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Efficiency Frontier for Chinese Stock Markets under Influence of Financial Crises

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Abstract Financial crises, like Asian financial crisis in 1997 and credit crunch from USA in 2007, have huge influence worldwide. For the importance and uniqueness of China's stock market, it is interesting and attractive to research it under influence of financial crises. The purpose for this research is to find out the influence of financial crises on Chinese stock market and focus on efficiency frontier. For research methodology, the efficiency frontiers are built using cross-sectional data through linear programming with an optimization model for different periods for Chinese stock markets portfolios and for a portfolio from Chinese, UK and USA stock markets together under current financial crisis. This research finds out that Chinese stock markets have a positive risk return trade off and it varies under the influence of financial crises; the investment efficiency in Chinese stock markets are relative good currently and if further diversified with western markets, higher investment efficiency can be achieved. The implication for this paper is to offer a suitable method to construct Chinese stock market efficiency frontier, and to improve investment efficiency through further diversification. This paper enjoys the originality that it perhaps is the first paper to build Chinese stock market efficiency frontier through linear programming.

Keywords Efficiency Frontier； Financial Crisis； Linear Programming； Stock Market

1 Introduction

Financial crises, like Asian financial crisis in 1997 and credit crunch from USA in 2007, have huge influence worldwide. The current financial crisis developed with a speed which is faster than our most ambitious forecasting. At its very beginning—the mid of 2007, it was an USA subprime lending crisis. But at the end of 2009, it was a big recession globally. With the development of this crunch, more and more economists believed that this crisis is different compared with other recessions not only for its deep and wide influence, but also for some special features within it. Nowadays, the global economy does not walk out of this crisis entirely from an overall view although some indices do indicate the sign of economic renaissance.

China's economy is one of the most important economies worldwide. Chinese capital market is one of the most important emerging capital markets as well. Under the dominoes influence of this crisis, it is quite sure that China undertakes huge lost.

1.1 Chinese Stock Markets

Chinese stock markets established in 1990. Currently, there are two stock markets in Chinese mainland: Shanghai Stock Market and Shenzhen Stock Market. The basic trend during their tough development is trying to be more rational, more efficient and more global. With the sustainable growth of Chinese economy, Chinese stock markets grew rapidly in the past 20 years.

But first of all, Can stock market be a good method to boost economy? Minier[1] critically discussed the relationship between the establishment of a stock market and the growth of economy and found that the result is ambiguous in the long-run.

However, Chinese stock markets have already been established. Naturally, people focus on the efficiency of Chinese two stock markets. C. Jeremy[2] finds out that the more and more sophisticated professional investors in the stock market can improve the efficiency as a whole and meanwhile they will improve the behavior of crowding and leverage creation. So, it is not necessarily true that with the development of the stock markets, the efficiency of the markets must be improved.

From the first beginning, Chinese stock markets had their own features. As its banking system, Chinese stock markets are government-oriented. Qinghua, Chung-Jen and Bing-Xuan[3] discussed the government role in the reform of China's banking system and the corresponding interaction between stock markets in China. Although Chinese banks lack experience in banking systems' management, but the reform in this system is still a good example which is reflected from the performance of its stocks in the markets.

Zhou and Sornette[4] studied the anti-bubble action and the reaction of Chinese stock markets and the real estate market. With several years rapid development, the Shanghai Composite Index (SHCI) and Shenzhen Component Index (SZCI) were much higher than they should be and this was what we called overvalue of stock market, or commonly, the "bubble stock market". The anti-bubble action during 2004 made more than one third of the total market value disappeared. Meanwhile, this action dropped China's real estate price at that time.

Leahy[5] also recorded that anti-bubble action from a different viewpoint. The size of Chinese stock market is so huge and is the second one in Asian market. In the 500 billion RMB total capitalization, only 200 billion RMB capitalization can be traded in the market and the rest is state-owned. This is the huge equity problem in Chinese stock market and Leahy thought that it was this problem which caused Chinese stock market overvalued.

