1} \setminus \Phi_t)] p_{j,t}$$

That is to say: the expected price of security j at time t+1 based on information set Φ_t fully reflected in the price at time t, is equal to one plus the expected return of security j in one period also based on the information set Φ_t, multiplying price of security j at time t. The points above p and r mean that they are random variables.

The most important implication under this theory is that it rules out the possibility of trading system having expected returns in excess of equilibrium return. Therefore :

$$(2) \qquad x_{j,t+1} = p_{j,t+1} - E(\dot{p}_{j,t+1} \setminus \Phi_t)$$

$$(3) \qquad E(\dot{x}_{j,t+1} \setminus \Phi_t) = 0$$

Of cause :

$$(4) \qquad z_{j,t+1} = r_{j,t+1} - E(\dot{r}_{j,t+1} \setminus \Phi_t)$$

$$(5) \qquad E(\dot{z}_{j,t+1} \setminus \Phi_t) = 0$$

$x_{j,t+1}$: the difference between real price and the expected price
$z_{j,t+1}$: the excess return

What we will do is all under this theory (1)~(5) and we will especially test (4) to verify something we want to know.

The main purpose of this paper is to examine: first, whether stock markets are weakly efficient in China. Second, whether the degree of market efficiency changes over time and how it changes. Third, what investors can do to make profits when the degree of market efficiency fluctuates over time. The specific research processes are stated as follow.

First, examine random walk hypothesis. If random walk model stands up, the return series of one certain security should be mutually independent and the results of statistical tests should not be significant. Specifically, first step, calculate stock return autocorrelations. Then calculate Ljung-Box test statistics (Ljung and Box(1978)) to confirm whether they are significant. Second step, check sign change of return series with runs tests. In order to check the sign change, three important values of a return series should be figured out: the number of positive returns, the number of negative returns and the run of the series, which is the maximal non-empty segment of the series consisting of adjacent equal elements. The former two are called plus and minus in this paper. Under random walk hypothesis, the true run value of a return series should not much higher or lower than the mean run value. If it is, the hypothesis of statistical independency is rejected. Well, this is exactly the essence of runs test. For deeper perception and cognition, four other values of a return series will also be calculated: the number of positives returns following by positive returns, the number of negative returns following by negative returns, the number of positive returns following by negative returns and the number of negative returns following by positive returns. They are called pplus, mminus, plusminus and minusplus in this paper for convenience. If random walk model is the true model, plus and minus should not have big difference. This also works for pplus, mminus, plusminus and minusplus.

Second, examine sub-martingale hypothesis. The implication contained in this hypothesis is that stock price is getting higher over time, so holding stock during a certain period is better than doing a "buy-and-sell" strategy during the same period. No one will be willing to lose profits from persistent rise of stock price. We construct concrete strategies and calculate strategy returns to confirm sub-martingale hypothesis. If the periods in which strategy returns are higher than holding returns indeed exist, sub-martingale hypothesis breaks down. In the meanwhile, it may be good news for investors because they can do more on their own wisdom and intelligence during those periods to obtain higher returns. It should be noted that transaction cost is not considered in this paper when calculate strategy returns. From existing documents the returns of strategies would be smaller even neutralized because of frequent trades although the transaction cost is very small. We use information set in the past to create strategies. The method for constructing strategies will be elaborated in the empirical part. It should be emphasized that in this part of research process, the information set used to construct strategies of one certain market is the information contained in the target market itself. For example, we use the return change of Shanghai Stock Exchange composite index as a benchmark to construct strategies targeted with Shanghai Stock Exchange composite index. This type of information set is called 'itself' in this paper.

Third, examine expected return theories in one market. That is analyzing market efficiency of every market respectively, individually and independently. It has been discussed in the last part that some implications are involved in the theories. The one considered here is that profitable strategies can not exist under these theories. Strategies generated above will be tested to see if they are profitable. On other words, (4) and (5) will be tested. In a certain example, the first item of (4) can be substituted by the return of a particular strategy, the second item, the expected return of a particular strategy based on past information, unfortunately, can not be calculated correctly and precisely. We can not get the distributions of any strategies if we do not have enough strategy returns and actually only one strategy return will be gathered for one certain strategy during one certain period. Therefore, finding a proper substitute for expected strategy return is crucial. Here we use the mean value of historical daily returns of one year' interval, whose interval is the same as the interval of the strategy being considered, to substitute expected strategy return. We also assume that the returns of one year' interval are distributed as normal distribution whose mean value is the sample mean value and variance is the sample variance of daily returns of one year's interval. Actually this can be verified to be proper through drawing a plot. Then testing of (4) and (5) of single strategy can be converted to the following hypothesis test with null hypothesis H0 and alternative hypothesis H1.

H0: mean return_year = strategy mean return

H1: mean return_year < strategy mean return.

Therefore, expected return theories of market efficiency are checked in the way that calculate all the values of hypothesis tests over time per strategy. If results of hypothesis tests of most strategies are consistent with H1 during some certain periods, it can be concluded that in those periods strategy mean returns are higher than mean return of one year's interval, profitable strategies exist and therefore the market is inefficient under expected return theory. Using historical return change to make the decision of buying or selling stock and than construct a strategy means that the information available is only from past. That is exactly one type of weak form test.

Fourth, examine expected return theories in whole market. That is analyzing market efficiency of whole market or regard all separated markets as a whole. Here, we also test (4) and (5). But, the substitutes for items in (4) have to be changed a little: one market to whole market. The first item of (4) can be substituted by the return of a particular strategy. It is the same here but we use new return values. Change the information set to create new strategies and calculate new returns. In above part, information set is the information contained in target market itself, well simply 'itself'. Here, two other information sets are proposed for whole market. First is the information from the other market except target market, called 'the other'. Second is the information from all markets, called 'both'. For example, we use two stock index data: Shanghai Stock Exchange composite index and Shenzhen Stock Exchange composite index. When construct strategies for Shanghai Stock Exchange composite index, 'the other' means the information from Shenzhen Stock Exchange composite index while 'both' means the information from both markets. The second item of (4) is also substituted by mean return of one year's interval but the mean return is mean value of all individual mean returns of one year's interval, here, of cause, is mean value of mean returns of Shanghai and Shenzhen Stock Exchange composite index. If results of hypothesis tests of most strategies are consistent with H1 during some certain periods, in those periods strategy mean returns are higher than mean return of one year's interval and therefore profitable strategies exist and the market is inefficient under expected return theory. Moreover, comparison among results of hypothesis tests calculated with three different information sets will be drown to see whether the degree of market efficiency changes when market extends in size.

Fifth, find relationship between market efficiency and volatility. The final analysis will draw a comparison between market efficiency and volatility. The former one uses the values of hypothesis test statistics calculated above as the degree of marker efficiency and the latter, volatility, uses the standard deviation of daily return series in one year's interval. We expect to see an efficient period with low volatility and an inefficient period with higher volatility.

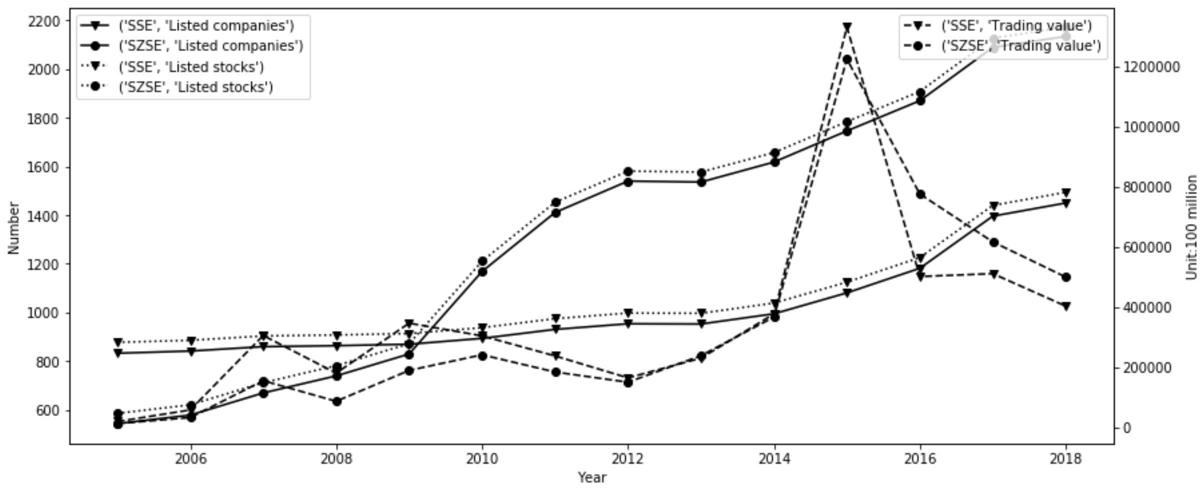
3. Summary statistics of the data

The data used in this paper are Shanghai Stock Exchange composite index (SSE composite index or SSEC) collected from Shanghai Stock Exchange Statistics Annuals, monthly magazines and Shenzhen Stock Exchange composite index (SZSE composite index or SZSEC) collected from Shenzhen Stock Exchange Statistics Fact Book, monthly magazines from January 4th 2005 to June 28th 2019. We first examine market efficiency in Shanghai Stock Exchange (SSE), Shenzhen Stock Exchange (SZSE) respectively and then examine it in an entire market containing SSE and SZSE. Before next step, review the evolution of two stock exchanges in China.

Plot 1 shows the evolution of three indicators of two stock exchanges: the number of listed companies, the number of listed stocks, one year's trading value from 2005 to 2018. In 2005, there were only 833 listed companies, 878 listed stocks in SSE, 544 and 586 in SZSE. The stock trading value were 1924021 millions yuan in SSE and 1242457 millions yuan in SZSE. It seems SSE developed more quickly and better than SZSE. While after 2009, the numbers of listed companies and stocks in SZSE were more than those in SSE and after 2015, the yearly trading value of SZSE were also higher than that of SSE. It seems SZSE began to outperform SSE. Despite that, both stock exchanges have been growing in high speed. Plot 2 shows the evolution of two composite indices. There are 3520 close prices for each index from January 4th 2005 to June 28th 2019. Before the global financial crisis in 2008 there were a period of prosperity in stock markets. After that markets tried to get back to high level. From 2014 two markets recovered gradually, welcomed a second period of prosperity and then fluctuated. During whole period, the highest close price was 6092.06 points in October 16th 2007 and the lowest close price was 1011.5 points in July 11th 2005 for SSEC while 3140.66 points in June 12th 2015, 237.18 points in July 18th 2005 for SZSEC. The lowest stock return was -0.09256 in February 27th 2007 and the highest stock return was 0.09034 in September 19th 2008 for SSEC while -0.08929 in February 27th 2007 and 0.08515 in September 19th 2008 for SZSEC. Both the highest reruns and the lowest returns happening in the time around 2007, 2008 also indicates dramatical market fluctuation during global financial crisis. Moreover, the lowest close price, the highest close price, the lowest return and the highest return in a certain year, for example in 2010, are almost consistent in time for two indices. In most cases these four indicators realize in the same day or realize in close days. Although there is no distribution for the lowest or highest stock return because of lack of data, it is true that the close price of SSEC and SZSEC usually gets to the extreme values in quarter 1 and 4 of a year. The close price of SSEC reached the highest value in quarter 1 and 4 expect 2009, 2011, 2015 and that of SZSEC reached the highest value in quarter 1 and 4 expect 2015.

Plot 1 The overview of SSE and SZSE

Note: This plot shows three factors of SSE and SZSE: Listed companies, Listed stocks and Trading value from 2005 to 2018.



Plot 2 The evolution of SSEC and SZSEC

Note: This plot shows daily close prices of SSEC and SZSEC from January 4th 2005 to June 28th 2019. There are 3520 data for each index.

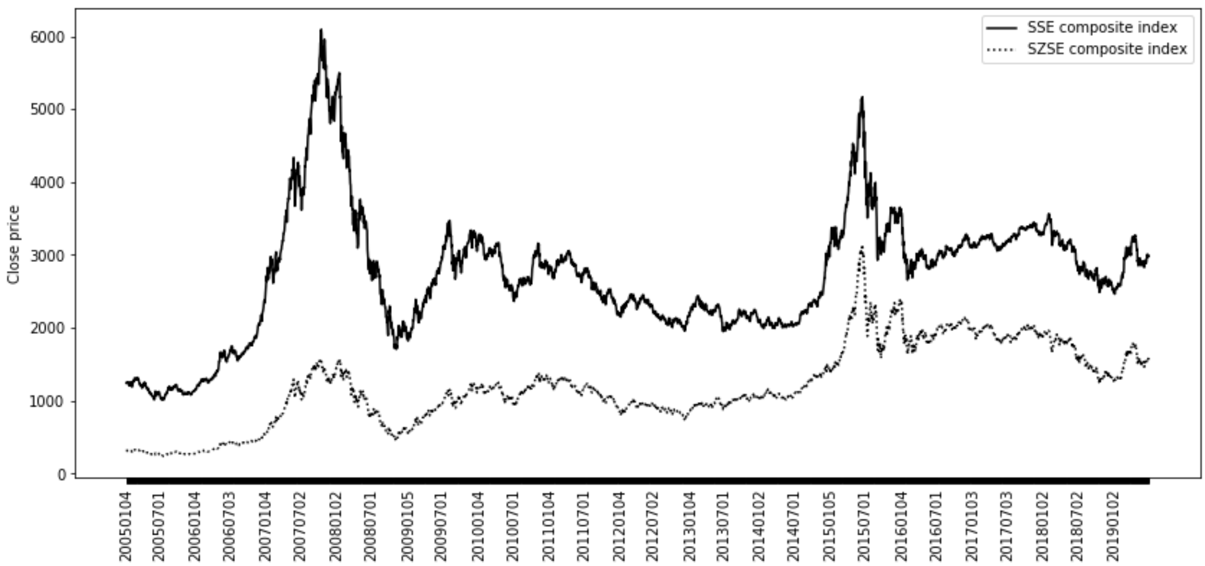


Table 1 shows summary statistics of returns from 2005 to 2018. We can draw four main conclusions: First, both indexes have small positive mean returns for whole period, 14 years, and have six years' positive and five years' negative mean returns happening in the same year. However, in 2010, 2013, 2017, the sign of mean returns were different but this did not result in a bigger margin between SSEC and SZSEC compared with the other years. The bigger margin appearing in 2007 and 2015 are caused by higher mean returns of SZSEC. There was no strong evidence indicating that mean return of one index are higher than the other one because the margin in fourteen years were with 8 times when the return of SSEC was higher and with 6 times when the return of SZSEC was higher. Second, the highest standard deviation(SD) appeared in 2008 and the bigger margin between SSEC SD and SZSE SD was in 2012, 2016. Third, skewness values were negative expect 2005 and 2012. The lowest absolute value was in 2014 for SSEC and in 2012 for SZSEC. In the meanwhile, kurtosis values were very close to 3 in 2008 and 2011 but were always higher than 3 in the other years meaning a distribution with a sharp peak compared with normal distribution. Fourth, the values of Jarque-Bera statistics confirm that null hypothesis of normal distributions are rejected in most years except 2011 for SSEC and except 2008, 2011, 2012 for SZSEC. Interestingly, the interval, when return distribution is closest to normal distribution, is between 2008 and 2012 while these years was exactly suffering a global crisis. We still consider the distribution of one year interval's return series as normal distribution for simpleness of calculation.