Not only in practice, but also in research, Chinese nurture their stock markets. Zhou, Xu, Cai et al.[6] point out the statistical features for Chinese stock market by focusing the data spanning from January 2006 to October 2007, which was a big bull market and from January 2001 to December 2005, which was a big bear market. By using the statistical indices of log-return r(t) for both markets, three important features were found and these statistical features help understanding Chinese economic systems.

1.2 Efficiency Frontier

Portfolio theory is the first theoretical landmark during the research of modern investment. The basic viewpoint of this theory is that investors can invest into many assets at the same time and this investment behavior can achieve the relative same level of return with a substantial lower risk level. Portfolio theory has a premise that investors are risk-averse. If they take on risk, they must get corresponding return.

Portfolio theory makes it possible first time that investors can measure quantitatively risk return trade off. This theory tremendously changes investment behavior. Nowadays, people think it is rational to invest into a portfolio rather than an individual stock. It is meaningless to discuss risk level without a portfolio.

Efficiency frontier is built up by those special portfolios which have two features. One is that the portfolios in efficiency frontier have the highest rate of return compared with other portfolios which have the same risk level; the other is that the portfolios in efficiency frontier have the lowest risk level compared with other portfolios which have the same rate of return. Efficiency frontier is a curve which is combined by all these portfolios.

The construction of efficiency frontier is the first important step in modern investment practice. Unfortunately, to construct efficiency frontier with high quality is not so easy and it is still a hot issue in research. Kumar and Gulati[7] use linear programming in 2010 to construct efficiency frontier for 27 public sector banks operating in India and find out that high efficiency does not necessarily create high effectiveness and performance.

New techniques are used to improve portfolio building. Huang[8] applies fuzzy theory and VPRS (Variable Precision Rough Set) model in order to build a better portfolio through stock forecasting and stock selection.

Other research[9] argued that with the liberalization of stock market, investors can improve their invest efficiency by constructing their portfolio worldwide. The research supports the basic viewpoint that the less market limitation, the larger return will be achieved.

To further improve the investment efficiency, the risk and return trade off during investment is carefully researched. Through the extreme value theory framework and value at risk estimates, Liow[10] provides a development for portfolio construction with the consideration of extreme risk.

Cai, Liu and Mase[11] analyzed the performance of IPO and its further development in the stock market. Bitzenis, Tsitouras and Vlachos[12] tried to determine the inward FDI in Greece by MNCs worldwide through a questionnaire survey and the impact on stock market in Greece. The outcome is Greece should improve its attractiveness through modernize and update market mechanisms. These researches help to improve investment efficiency as well.

The risk research under crisis period is another hot issue recently. Wang and Moore[13] analysed the sudden change in the volatility in five central European stock markets. They think the change in volatility may be used as an index to test the influence of financial crisis in stock market.

Wang, Meric, Liu et al.[14] focuses on factors on variance and co-movement on stock market during and after stock market crashes and try to improve return management during crisis period in the market.

2. Research Methodology

2.1 Research Design

The method for this research is quantitative and qualitative as well. The empirical researches are quantitative. Three empirical researches are used to investigate the volatility, correlation coefficient and efficiency frontiers of stock markets and offer quantitative outcomes. This research uses classical statistics to estimate the variance of index returns, and correlation coefficient of index returns; uses linear programming to construct efficiency frontiers.

This research is also a theory testing, or positivist research. The research objectives are achieved through positivist research mainly. However, research objectives can not be achieved entirely through empirical analyses. Qualitative analyses are unavoidable here and commonly the deductive, however some inductive reasoning is used to get the final results.

A combination of case study design, cross-sectional design, longitudinal design and comparative design is used in the research.

The software used in this research includes Office Excel, and SPSS.

2.2 Data Source and Collection

Only secondary data has been used in this research. Specifically, the datasets used are: Shanghai Composite Index (SHCI), Shenzhen Component Index (SZCI), Shanghai and Shenzhen 300 Index (SH&SZ300), FTSE100 and S&P500.

The data of SHCI, SZCI and SH&SZ300 are obtained from Guo-Tai-An academic database[15], which is one of the leading economics and finance academic databases in China. The data of FTSE100 and S&P500 are obtained from a business website—yahoo finance[16].