Table 1 Summary statistics of daily returns

Note: This table shows summary statistics of daily returns of SSEC and SZSEC from 2005 to 2018 including: mean, standard deviation, skewness, kurtosis and Jarque-Bera statistics.

Year	Indices	Mean	Sd	Skewness	Kurtosis	JB
200501 ~ 201906	SSEC	0.000248	0.016434	-0.555815	7.389925	3006.862883
	SZSEC	0.000459	0.018567	-0.698657	5.848482	1475.977277
2005	SSEC	-0.000282	0.013655	1.047398	7.568059	253.605692
	SZSEC	-0.000449	0.014938	0.633275	5.468145	77.279539
2006	SSEC	0.003407	0.013498	-0.393371	5.537314	70.569228
	SZSEC	0.002766	0.0141	-0.85116	5.807838	107.818455
2007	SSEC	0.002744	0.022377	-1.032387	4.953596	81.134976
	SZSEC	0.003986	0.023524	-1.118219	4.824433	83.649192
2008	SSEC	-0.00434	0.028596	0.289299	**3.890589**	**11.514218**
	SZSEC	-0.003995	0.030336	-0.09485	**3.36327**	**1.714502**
2009	SSEC	0.002285	0.019014	-0.639587	4.299188	33.657292
	SZSEC	0.00306	0.021137	-0.82613	4.359672	46.359075
2010	SSEC	-0.000598	0.014295	-0.617571	4.561973	39.818585
	SZSEC	0.000307	0.016919	-0.683325	4.119841	31.347854
2011	SSEC	-0.00107	0.011561	-0.271758	**3.572117**	**6.305125**
	SZSEC	-0.001704	0.014431	-0.362393	**3.175152**	**5.62944**
2012	SSEC	0.000186	**0.01092**	0.603574	4.649138	42.1167
	SZSEC	0.000179	**0.014856**	**0.004887**	3.708726	**5.06575**
2013	SSEC	-0.000309	0.011638	-0.374843	5.326684	59.007946
	SZSEC	0.000787	0.01428	-0.674384	4.569848	42.300542
2014	SSEC	0.001752	0.010868	**-0.208992**	6.866447	153.761926
	SZSEC	0.001153	0.012111	-0.81555	4.301204	44.261811
2015	SSEC	0.000225	0.024675	-0.936968	5.007839	76.373434

Year	Indices	Mean	Sd	Skewness	Kurtosis	JB
2015	SZSEC	0.001952	0.02665	-0.828936	3.823569	34.696389
2016	SSEC	-0.000248	**0.014033**	-1.560887	10.119374	611.863453
	SZSEC	-0.000302	**0.018329**	-1.317797	7.764225	300.147425
2017	SSEC	0.000219	0.005447	-0.31896	4.537579	28.057303
	SZSEC	-0.000184	0.009167	-1.045148	5.850118	126.486701
2018	SSEC	-0.001217	0.012442	-0.473597	4.972	48.258406
	SZSEC	-0.001713	0.015015	-0.545365	5.276442	64.249788

4. Empirical results

In this part, we convert literal statements of empirical processes in part two to statistical forms and get some conclusions.

4.1 Tests of random walk hypothesis

First, calculate return autocorrelations and Ljung-Box statistics for whole periods and for each year from 2005 to 2018 (data of 2019 is not complete) for both indexes. For saving space, only results of whole period and rejected years are displayed in Table 2 and 3. In whole period, returns of SSEC are with no autocorrelation in lag1 and lag2 but from lag3 the null hypothesis considering zero autocorrelations from lag1 to lagk is significantly rejected. There is even stronger evidence proving that returns of SZSEC are autocorrelated because all the null hypotheses from lag1 to lag15 are rejected in whole period. Although hypothesis tests of Ljung-Box test are significantly rejected in whole periods for both indices, the autocorrelation values themselves, with biggest value 7.03%, are so small that they do not have enough information for investors to make profits. On the other hand, conditions are quite different if data are divided into small parts, year by year. There are four years, 2006, 2014, 2015, 2016, in which the no autocorrelation hypotheses are rejected for SSEC and only two years, 2015, 2016 for SZSEC. Especially in 2015 and 2016, null hypotheses of no autocorrelations are strongly rejected for both indices with high autocorrelations: 0.1489(lag1, 2015, SSEC), -0.145(lag2, 2015, SSEC), -0.1786(lag1, 2016, SSEC) and 0.2059(lag1, 2015, SZSEC), -0.1813(lag5, 2016, SZSEC). The autocorrelation values during these years are about several times compared with the other years. Although some studies think that significant autocorrelation is against random walk model and therefore against weak-form market efficiency, some thinks that they are not high enough for investors to predict future or make profits. By the way, it is quite interesting that no evidence indicating autocorrelation existing in return series during 2008 is found but clear evidence indicating the existence of them during 2015 and 2016 is found, while close prices in both periods were volatile and changed greatly although the former period rose and fell more dramatically. This phenomenon seems to be the evidence that self-influence of stock market in China, such as policy and big events, is more important than the influence from outside, for example influence from other markets, although outside influence may be something throughout the world like global economic crisis.

Table 2 Autocorrelations and P values of Ljung-Box tests - SSEC

Note: This table shows autocorrelation values and P values of Ljung-Box tests of whole period and rejected years for SSEC. ac means the autocorrelation value.

SSEC	200501~201906		2006		2014		2015		2016	
Lag	ac	P value	ac	P value	ac	P value	ac	P value	ac	P value

SSEC	200501~201906		2006		2014		2015		2016	
1	0.0195	0.2462	0.0534	0.4052	0.0318	0.6169	0.1489	**0.0196**	-0.1786	**0.0051**
2	-0.0247	0.1737	-0.0165	0.6841	0.1049	0.2254	-0.145	**0.0049**	0.1483	**0.0013**
3	0.0352	**0.0487**	0.0481	0.723	-0.0958	0.1534	0.0005	**0.0138**	-0.0926	**0.0015**
4	0.0608	**0.0003**	0.0592	0.7013	0.1673	**0.0155**	0.1358	**0.0042**	0.09	**0.0016**
5	0.0027	**0.0008**	0.1857	0.0574	-0.1122	**0.0087**	0.0555	**0.0068**	-0.1752	**0.0001**
6	-0.0627	**0**	-0.1377	**0.0172**	-0.0031	**0.0172**	-0.1154	**0.0036**	-0.0184	**0.0003**
7	0.0307	**0**	-0.0626	**0.0217**	0.0571	**0.0229**	0.0038	**0.0071**	-0.0046	**0.0007**
8	0.0167	**0**	-0.0471	**0.0306**	0.0904	**0.0189**	0.1415	**0.0019**	0.0108	**0.0014**
9	0.007	**0**	0.0642	**0.0352**	0.0017	**0.0315**	-0.0113	**0.0036**	0.1143	**0.0008**
10	-0.0042	**0**	0.1416	**0.0105**	0.094	**0.0241**	-0.1573	**0.0006**	-0.0171	**0.0014**
11	0.0236	**0**	0.1049	**0.0068**	0.0907	**0.0194**	-0.1131	**0.0004**	0.1515	**0.0003**
12	0.0202	**0**	0.0019	**0.0113**	-0.147	**0.005**	0.0686	**0.0004**	-0.1171	**0.0002**
13	0.057	**0**	0.0049	**0.0178**	-0.062	**0.0059**	0.0938	**0.0003**	0.1833	**0**
14	-0.0303	**0**	0.0572	**0.0211**	0.0663	**0.0066**	-0.0868	**0.0003**	-0.213	**0**
15	0.0508	**0**	0.0499	**0.0261**	0.0736	**0.0067**	-0.0047	**0.0005**	0.1597	**0**

Table 3 Autocorrelations and P values of Ljung-Box tests - SZSEC

Note: This table shows autocorrelation values and P values of Ljung-Box tests of whole period and rejected years for SZSEC. ac means the autocorrelation value.

SZSEC	200501~201906		2015		2016	
Lag	ac	P value	ac	P value	ac	P value
1	0.0703	**0**	0.2059	**0.0012**	-0.1004	0.1152
2	-0.0216	**0.0001**	-0.0408	**0.0044**	0.1113	0.0627
3	0.0459	**0**	0.0578	**0.0086**	-0.0846	0.0625
4	0.045	**0**	0.0715	**0.0115**	0.0968	**0.0468**
5	0.0003	**0**	0.0981	**0.0089**	-0.1813	**0.0031**
6	-0.0277	**0**	0.0454	**0.0145**	-0.0086	**0.0065**
7	0.0369	**0**	0.0699	**0.0167**	-0.0518	**0.0097**
8	0.0147	**0**	0.1818	**0.0013**	0.0182	**0.0169**
9	-0.0009	**0**	-0.0602	**0.0018**	0.0848	**0.0152**
10	0.003	**0**	-0.1858	**0.0001**	-0.0996	**0.0107**

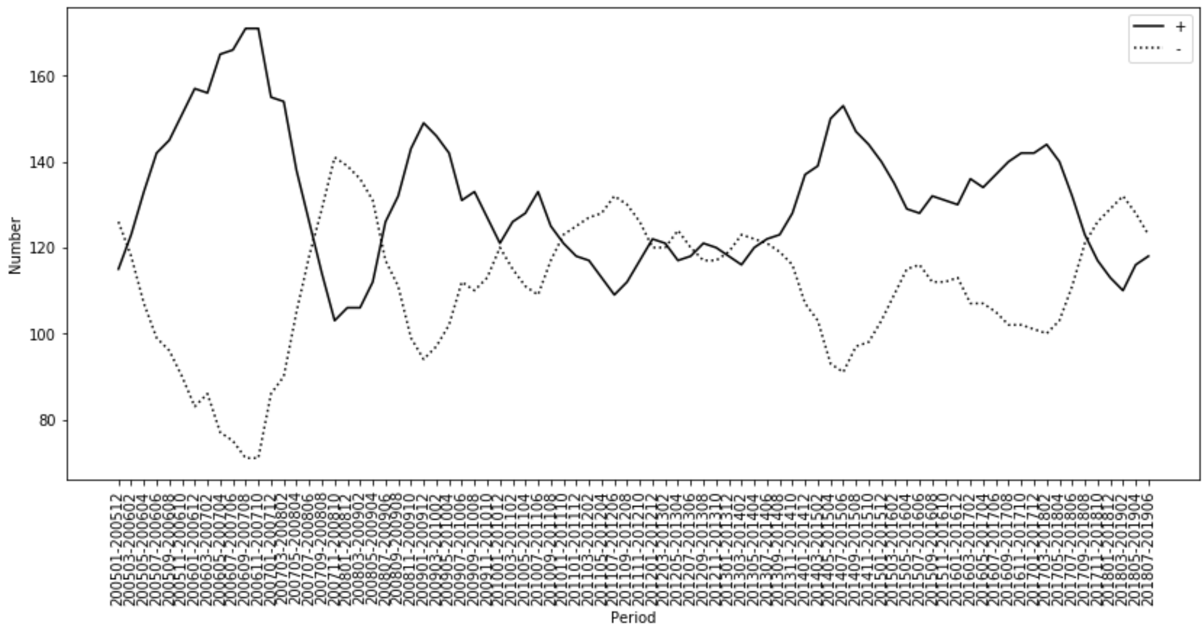
SZSEC	200501~201906		2015		2016	
11	0.0388	**0**	0.002	**0.0002**	0.13	**0.0041**
12	0.0172	**0**	0.0132	**0.0004**	-0.0352	**0.0062**
13	0.0374	**0**	0.1008	**0.0003**	0.0777	**0.0061**
14	-0.0158	**0**	-0.0371	**0.0005**	-0.1738	**0.0007**
15	0.0448	**0**	-0.0012	**0.0008**	0.157	**0.0001**

Second, calculate the number of return sign (plus, minus, pplus, mminus, plusminus and minusplus) and runs test statistics. The null hypothesis of runs test is that the elements of the sequence are mutually independent. For whole periods, runs test is not rejected for SSEC but rejected for SZSEC at alpha=0.01. The conclusion of whole periods is similar with Ljung-Box test to some extent. For SSEC Plot 3 (A) shows the numbers of positive and negative returns (or plus and minus) from January 2005 to June 2019. Every interval is one quantitative year and the next interval after the former one steps two months. For example, the first interval is 200501~200512. The second interval is 200503~200602. It is obvious that there was a boom in economic around 2005 with increasing numbers of positive returns and decreasing numbers of negative returns. When the global crisis influence in 2008 reached Chinese stock markets, it struck the markets so seriously that the numbers of positive returns declined dramatically during a short period and after September 2007, it had already declined lower than the numbers of negative returns calculated in the same intervals. The numbers of positive returns started going up and changing frequently after 2008 although they have never gone back to the high level around 2006 up till now. Plot 3 (B) shows the numbers of positive return following by positive return (pplus), negative return following by negative return (mminus) and positive return following by negative return (minusplus), negative return following by positive return (plusminus). If the elements of return series are mutually independent, the four numbers should not have big difference as well. Obviously the results did not stand up for this. pplus and mminus have the similar change trend with plus and minus but clearly different from plusminus and minusplus. The results of runs tests for SSEC are plotted in Plot 5. The solid line plots real runs of return series in each interval, with dotted line meaning confidence interval at alpha=0.01. The solid line extends between two dotted lines, which means no rejections of the null hypotheses around 2006 but stretched out of these lines, which means significantly rejections around 2015 and 2016. This is consistent with the Ljung-Box test results. While SZSEC in Plot 4 (A) and (B), the situations are similar to SSEC. As for runs test, except periods around July 2011 and January 2013, there is no sufficient evidence informing dependent relationship in return series. We indeed found evidence against mutually independency or random walk.

Plot 3 The numbers of return signs - SSEC

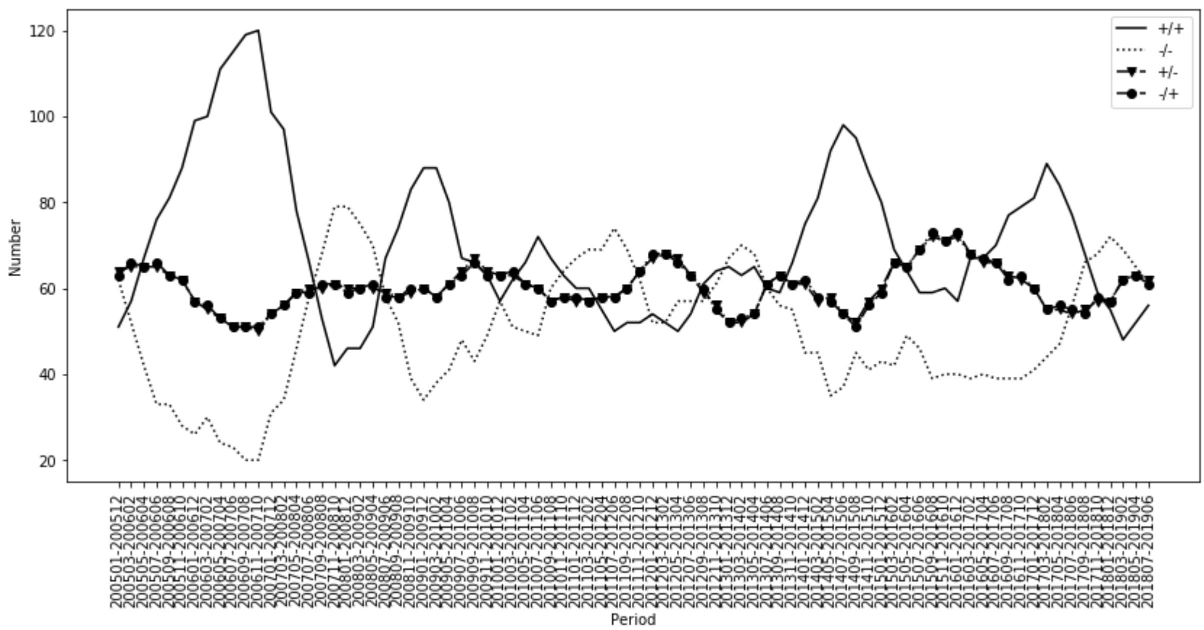
(A)

Note: This plot shows the numbers of positive and negative returns (or plus and minus) from January 2005 to June 2019 in every quantitative one-year-interval for SSEC.



(B)

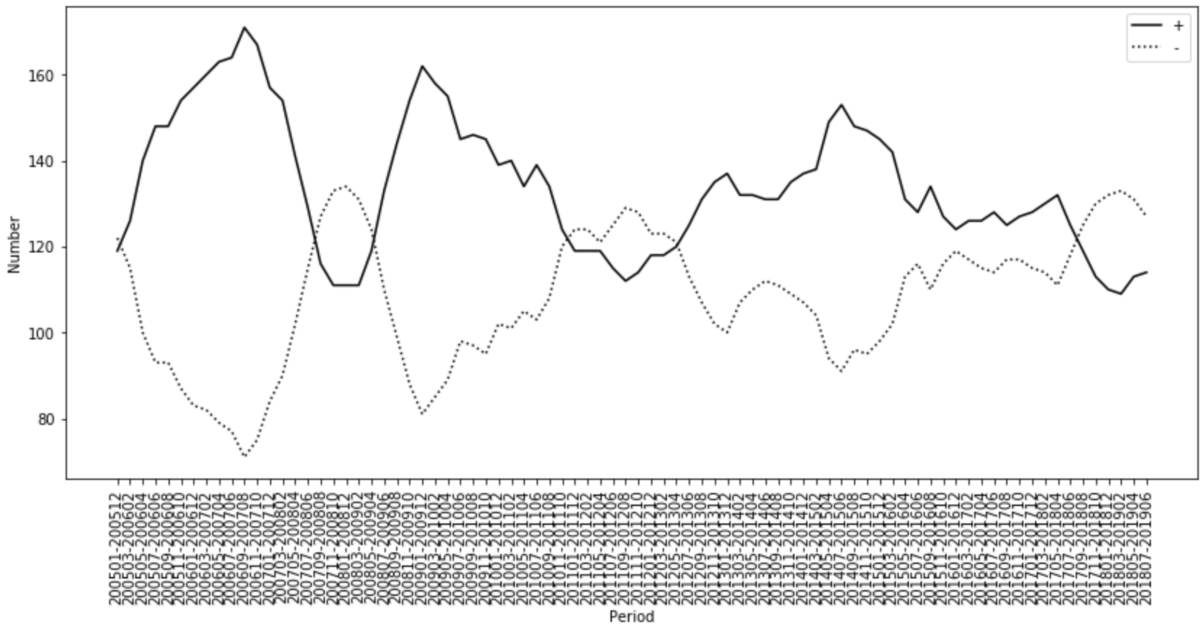
Note: This plot shows the number of positive return following by positive return (pplus), negative return following by negative return (mminus) and positive return following by negative return (minusplus), negative return following by positive return (plusminus) from January 2005 to June 2019 in every quantitative one-year-interval for SSEC.



Plot 4 The numbers of return signs - SZSEC

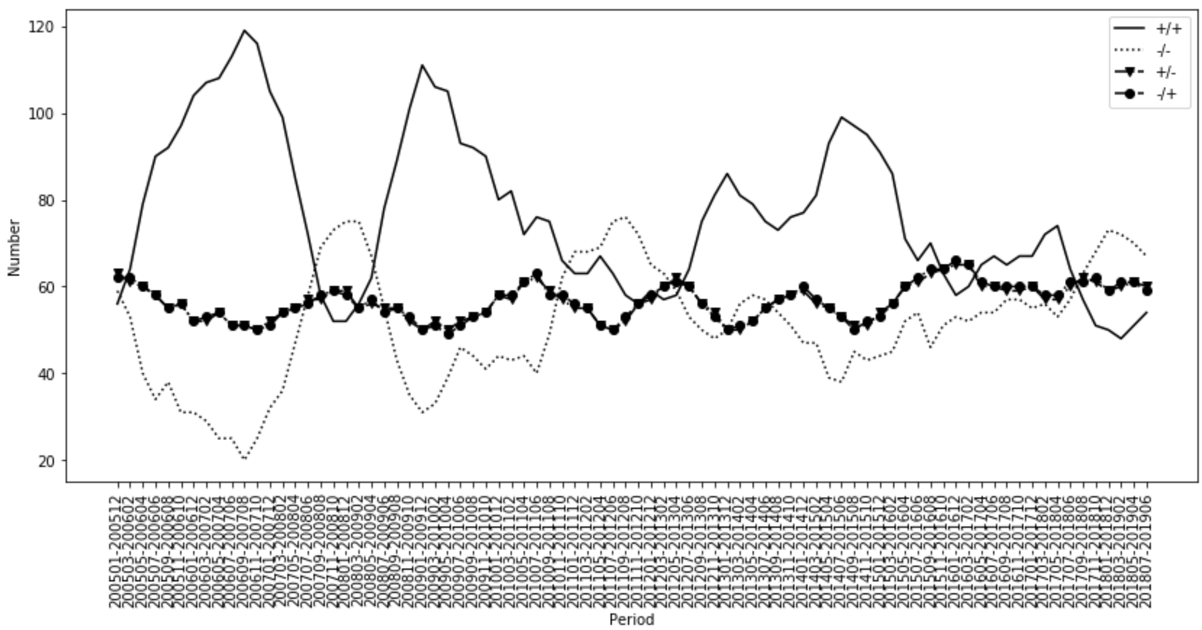
(A)

Note: This plot shows the numbers of positive and negative returns (or plus and minus) from January 2005 to June 2019 in every quantitative one-year-interval for SZSEC.



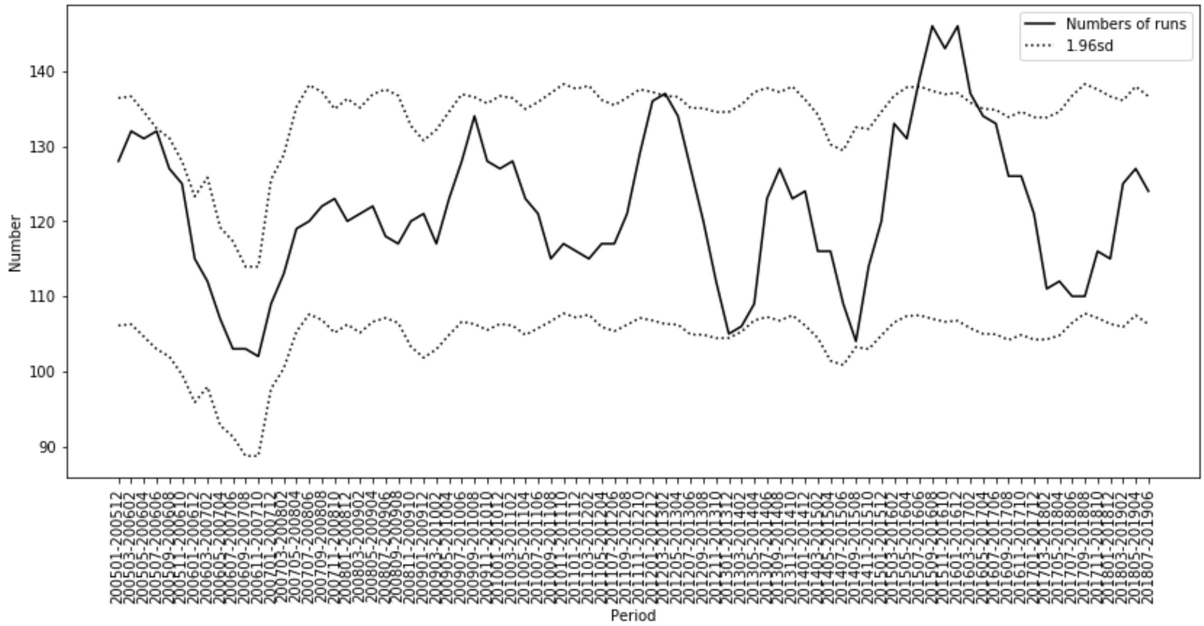
(B)

Note: This plot shows the number of positive return following by positive return (pplus), negative return following by negative return (mminus) and positive return following by negative return (minusplus), negative return following by positive return (plusminus) from January 2005 to June 2019 in every quantitative one-year-interval for SZSEC.



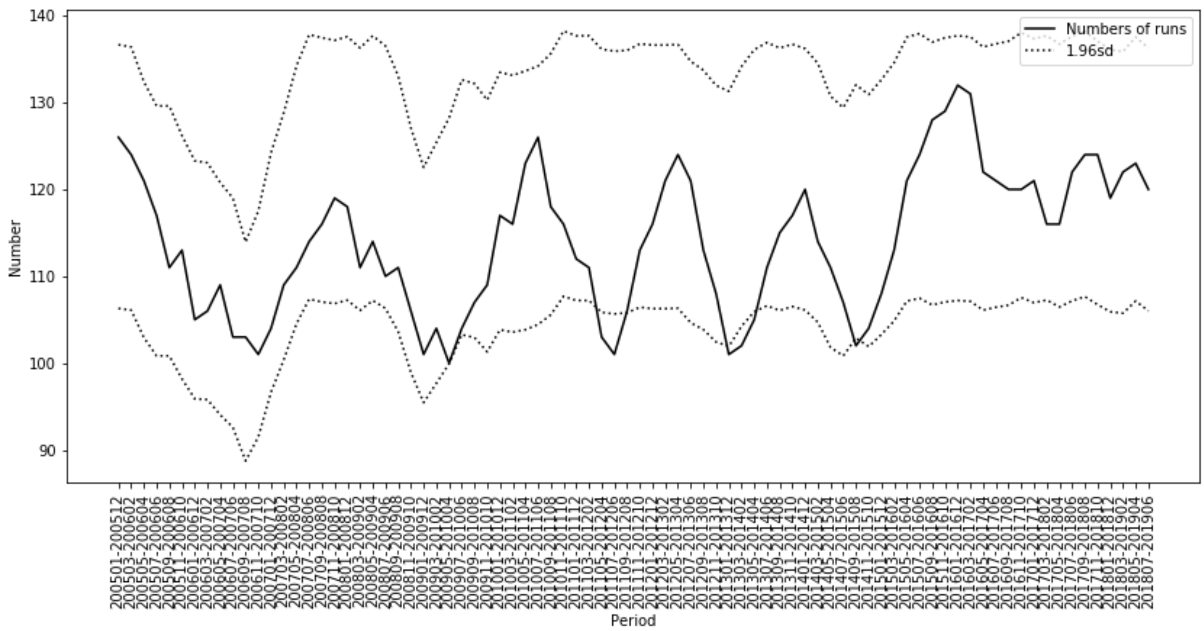
Plot 5 Runs tests - SSEC

Note: This plot shows the results of runs tests in every quantitative one-year-interval for SSEC.