2.3 Samples

It is widely believed that the time span of Asian financial crisis is from the July 2, 1997 (When Thai government announced that fixed exchange rate system of Thai Baht was abandoned) to December 31, 1998 (When Russian economy initially began to go out from its deepest recession).

The current financial crisis begins as a subprime credit crunch in the USA in the summer of 2007 and now it is still not the end. So, it is determined in this research that the current financial crisis is from the July 1, 2007 till now. The dataset is obtained till December 31, 2010.

A dataset for daily trading record in two years is enough for the majority of empirical study, including time series analysis. Based on the empirical study design for this paper, we choose daily trading data from June 30, 1995 to June 30, 1997 as a sub-sample representing the period before Asian financial crisis.

To sum up, by using cluster sampling method, we sample the dataset as following: daily trading data from June 30, 1995 to December 31, 2010 for SHCI, SZCI, FTSE100 and S&P500; daily trading data from April 8, 2005 (This index was created at that time.) to December 31, 2010 for SH&SZ300.

The SHCI, SZCI, FTSE100 and S&P500 are sub-divided into the following four cross-sectional subsamples: period before Asian financial crisis (06/30/1995 – 06/30/1997); period during Asian financial crisis (07/01/1997 – 12/31/1998); period between two financial crises (01/01/1999 – 06/30/2007) and period during current financial crisis (07/01/2007 – 12/31/2010).

For SH&SZ300, the subsamples are: period before current financial crisis (04/08/2005 – 06/30/2007) and period during current financial crisis (07/01/2007 – 12/31/2010).

3. Data Analysis and Results

3.1 Risk Level

If we define expected return (mean) as the arithmetic average return for the period, then the statistical expression of expected return is:

$$\overline{R} = \frac{\sum_{i=1}^{n} \frac{P_{i+1} - P_i}{P_i}}{n} \tag{1}$$

where P_i is the closing price for the i th trading day, P_{i+1} is the closing price for the $(i+1)$ th trading day and n is the total number of trading days during a specific period. $\overline{R}$ is the expected return.

The statistical expression of standard deviation (risk level) is:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (R_i - \overline{R})^2}{n}} \tag{2}$$

where $\sqrt{\ }$ represents the positive square root of variance, σ^2; R_i refers to $(P_i - P_{i-1})/P_{i-1}$ and is the return for i th trading day.

3.2 Correlation Coefficients

To test the correlation coefficient between Chinese stock markets and other major stock markets worldwide, we choose UK stock market and USA stock market as two cases in our study here.

This is done by using the classical definition of correlation coefficient in statistics. The formula is:

$$r_{XY} = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}} \tag{3}$$

where x_i and y_i are observations for variables *X* and *Y*, respectively, $\bar{x}$ and $\bar{y}$ are the means for observations of variables *X* and *Y*, respectively.

3.3 Efficiency Frontier

The basic idea is, first we use the above risk level and correlation coefficients as input data to construct an equally-weighted portfolio to determine a specific portfolio expected return. Then we try to find out the minimum portfolio variance for this specific expected return by adjusting investment weight for each market. The optimization model used here is:

$$\text{Min.} \quad \text{var}_p = \sum_{j=1}^{m} \sum_{k=1}^{m} w_j w_k \sigma_{j,k} \tag{4}$$

$$\text{Subject to:} \quad \sum_{j=1}^{m} w_j = \sum_{k=1}^{m} w_k = 1$$

$$\sum_{j=1}^{m} w_j E(r_j) = \sum_{k=1}^{m} w_k E(r_k) = cons.$$

$$w_j \geq 0 \qquad (j = 1,2,3,...m)^*$$

$$w_k \geq o \qquad (k = 1,2,3,...m)^*$$

where var_p refers to variance of portfolio; w_j and w_k refer to the investment weights of the *j* th and the *k* th security (or market) in the portfolio; $\sigma_{j,k}$ refers to the covariance between the *j* th and the *k* th security (or market) in the portfolio; $E(r_j)$ and $E(r_k)$ refer to the expected return for the *j* th and the *k* th security (or market) in the portfolio; *cons.* refers to a constant. * represents this constraint is optional.