Plot 6 Runs tests - SZSEC

Note: This plot shows the results of runs tests in every quantitative one-year-interval for SZSEC.



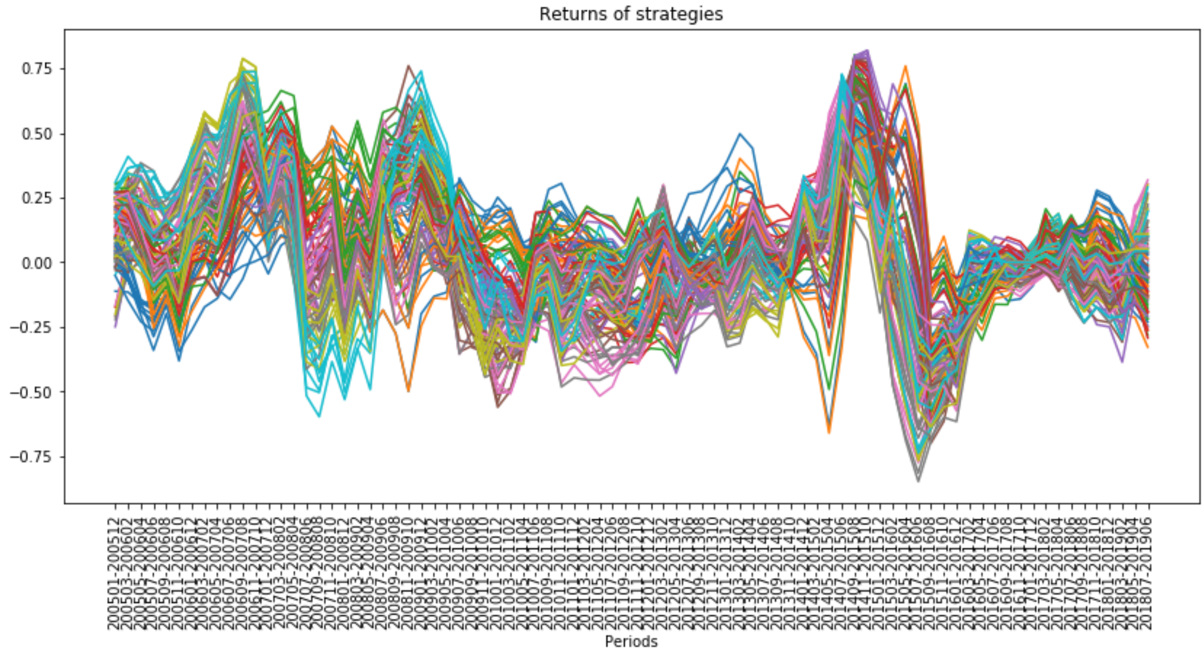
4.2 Tests of sub-martingale hypothesis

Under sub-martingale hypothesis, returns produced by strategies are always lower than returns produced by holding stocks during the same interval because stock price is rising all the time. However, from Plot 2, it is clear that the stock prices are not rising all the time. Although sub-martingale hypothesis of stock price is not rational, here, not only this phenomenon can be analyzed but also some other useful conclusions can be drawn: what time should investors construct own strategy rather than holding portfolio all the time. The construction process of strategies is: during one certain interval, such as interval from January 2005 to December 2005, check the return value from the start date. Find the first day of strategy when the return is higher (lower) than a (b). If no days satisfy this condition before day Z and day Z satisfies this condition, day Z is the first day for this strategy. Start one strategy through buying (selling) one share in day Z. Then find the next transaction day Y when the return is lower (higher) than b (a) and sell (buy) two shares, one for covering the former transaction and the other for starting a new investment action. Find the third transaction day X when the return is higher (lower) than a (b) and buy (sell) two shares. If the return is higher than b but lower than a, do nothing but wait. Repeat the processes above until the end of the interval. While in the last day of strategy, just buy or sell one share to end the strategy. In the end, calculate the total return of this strategy. This type of strategy is named s(a,b) in this paper. In the meanwhile, calculate total return of holding the portfolio from the first day of the strategy to the last day of the strategy. Here, let a in the range of (0.002,0.02) stepped by 0.002 and b in the range of (-0.002,-0.02) stepped by 0.002. Therefore, one hundred strategies are constructed, returns of all strategies and of all holdings are plotted respectively in Plot 7 and Plot 8. The lines of strategy returns fluctuate and intertwine so tightly that it is difficult to capture specific characteristics but we also can see that during periods around 2008 and 2015 there are strategies performing better than holding portfolio all the time. While in the same interval, different strategies have different path, some similar but some far more different. For example, in interval of 200811~200910, the highest strategy return of SSEC is about 0.75 while the lowest strategy return is about -0.5 but both with a little positive holding return around 0.5. How to make a wise strategy is a big challenge for investors. In order to have a deep look, calculate ratios for 100 strategies respectively, which indicate the proportion of strategy returns when strategy returns are higher than holding returns in a certain interval. Plot 9 pictures the ratio lines of SSEC and SZSEC. Now it is clear to declare that all 100 strategies have the time during which they performed better. For SSEC, the highest ratio is 0.61 from s(0.02,-0.02) and for SZSEC is 0.707 from s(0.002,-0.002). Apparently, the sub-martingale hypothesis is false. Plot 10 are two exact examples of strategies. However, few strategies failed to be constructed because of lack of suitable returns: interval 201609-201708, s(0.02,b) (b is from -0.002 to 0.002) do not exist because of no enough positive returns. Under this circumstance, the return of strategy is actually equal to zero. There are always strategies existing although some failed to be constructed in the same period. It is easy to find that the line of strategies are little fluctuant and more smoother compared with the line of holdings. Moreover, around 2008 and 2015, when holding returns were in valley, the strategy returns were much higher so that using strategies is a smarter choice for these time. While around 2006 and 2014, when stock prices were rising constantly, strategies preformed worse. These results are consistent with the change trend of stock prices of two indexes. In a ward, sub-martingale hypothesis implying nonexistence of strategy returns higher than holding returns does not hold for both indexes.

Plot 7 Strategies and holdings - SSEC

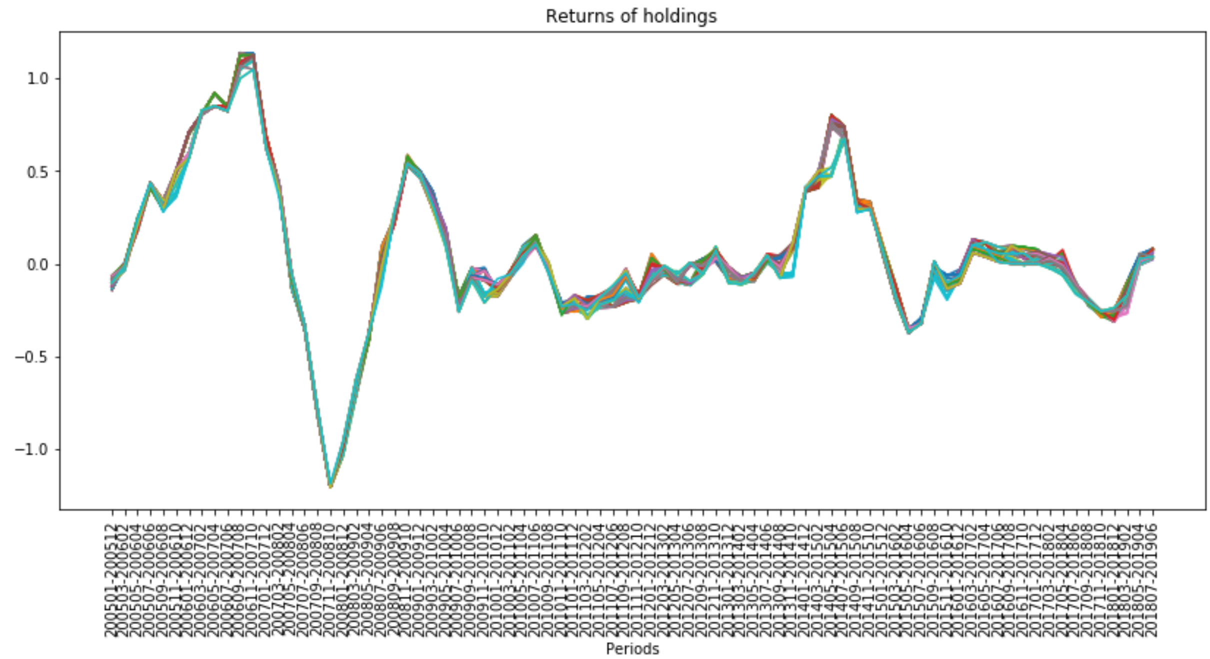
(A)Itself

Note: This plot shows returns of one hundred strategies in every quantitative one-year-interval for SSEC using information of SSEC itself.



(B)Itself

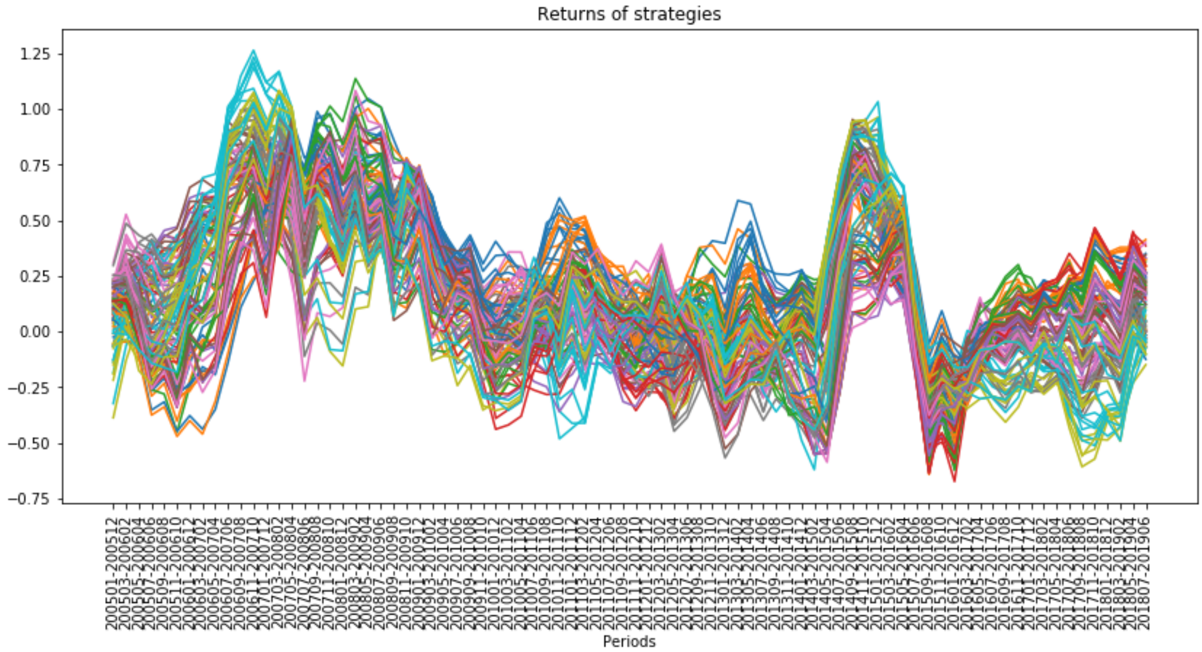
Note: This plot shows returns of holdings which is consistent with periods of corresponding strategies in every quantitative one-year-interval for SSEC using information of SSEC itself.



Plot 8 Strategies and holding - SZSEC

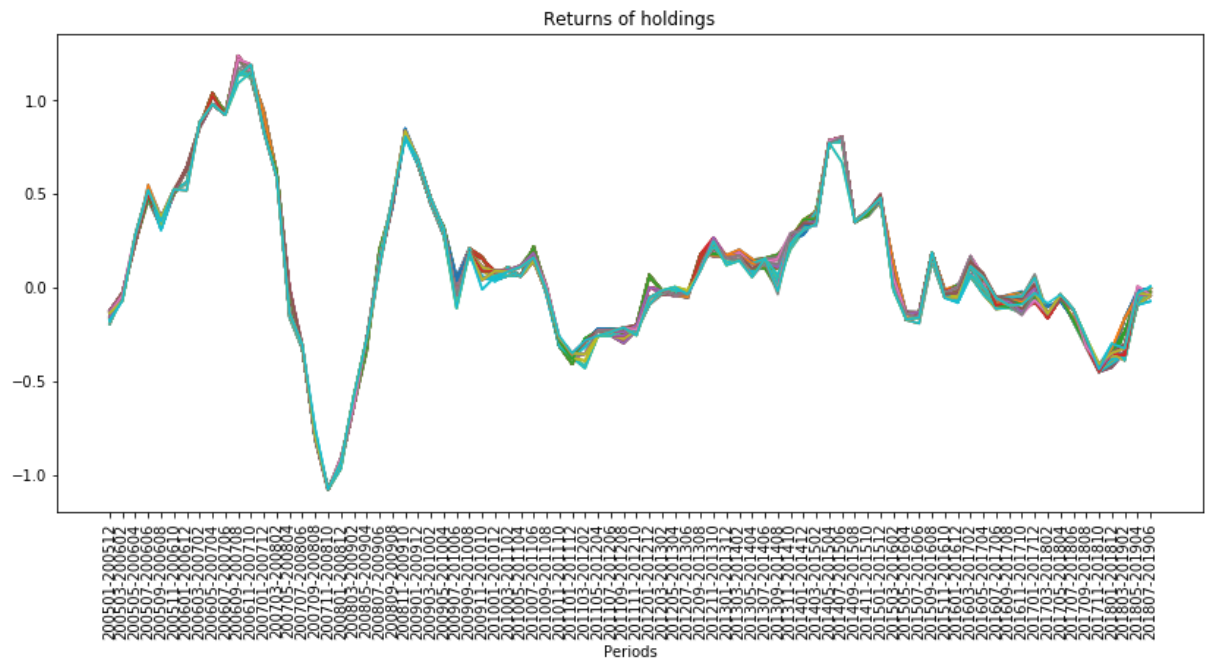
(A)Itself

Note: This plot shows returns of one hundred strategies in every quantitative one-year-interval for SZSEC using information of SZSEC itself.



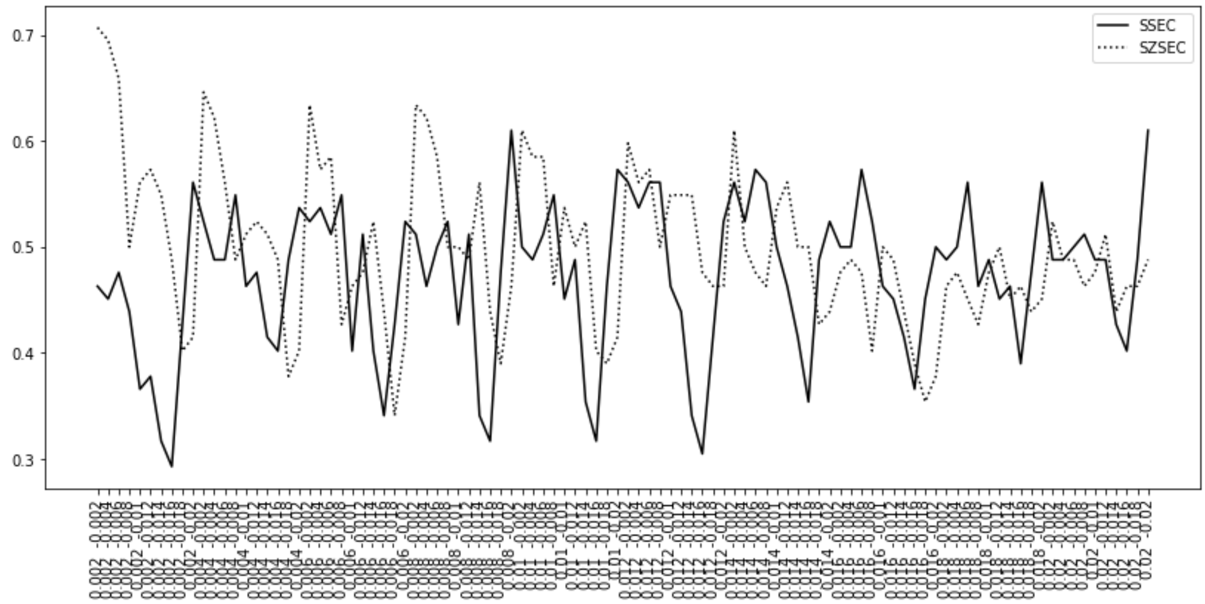
(B)Itself

Note: This plot shows returns of holdings which is consistent with periods of corresponding strategies in every quantitative one-year-interval for SZSEC using information of SZSEC itself.



Plot 9 Strategies vs holdings - Itself

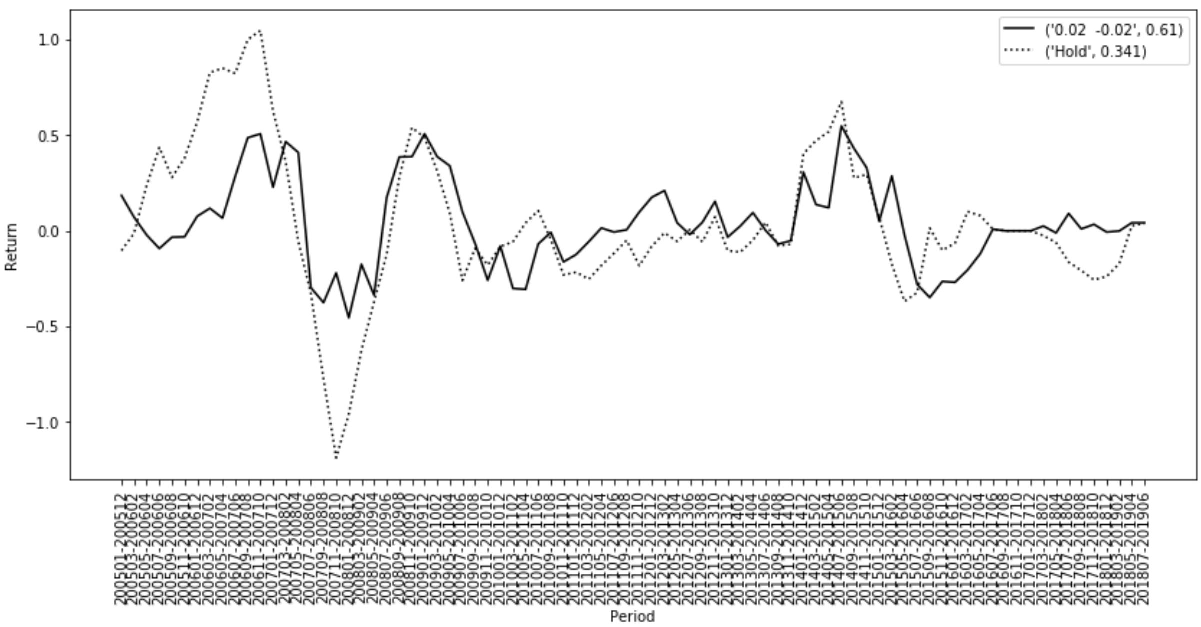
Note: This plot shows ratios of 100 strategies indicating the proportion of strategy returns when strategy returns are higher than holding returns in 82 quantitative one-year-interval.



Plot 10 Examples of strategies

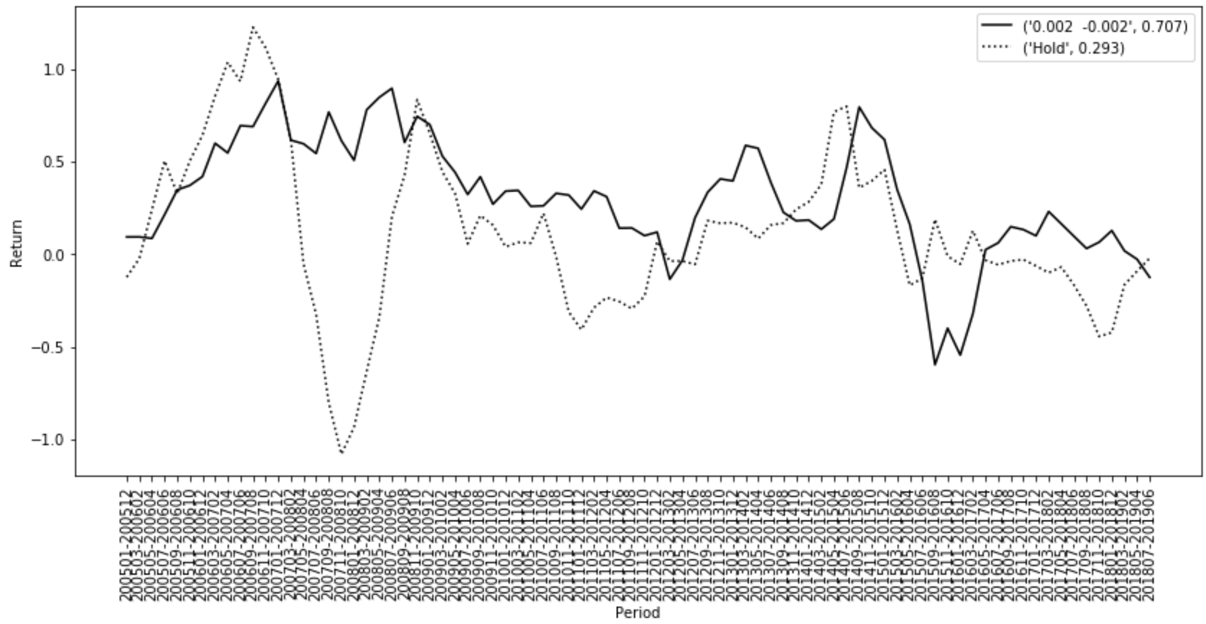
(A) s(0.02,-0.02) for SSEC

Note: This plot shows a concrete example of strategies, s(0,02,-0.02), for SSEC.



(B) s(0.002,-0.002) for SZSEC

Note: This plot shows a concrete example of strategies, s(0,002,-0.002), for SZSEC.



4.3 Expected return theory of efficient market model - one market

Under expected return theories, profitable strategies can not exist. Here, we make the following hypothesis:

H0: mean return_year = strategy mean return

H1: mean return_year < strategy mean return.

If strategy mean return is high enough to reject H0, profitable strategy exists, meaning an inefficient market under expected return theory. Because it may be improper to use daily mean return of one year' interval as a substitute for expected strategy return, another rational explanation is that whether daily strategy mean return is statistically higher than daily mean return of one year' interval. If the answer is yes, we can also say that using one certain specific strategy is a better choice for a certain interval. Here, because the distribution of one year interval's return series is considered as normal distribution, the distribution of daily mean return of one year interval's is also normal distribution. Now we can calculate statistical values of hypothesis tests: (daily mean return of one year interval's - daily strategy mean return)/(standard deviation of daily mean return of one year interval's). Again, daily strategy mean return are calculated from strategy constructed above. That means in this part, 'itself' is considered as information set.

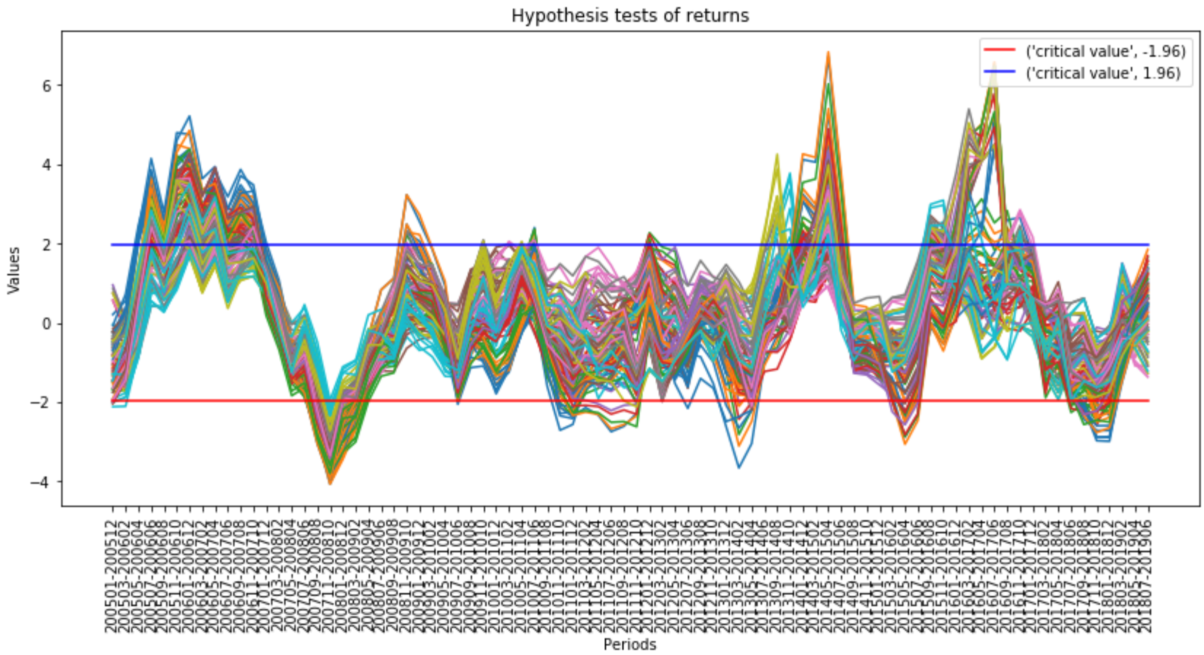
Plot 11 shows the movement trends of statistics of hypothesis tests for one hundred strategies. The straight red lines are critical lines for H1. Both indices indicate inefficient markets around 2008, 2011 and 2018 under expected return theory. SSEC also indicates market inefficiency around 2013 and 2015. Almost all strategies performed better around 2008 indicating solid evidence of market inefficiency. Correspondingly, it is clear that holding market portfolio is a better choice around 2006, 2014 and 2016 while making own strategies is a better choice around 2008, 2011 and 2018. Here, the rejection ratio, conditional on strategies s(a,b) (a and b have the same values as defined above), of 100 hypothesis tests during one certain interval is used as a substitute for the level of market inefficiency. There are calculated by the number of rejections divided by the total number of strategies, 100. Rejection ratios only higher than 0.1 for either index are summarized in Table 4 (B). Obviously, the most inefficient time under expected return theory with the considerably high conditional rejection ratios very close to 1 was around 2008. As for each strategy, rejection ratios of strategies are calculated by the number of rejections in 82 intervals divided by the total number of intervals, 82. Among 82 intervals s(0.02,-0.002) has the highest rejection ratio 0.207 for SSEC and 0.22 for

SZSEC. Another interesting finding is that except little intervals all the other ratios of SZSEC are higher than the ratios of SSEC. If the same external environment and conditions are assumed, we can find that SZSEC is more sensitive to all these things because the ratios of SZSEC higher than 0 happened early and ended late than the ratios of SSEC did. The affected scope of time is always longer for SZSEC. It may be the evidence that SZSEC is more appealing to investors than SSEC is.