Efficiency frontier can be constructed with or without short sales. Constructing an efficiency frontier with the optional constraints in Eq. 4 means that short sales are not permitted. Otherwise, short sales are permitted. If short sales are permitted in a market, they will make investment more efficient. For short sales are permitted in China at present, we construct efficiency frontier without the optional constraints in Eq. 4.

The result from the above optimization model can be used to pinpoint just one point within the curve of efficiency frontier. To get more points so that we can link those points with a curve, we repeat our calculation on the above model by changing the constant figures gradually. Finally a curve is constructed. And the portion within this curve, from the minimum variance point to the right-hand side, with upward sloping, is the efficiency frontier that we wanted[17].

We use excel solver to achieve linear programming.

Tab. 1 Chinese Stock Markets Efficiency Frontier during 06301995--06301997

The Efficiency Frontier (with short sales)			
		Markets Weights	
Mean	Std Dev	SHCI	SZCI
0.0006	0.019019	1.196915	-0.19692
0.0007	0.017889*	0.843957	0.156043
0.000798	0.0179	0.5	0.5
0.0008	0.017915	0.491	0.509
0.0009	0.019092	0.138042	0.861958
0.001	0.021256	-0.21845	1.218446
0.0011	0.024106	-0.5714	1.571403
0.0012	0.027441	-0.92436	1.924361
0.0013	0.031068	-1.27379	2.273789
0.0014	0.034957	-1.62675	2.626747
0.0015	0.039046	-1.98323	2.983235
0.0016	0.043168	-2.33266	3.332663
0.0017	0.047415	-2.68562	3.685621
0.0018	0.051725	-3.03858	4.038578

*: the minimum variance point

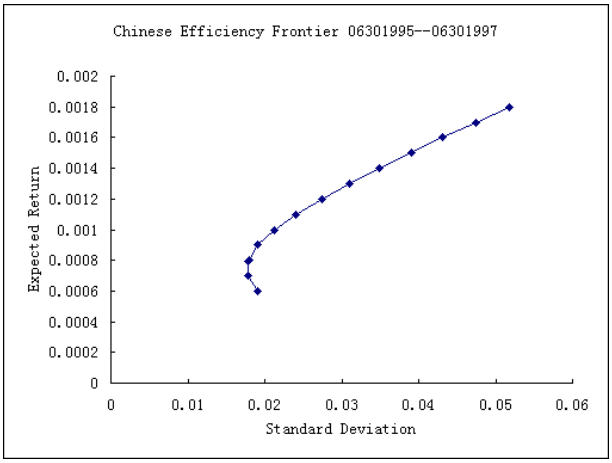

Fig. 1 Chinese Stock Markets Efficiency Frontier during 06301995--06301997

Tab. 2 Chinese Stock Markets Efficiency Frontier during 07011997—12311998

The Efficiency Frontier (with short sales)			
		Markets Weights	
Mean	Std. Dev	SHCI	SZCI
-0.0004	0.015117	0.673225	0.326775
-0.0003	0.015082	0.755923	0.244077
-0.0002	0.015071*	0.838622	0.161378
0	0.015118	1.004846	-0.00485
0.0001	0.015177	1.087545	-0.08754
0.0002	0.015258	1.170243	-0.17024
0.0003	0.015361	1.252115	-0.25212
0.0004	0.015486	1.334814	-0.33481
0.0005	0.015634	1.417512	-0.41751
0.0006	0.015804	1.501038	-0.50104
0.0007	0.01599	1.58291	-0.58291
0.0008	0.016199	1.665608	-0.66561
0.0009	0.016425	1.748307	-0.74831
0.001	0.016673	1.831832	-0.83183
0.0011	0.016935	1.914531	-0.91453
0.0012	0.017214	1.99723	-0.99723
0.0013	0.017509	2.079928	-1.07993