Plot 11 The results of hypothesis tests

(A)SSEC-itself

Note: This plot shows the movement trends of statistics of hypothesis tests for one hundred strategies in every quantitative one-year-interval for SSEC using information of SSEC itself.



(B)SZSEC-itself

Note: This plot shows the movement trends of statistics of hypothesis tests for one hundred strategies in every quantitative one-year-interval for SZSEC using information of SZSEC itself.

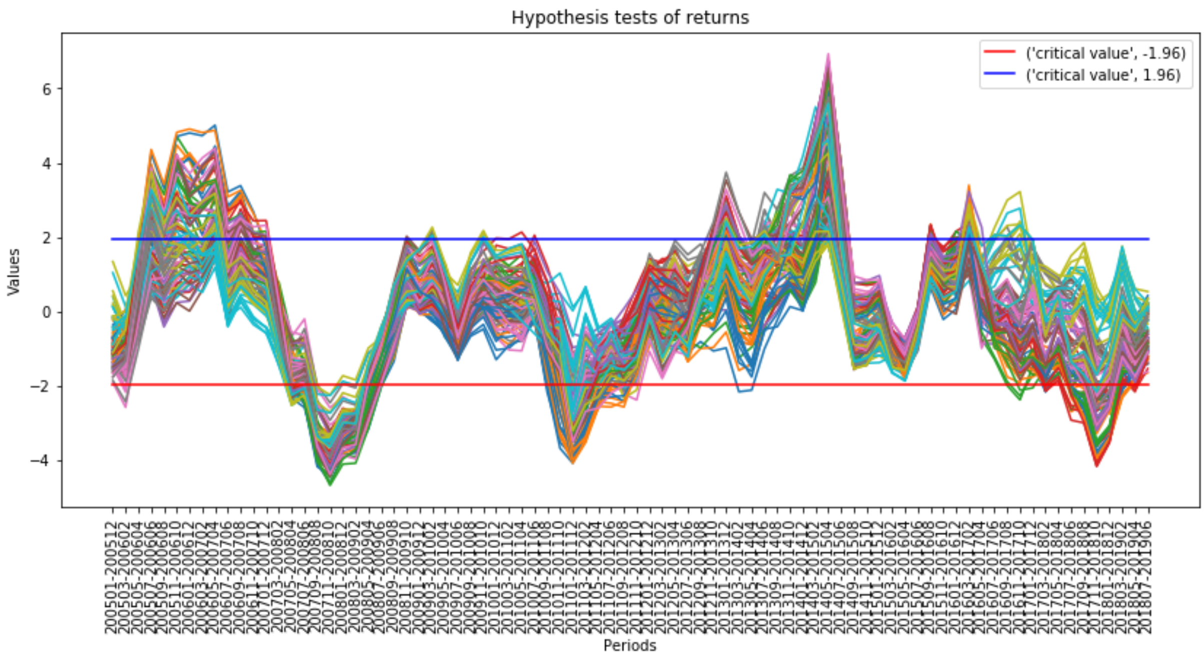


Table 4 Rejection ratios - itself

(A)Different strategies

Note: The rejection ratio, conditional on strategies s(a,b), of one certain strategy, is calculated by the number of rejections during all intervals divided by the total number of intervals, 82.

Strategies	SSEC	SZSEC
s(0.02,-0.002)	0.207	0.22

(B)Different intervals

Note: The rejection ratio, conditional on strategies s(a,b), of 100 hypothesis tests during one quantitative one-year-interval, is calculated by the number of rejections in one certain one-year-interval divided by the total number of strategies, 100.

Intervals	SSEC	SZSEC
200705-200804	0	0.38
200707-200806	0	0.37
200709-200808	0.51	**1**
200711-200810	**0.99**	**1**
200801-200812	0.71	**0.97**
200803-200902	0.5	**0.99**
200805-200904	0.01	0.53
201011-201110	0.07	0.21
201101-201112	0.13	0.78
201103-201202	0.04	0.46
201105-201204	0.05	0.24
201107-201206	0.05	0.11
201109-201208	0.06	0.13
201505-201604	0.23	0
201707-201806	0.06	0.22
201709-201808	0.17	0.23
201711-201810	0.22	0.58
201801-201812	0.19	0.51

4.4 Expected return theory of efficient market model - whole market

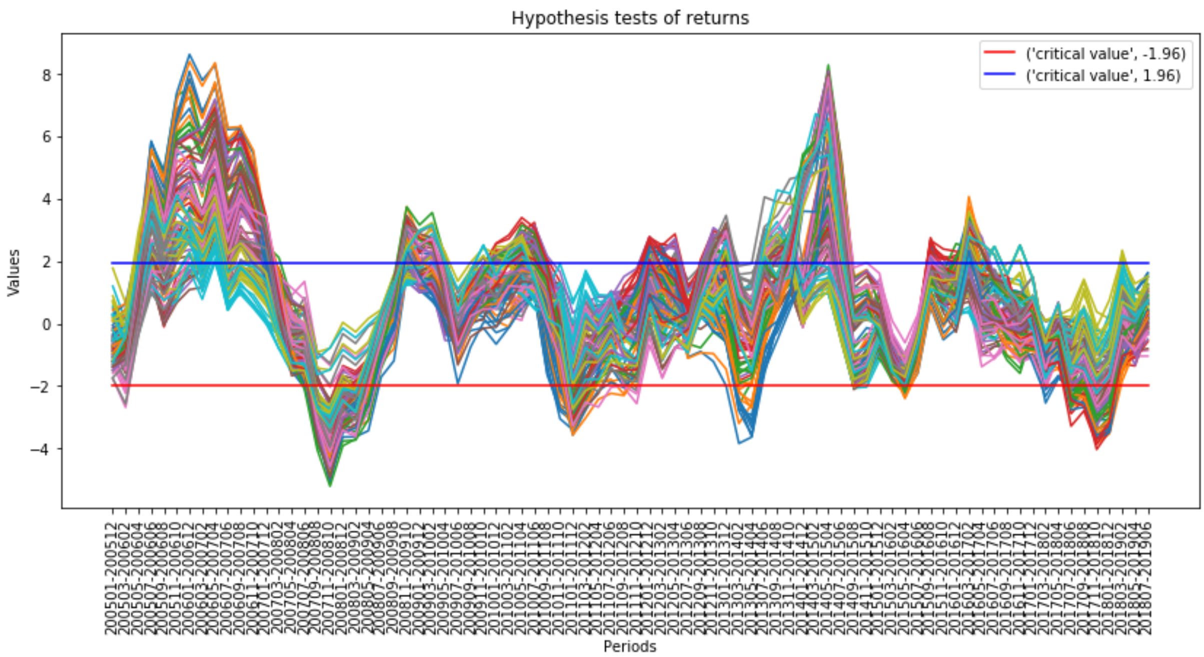
Part 4.3 analyzed market efficiency level of one market only using information from targeted market itself. In this part, other information sets, 'the other' and 'both', are used to construct new strategies. Again, when make strategies of SSEC, use return change of SZSEC as benchmark or use return changes of both indexes as benchmark. Not only do information sets change, actually the contents of hypothesis test, or substitutes of mean return_year and strategy mean return in H0 and H1, have a litter change. When 'itself' is used, the hypothesis test concentrates on testing the efficiency of the market itself, or efficiency of one market. When 'the other' and 'both' are used, hypothesis test concentrates on analyzing the efficiency of the markets producing information. That is analyzing the efficiency of whole market. Two groups of strategies based on 'the other' and 'both' are newly constructed. In the meanwhile, mean value of two mean returns of two indexes is used as the mean return of one year's interval in hypothesis.

The same phenomenon as Plot 11 can also be observed from Plot 12 and 13: In the whole market consisting SSE with SZSE, inefficient markets exited around 2008, 2011 and 2018. SSEC also indicates inefficiency of market around 2013 and 2015. Similarly, it is a better choice for investors to hold market portfolio around 2006 and 2014 but make own strategies around 2008, 2011 and 2018 whatever information set is used.

Plot 12 The results of hypothesis tests - SSEC

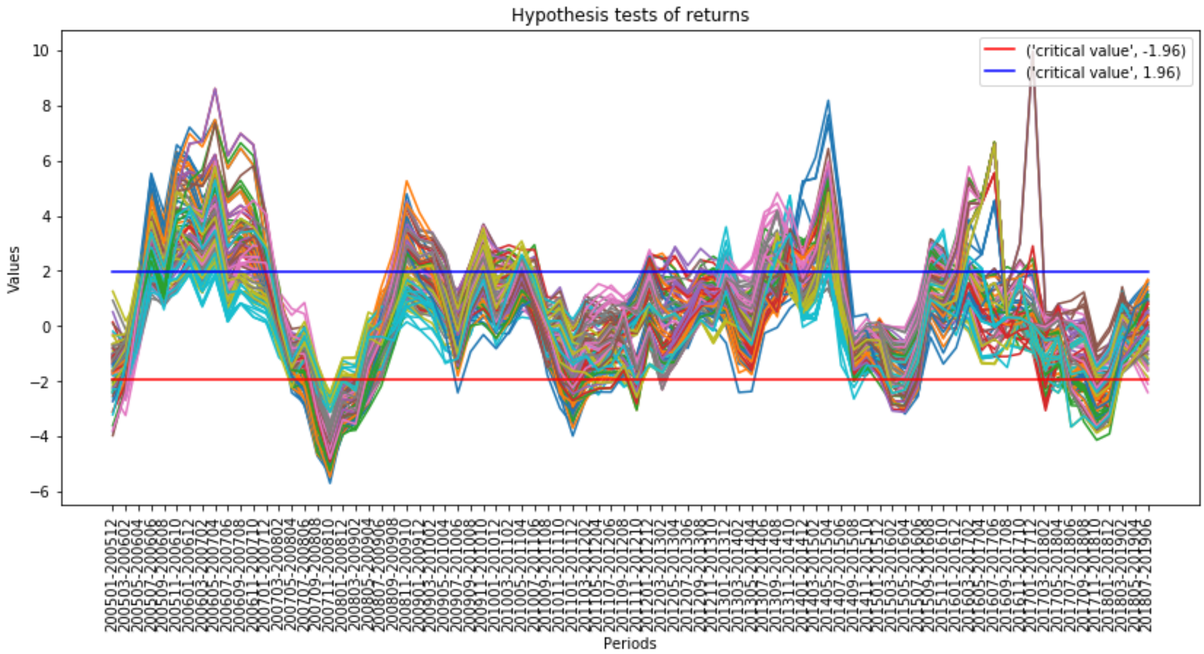
(A)The other

Note: This plot shows the movement trends of statistics of hypothesis tests for one hundred strategies in every quantitative one-year-interval for SSEC using information of SEZEC ('the other').



(B)Both

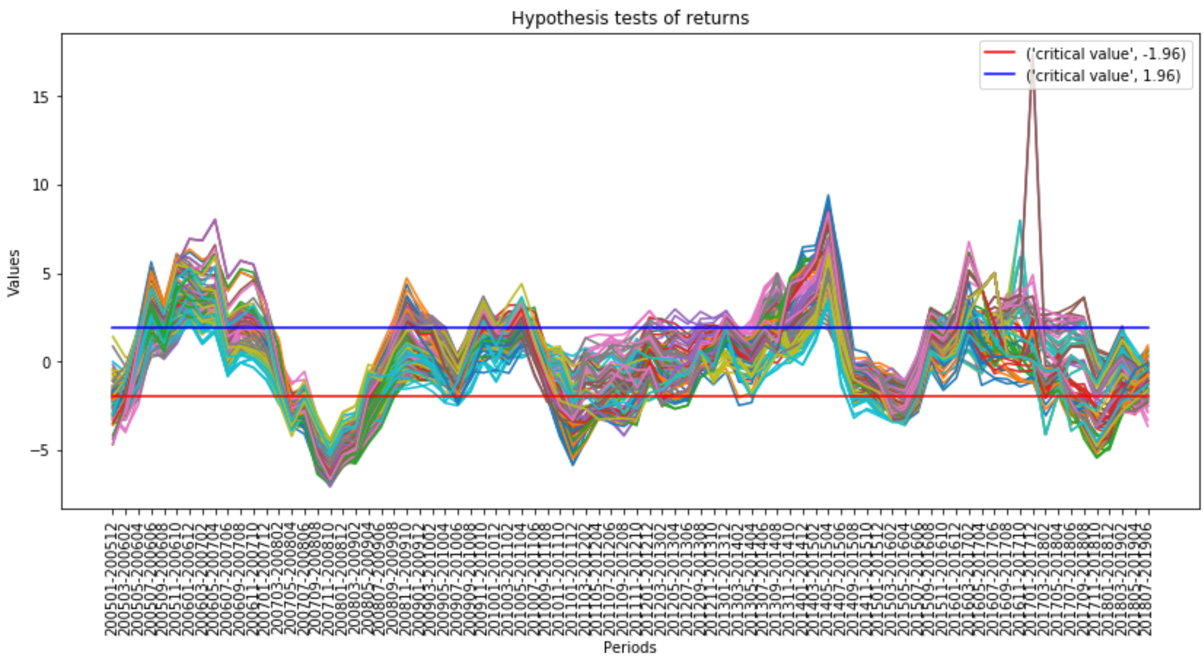
Note: This plot shows the movement trends of statistics of hypothesis tests for one hundred strategies in every quantitative one-year-interval for SSEC using information of SSEC and SEZEC (‘both').



Plot 13 The results of hypothesis tests - SZSEC

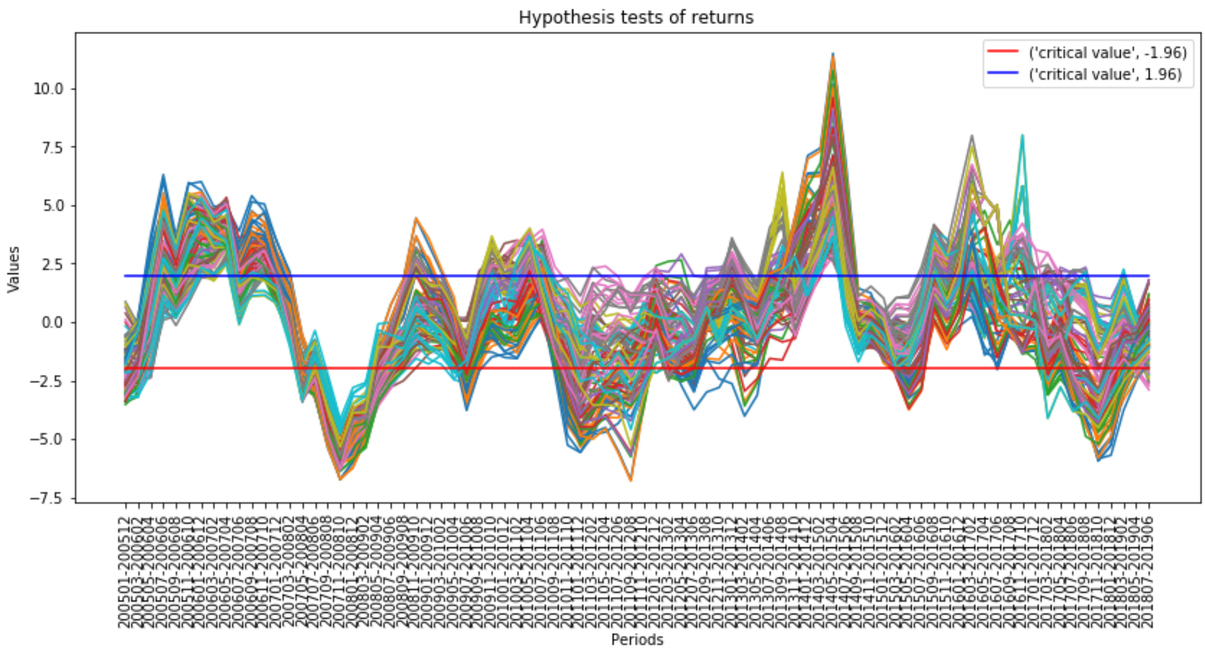
(A)The other

Note: This plot shows the movement trends of statistics of hypothesis tests for one hundred strategies in every quantitative one-year-interval for SZSEC using information of SSEC (‘the other’).



(B)Both

Note: This plot shows the movement trends of statistics of hypothesis tests for one hundred strategies in every quantitative one-year-interval for SZSEC using information of SSEC and SZSEC ('both').



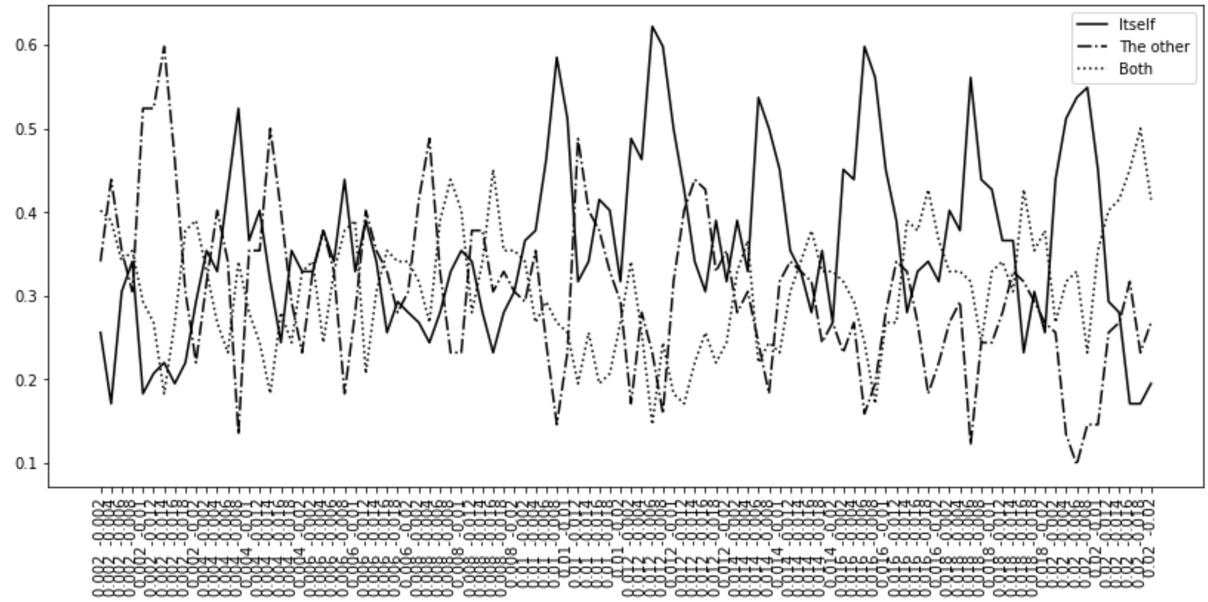
Plot 14, 15 and 16, show something interesting and important. Plot 14 draws ratios of 'itself', 'the other' and 'both' per strategy, which are calculated by the number, when they are the highest return respectively in a certain interval, divided by 82. For example, the solid black line in Plot 14 plots ratios, or proportion of returns of strategy based on 'itself', when they are the highest returns among three returns in a certain interval. There is no strong evidence indicating that strategies with higher return exiting when information set changes because no matter which information set three lines fluctuate from strategy s(0.002,-0.002) to s(0.02,-0.02) and there is even a little evidence supporting 'itself' to be more important. In some strategies, such as s(0.012,-0.01) of SSEC, 'itself' are higher than 'the other' and 'both' in 82 intervals with probability over 0.5. It seems that the information contained in one certain market plays a comparatively more important role for investors when they make their own strategies. On the other hand, strategies like s(0.008,-0.016) supported the 'both' for SSEC. Apparently, the value of filter ratios are somewhat relevant to what strategy is under consideration. Anyway, during half of intervals solid black line is above the other two lines for both SSEC and SZSEC.

One more interesting thing is that in Plot14 (A) and (B) the returns of 'itself' are higher when roughly (not exactly) a>0.01 for SSEC and when a<0.014 for SZSEC. That is to say: what kind of information we have leads to different strategy construction, referring to the setting of a and b. Although conclusions from different information sets about the level of market efficiency and investment timing are the same and information sets except 'itself' did not play an important part in making strategies of higher returns, however, the rejection ratios become higher when information sets change, which indicates a more inefficient market. (A) of Plot 15 and Plot 16 show rejection ratios among 82 intervals per strategy based on three different information sets. The dotted lines indicating 'both' and the solid-dotted lines indicating 'the other' are always above the solid lines expect few intervals. This means a rise in probability of rejection of hypothesis tests when information set changes. (B) of Plot 15 and Plot 16 show rejection ratios of hypothesis tests among 100 strategies per interval. Similarly, the dotted lines and solid-dotted lines are always above the solid lines in almost all intervals, indicating a rise in probability of rejection of hypothesis tests that the market is efficient. In a ward, when market extends in size, here meaning that SSE or SZSE individually extends to the union of SSE and SZSE, the level of whole market efficiency declines.

Plot 14 Filters ratios- different information sets

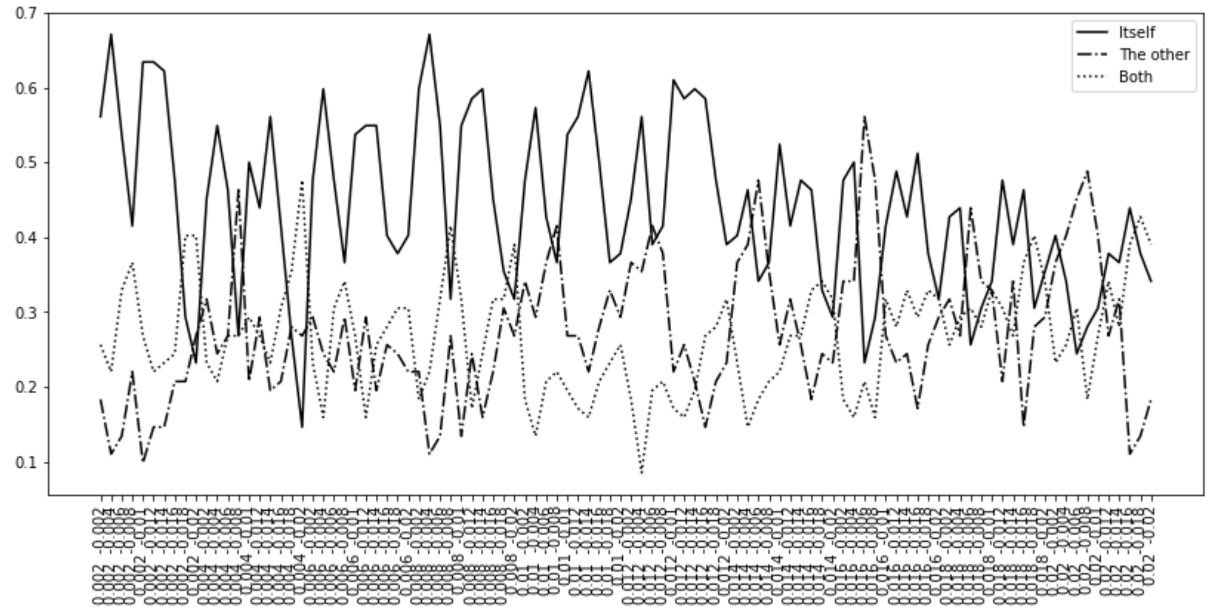
(A)SSEC

Note: This plot shows ratios of itself', 'the other' and 'both' per strategy for SSEC, which are calculated by the number, when they are the highest return respectively in a certain interval, divided by 82.



(B)SZSEC

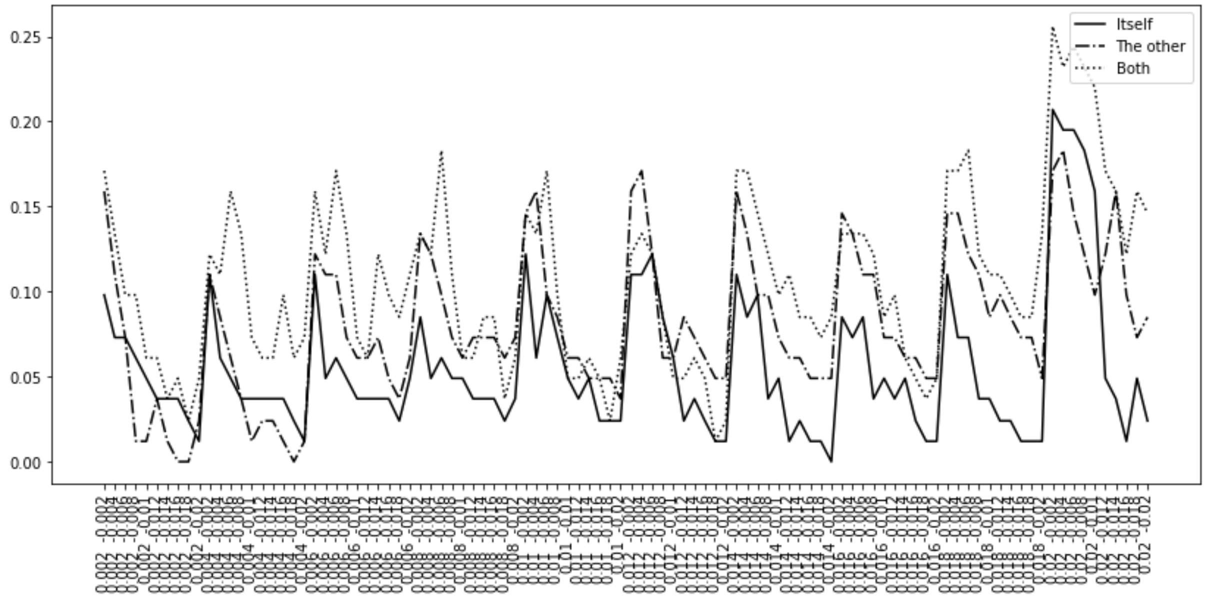
Note: This plot shows ratios of itself', 'the other' and 'both' per strategy for SZSEC, which are calculated by the number, when they are the highest return respectively in a certain interval, divided by 82.



Plot 15 Rejection ratios - SSEC

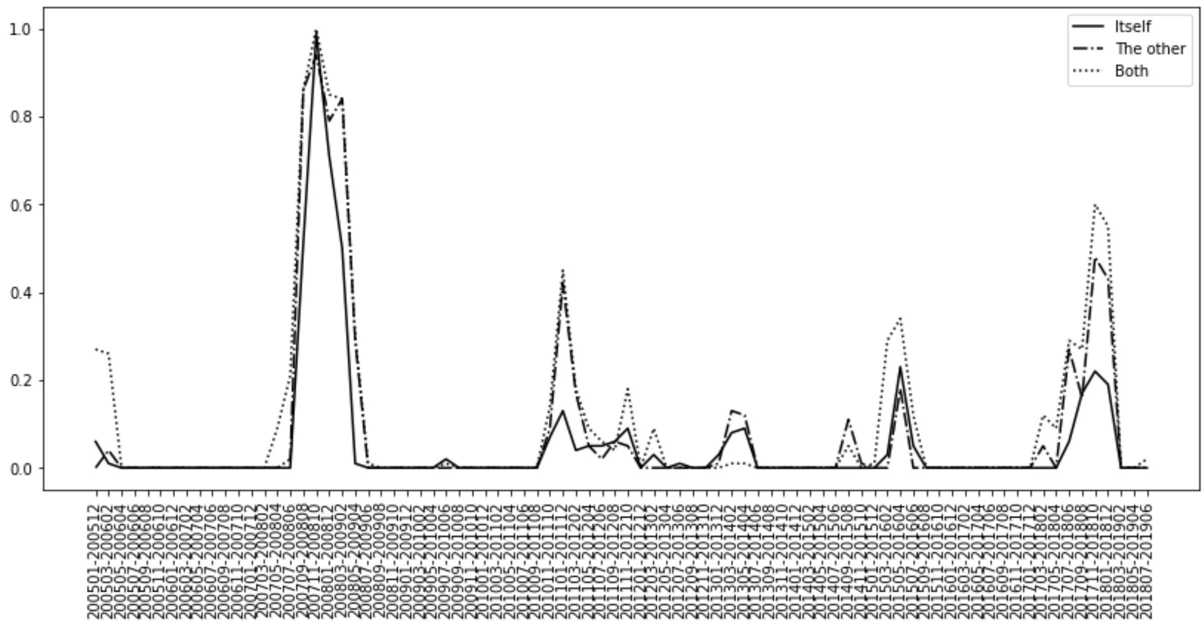
(A)Different strategies

Note: This plot shows rejection ratios among 82 intervals per strategy based on three different information sets, ‘itself’, ‘the other’ and ‘both’, for SSEC.