*: the minimum variance point

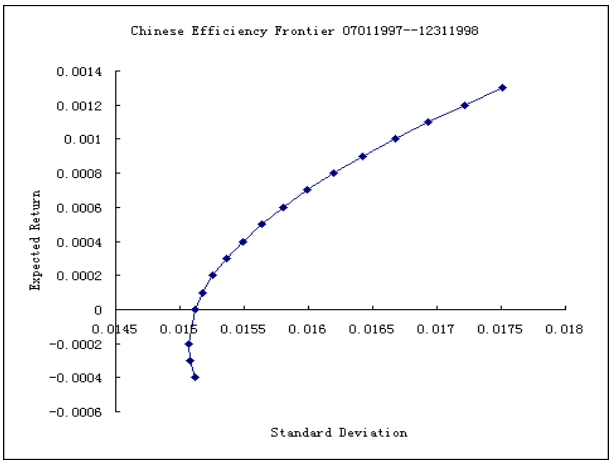

Fig. 2 Chinese Stock Markets Efficiency Frontier during 07011997—12311998

Tab. 3 Chinese Stock Markets Efficiency Frontier during 01011999—06302007

The Efficiency Frontier (with short sales)			
		Markets Weights	
Mean	Std. Dev	SHCI	SZCI
0.0006	0.015386	1.771498	-0.7715
0.00065	0.015026	1.418679	-0.41868
0.0007	0.014955*	1.079696	-0.0797
0.000784	0.015471	0.491664	0.508336
0.00085	0.016388	0.035074	0.964926
0.0009	0.017331	-0.30834	1.308336
0.00095	0.018471	-0.65673	1.656728
0.001	0.019755	-1.00263	2.002629

*: the minimum variance point

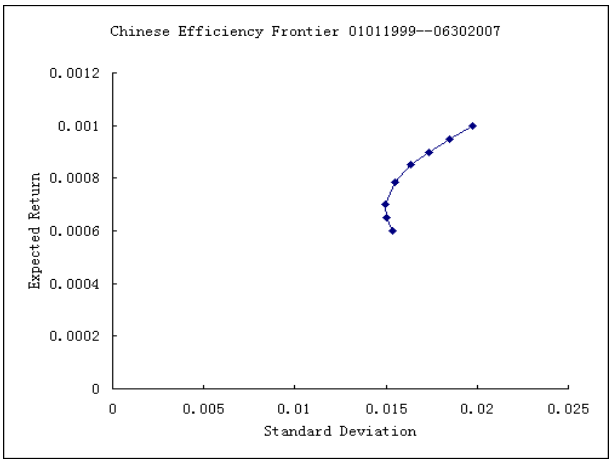

Fig. 3 Chinese Stock Markets Efficiency Frontier during 01011999—06302007

Tab. 4 Chinese Stock Markets Efficiency Frontier during 07012007--12312010

The Efficiency Frontier (with short sales)			
		Markets Weights	
Mean	Std. Dev	SHCI	SZCI
-0.0001	0.024401	1.183429	-0.18343
0	0.02437*	0.955991	0.044009
0.0001	0.024525	0.730827	0.269173
0.0002	0.02487	0.501114	0.498886

0.0003	0.025389	0.273676	0.726324
0.0004	0.026075	0.046238	0.953762
0.0005	0.026914	-0.1812	1.1812
0.0006	0.027894	-0.40864	1.408638
0.0007	0.028999	-0.63608	1.636076
0.0008	0.030216	-0.86351	1.863514
0.0009	0.031546	-1.09323	2.093227
0.001	0.03295	-1.32067	2.320665