(B)Different intervals

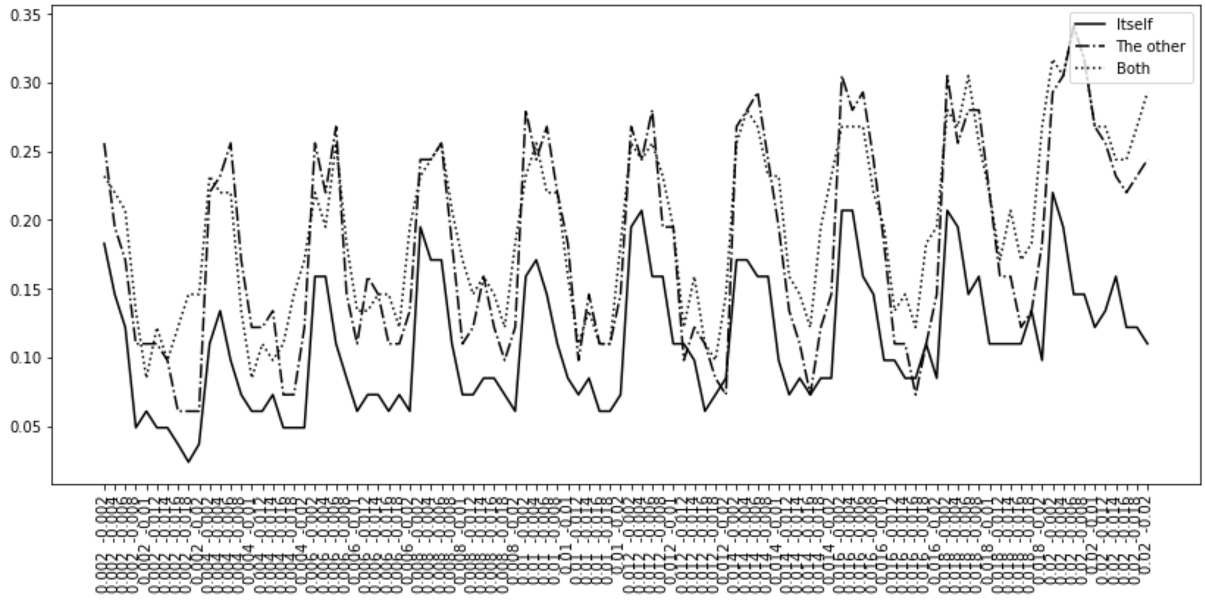
Note: This plot shows rejection ratios of hypothesis tests among 100 strategies per quantitative one-year-interval based on three different information sets, ‘itself’, ‘the other’ and ‘both’, for SSEC.



Plot 16 Rejection ratios - SZSEC

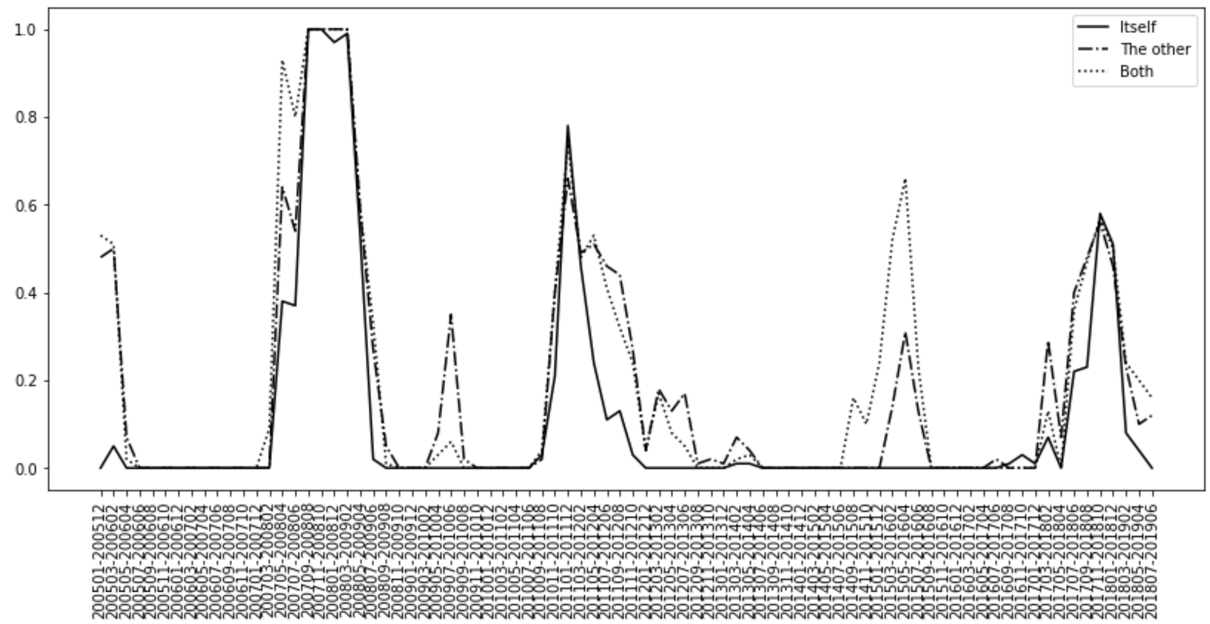
(A)Different strategies

Note: This plot shows rejection ratios among 82 intervals per strategy based on three different information sets, 'itself', 'the other' and 'both', for SZSEC.



(B)Different intervals

Note: This plot shows rejection ratios of hypothesis tests among 100 strategies per quantitative one-year-interval based on three different information sets, 'itself', 'the other' and 'both', for SZSEC.



In the end of this part, selection rules of strategies are summarized in Table 5 based on historical SSEC and SZSEC data.

Table 5 Selection rules of strategies

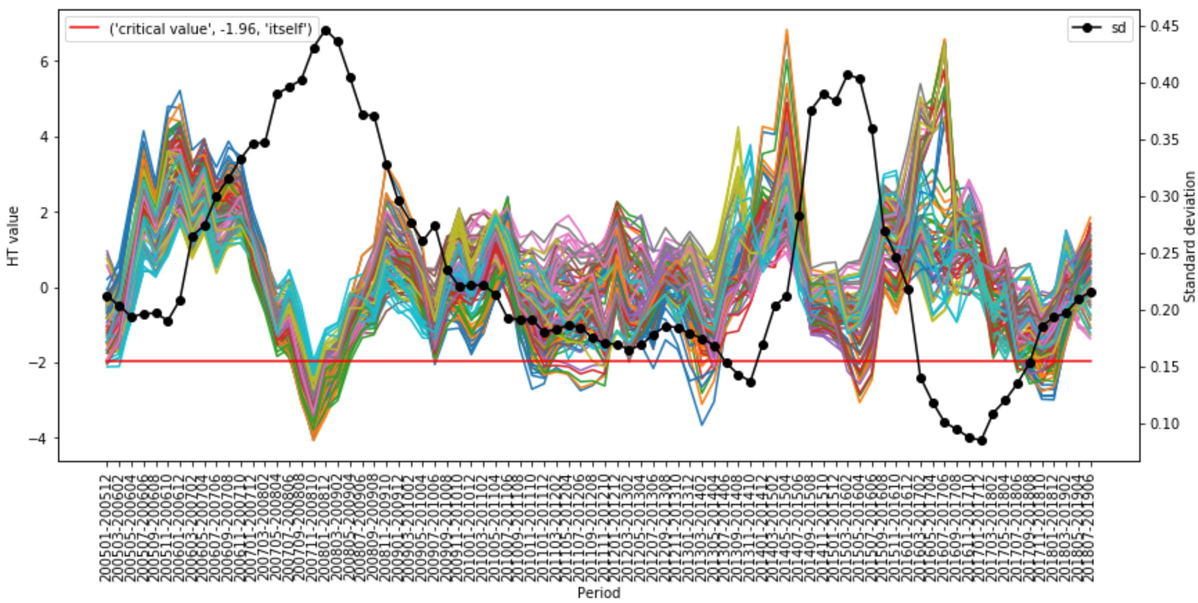
	SSEC	SZSEC
itself	a>=0.01 b>=-0.01	a<=0.012 b>=-0.014
the other	a<=0.08 b>=-0.14	Not recommend
both	Not recommend	Not recommend

4.5 Efficiency and volatility

Finally, investigate the relationship between values of hypothesis tests and market volatilities for finding some linkage between market efficiency and market volatility. Calculate volatility of one year's interval for 82 intervals and draw Plot 17. Use standard deviation of one year's daily return series as volatility. Because relationship of these two variables shows similar change trend whatever information set is considered, here just use SSEC on 'itself' as an analytical object.

Plot 17 Efficiency vs Volatility - SSEC(itself)

Note: This plot shows the movement trends of hypothesis tests results of SSEC using information 'itself' and quantitative one-year-interval's standard deviations.



Generally speaking, the change trend of volatility is consistent with the results of hypothesis tests. Around 2008 and 2015, the volatilities were much higher than normal level and the level of market efficiency declined in these periods. When volatility rises, the value of hypothesis test tends to drop. However, there is another interesting phenomenon that can not be explained rationally. Around 2011 and 2013, volatilities were much lower compared with the other time but there were profitable strategies indicating inefficient market. Therefore, although market volatilities are at low level, we can not conclude the market is efficient. From this point volatility observing in this way is not a very good criterion for market efficiency under expected return theory.

There is a useful finding which can help investor to judge if it is the time to make strategies. From Plot 17, the rise of standard deviation always happens early than the fall of hypothesis test value. Therefore, the rise of standard deviation can be seen as a signal for strategies. Roughly when standard deviation of one year's interval is gradually rising and when it is high than 0.3, it is the time to construct strategies. The value of 0.3 can be seen as a critical values.

All critical values of SSEC and SZSEC in different information set are summarized in the Table 6. There are two conditions for strategy construction: constant rise of standard deviation and critical values.

Table 6 Judgement of strategy construction

	SSEC	SZSEC
itself	0.3	0.3
the other	0.2	0.25
both	0.25	0.25

There is also another situation for strategy construction. That is when the standard deviation is pretty low and in the following step strategies should be considered. 2016~2017 is exactly this type of time. Obviously, now it is the time to think about some strategies.

5.Conclusions and problems

This paper studied market efficiency under expected return theory from weak form aspect using data of Shanghai Stock Exchange composite index and Shenzhen Stock Exchange composite index from January 4th 2005 to June 28th 2019.

The concrete contents are tests of random walk hypothesis, tests of sub-martingale hypothesis, tests of expected return theory in three different information sets and comparison between market efficiency and volatility. Conclusions of these empirical results are summarized as follow.

First, zero autocorrelations of return series hypotheses are significantly rejected for whole periods for both indices, but the autocorrelation values themselves are so small that they do not have enough information for investors to make profits. Especially in 2015 and 2016, null hypotheses are strongly rejected for both indices with high autocorrelations. As for runs test, it is not rejected for SSEC but rejected for SZSEC at alpha=0.01 in whole periods. We found evidence against random walk model.

Second, sub-martingale hypothesis implying nonexistence of strategy returns higher than holding returns does not hold for either index. All 100 strategies have the time during which they performed better than holding stock all the time.

Third, under information 'itself', both indices indicate inefficient markets around 2008, 2011 and 2018 under expected return theory. Holding market portfolio is a better choice around 2006, 2014 and 2016 while making own strategies is a better choice around 2008, 2011 and 2018. It is known from rejection ratios that the most inefficient time with the considerably high conditional rejection ratios very close to 1 was around 2008. Moreover, SZSEC is more sensitive to information and therefore may be more appealing to investors.

Fourth, there is no strong evidence indicating that strategies of higher return exiting when information set changes. Conclusions from different information sets about inefficient markets and investment timing are the same and the information contained in one certain market seems more important. Moreover, when market extends in size the level of market efficiency declines.

Fifth, the change trend of volatility is consistent with the results of hypothesis tests to some extent. Around 2008 and 2015, the volatilities were much higher and the level of market efficiency declined. Around 2011 and 2013, volatilities were much lower but there were strategies indicating inefficient market, which means that volatility is not a good criterion for market efficiency. From volatility value it is the time to think about doing some strategies.

Two problems are proposed for future study. First, as we said above the substitutes of elements in (4) may not be proper. We expect to find other proper substitutes. Second, yearly volatility is not a good criterion for market efficiency. We want to find if there are some other criteria which have closer relationship with market efficiency and are easier for investors to make judgement.

In the end, it is an interesting topic that 2008 is a mysterious year containing a lot of phenomena and problems. We hope to find more interesting things and if possible reasonable answers to these phenomena and problems.

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