*: the minimum variance point

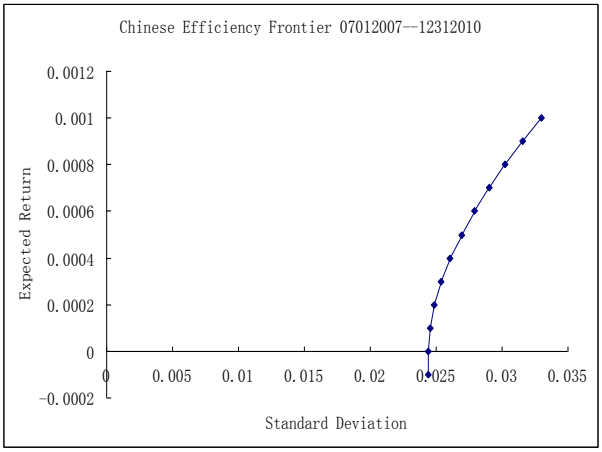

Fig. 4 Chinese Stock Markets Efficiency Frontier during 07012007--12312010

Tab. 5 International Stock Markets Efficiency Frontier: 07012007—12312010

The Efficiency Frontier (with short sales)					
		Markets Weights			
Mean	Std. Dev	FTSE100	S&P500	SHCI	SZCI
-0.0004	0.015673415	0.348774355	0.319528448	0.501186747	-0.16948955
-0.0003	0.015610124*	0.347963563	0.299105433	0.319555425	0.033375579
-0.0002	0.015805874	0.347152818	0.278682342	0.137924168	0.236240672
-0.0001	0.016258865	0.346342019	0.258259336	-0.043707166	0.439105812
0	0.016939995	0.345523094	0.237632126	-0.227154837	0.643999617
0.0001	0.017816234	0.344720328	0.217413463	-0.406969959	0.844836168
0.0002	0.018888109	0.343909468	0.196990549	-0.588601376	1.047701359
0.0003	0.020085636	0.343098619	0.176567617	-0.770232777	1.25056654

0.0004	0.021431758	0.342287701	0.156144791	-0.951864272	1.45343178
0.0005	0.022866699	0.341476831	0.135721893	-1.133495704	1.65629698
0.0006	0.024385285	0.340666049	0.115298859	-1.315127012	1.859162104
0.0007	0.025956675	0.33985515	0.094877601	-1.496758483	2.062027329
0.0008	0.027617501	0.339044262	0.074453135	-1.678389941	2.264892545
0.0009	0.029309629	0.338233422	0.05403019	-1.860021331	2.467757719

*: the minimum variance point

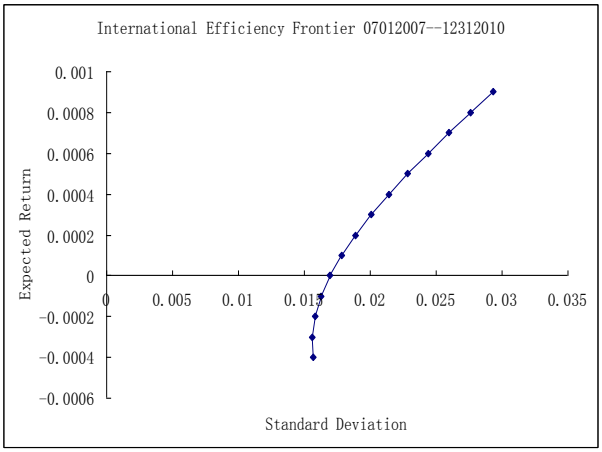

Fig. 5 International Stock Markets Efficiency Frontier during 07012007—12312010

4. Conclusion

Tabs. 1-5 and figs. 1-5 indicate that positive risk return trade off is always maintained during the entire period. This means Chinese markets have investment value, or one can make money with them. The risk return trade off varies under the influence of financial crises.

China improved its investment efficiency during the first crisis. From the mean and standard deviation of the efficiency frontiers before and after Asian financial crisis, we find under the same mean level, the standard deviation is lower during crisis. This means higher efficiency.

Though it is strange that Chinese markets offered more attractive risk return trade off during Asian financial crisis, this is reasonable. If a market wants to survive the crisis successfully, it must have strength. During that crisis, international financial tycoons manipulated stock markets to make it drop substantially during a very short period and earned money by taking short position in that market earlier.

But they did not do this strategy in Chinese mainland stock markets, Hong Kong stock market and Japanese stock market. The financial strength in these areas is so powerful that it is impossible for them to fulfill this strategy in these markets.

One can also find out that situation changed entirely in current crisis. China dropped its investment efficiency. The risk level increases substantially and by taking short position entirely in Shanghai market can achieve highest return level in practice. Two reasons account for this phenomenon. Economic structure adjustment in current China increases uncertainty during development; and there is not global "hot money" which wants to affect Chinese stock markets.

Currently, to invest in China and western countries together at the same time could help improve efficiency. Comparing tab. 7, fig. 4 with tab. 8, fig. 5, we find out that for the same expected return level, the risk level (standard deviation) for the international portfolio is lower than the risk level for Chinese markets portfolio during this crisis.

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