A Panel Threshold Regression Approach Idiosyncratic Risk and Expected Stock Returns in Taiwan Stock Market

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Abstract

The objective of this research is to re-examine the relationship between idiosyncratic risk and expected stock returns using panel threshold regression method in Taiwan stock market. According to CAPM, idiosyncratic risk should not bear a relationship with expected stock returns because it can be diversified away. This paper employs threshold regression model to uncover the underlying relationship between idiosyncratic risk and expected stock returns in Taiwan stock market from 1994/1 to 2013/12. Grounded on Merton (1987) that a positive relation exists between idiosyncratic risk and stock returns because investors are not well-diversified, we hypothesize that investors' incentive to diversify varies over time. Our results support Merton (1987) argument, the relationship between idiosyncratic risk and expected stock returns are often positive. However, when investors have strong incentive to well-diversify the idiosyncratic risk in their investments during a bear market, a weaker or no relation exists. In other words, investors' diversified degree of the idiosyncratic risk in their investmentsvaries with economic cycle and time and the positive relationship between idiosyncratic risk and expected stock returns doesn't always hold. The results will help reconcile the conflicting results found in the literatures.

Keywords: Expected stock returns; CAPM; Idiosyncratic risk; Panel threshold regression.

1. Introduction

According to CAPM, investors can hold a perfectly stock portfolio to diversify the idiosyncratic risk so idiosyncratic risk can be neglected. Therefore, idiosyncratic risk should not bear a relationship with expected stock returns because it can be diversified away and only systemic risk can affect the stock returns. Although idiosyncratic risk can be eliminated by investing with a well-diversified portfolio, for some reasons, a market with incomplete information, investors in reality may not hold perfectly diversified portfolio. In a less-than-perfect market, idiosyncratic risk may be compensated for higher returns (Merton, 1987).

Although previous researchers have committed efforts in resolving these controversies, no consistent conclusion has been drawn. Some researchers find no significant relationship between the idiosyncratic risk and expected stock returns(Bali, Cakici, Yan and Zhang, 2005), some researchers find negative relationship between idiosyncratic risk and expected stock returns,(Ang, Hodrick, Xing, and Zhang 2006), and some predict that idiosyncratic volatilities will have a positively effect on the expected stock returns due to under-diversification(Levy,1978; Merton, 1987;Barberis and Huang, 2001;Malkiel and Xu, 2002;Goyal and Santa-Clara, 2003;Boehme et al, 2009;Fu, 2009; Huang et al., 2010;Vozlyublennaia, 2012). To resolve these controversies, this research re-examine the issue in Taiwan stock market because we postulate that investors have strong incentive to diversify their portfolios depending on the market sentiment.

This paper uses panel threshold regression method proposed by Hansen (1999) to re-examine the relationship between idiosyncratic risk and expected stock returns in Taiwan stock market. Because previous researchers did not consider the fact that time-varying market cycles will affect investors' investment preferences, risk aversion, and diversification incentives. Weexpect to observe a significant threshold effect using the threshold regression method and examine the relationship between idiosyncratic risk and stock returns, considering the market cycle which is conditioned on the investors' sentiment.

Because investors are momentum traders in a bull market, they might be poorly diversified. The frenzy trading of high tech stocks during the internet bubble period is a clear example. Such market imperfection may result in a significant relationship between idiosyncratic risk and expected stock returns due to the lack of diversification incentives. On the other hand, during the bear markets, investors turn to risk-averse, and hence may be better diversified. This research uses threshold regression method to test the idiosyncratic risk and expected stock returns based on the market cycle. The relationship is significant only when the idiosyncratic risk is below the threshold. The results will help to reconcile the conflicting results found in the literatures and make investors further understand the relationship between idiosyncratic risk and expected stock returns.

2. Literature review

Levy (1978) and Merton (1987)predicted that idiosyncratic volatilities will have a positive effect on the expected returns due to under-diversification. Grounded on Levy (1978) and Merton (1987), where a positive relation exists between idiosyncratic risk and stock returns because investors are not well-diversified, Barberis and Huang (2001) predicted that the higher idiosyncratic volatility should earn higher expected returns.Malkiel and Xu (2002) found a significant positive relation between idiosyncratic risk and expected returns. Goyal and Santa-Clara (2003) also found a significant positive relation between average stock variance (largely idiosyncratic) and the value-weighted portfolio return on the NYSE/AMEX/Nasdaq stock for the period of 1963:08 to 1999:12.However, Bali, Cakici, Yan and Zhang (2005) did n't find that the same conclusion from Goyal and Santa-Clarea exist for the 1963:08 to 2001:12, and they also find that there are no significant relation between the equal-weighted average stock volatility and the value-weighted portfolio return on the NYSE/AMEX or NYSE stocks. Boehme et al (2009) found evidence supporting Merton (1987) that the relation between idiosyncratic risk and stock returns is positive for the stocks with low levels of investor recognition and for which short selling is limited. Vozlyublennaia (2012) analyzed the relationship using a GARCH-in-Mean framework, and finds that 15% of stocks exhibit a significant relationship between returns and risk, of which 9% are positive. Moreover, these proportions vary over time and with model specifications.

On the other hand, Ang, Hodrick, Xing, and Zhang (2006) found that high idiosyncratic volatility in one month predicts abysmally low average returns in the next month. They also found that the stocks with high sensitivities to innovations in aggregate volatility have low average return and firms with high idiosyncratic volatility have very low average return. They think time-varying market volatility induces changes in the investment opportunity set by changing the risk-return trade-off. Nonetheless, Fu (2009) refuted this negative relationship as he finds a significantly positive relation between the estimated conditional idiosyncratic volatilities and expected returns. He employed the exponential generalized autoregressive conditional heteroscedasticity (EGARCH) model and out-of-sample data to estimate expected idiosyncratic risk.Then,he applied Fama-MacBeth regressions of monthly stock returns and other firm characteristics that are known to explain cross-sectional returns. Huang et al. (2010) argued that the negative relation between idiosyncratic risk and stock returns disappears after return reversals are controlled for. However, a positive relation still exists in the monthly data.

Given the fact that academic interest in this subject matter is strong and the conclusions are far from conclusive, we re-examine this issue from a different perspective and methodology.

3. Models

3.1.Hypothesis

We assume that investors are motivated to diversify risks based on the market condition. It means that the relationship between idiosyncratic risk and expected stock returns varies with the market cycle. Merton (1987) thinks that a positive relation exists between idiosyncratic risk and expected stock returns because investors are not well-diversified. Therefore, this research assumes that the over-confidence makes investors aggressive for high stock returns and not well-diversified for the idiosyncratic risk in their investments. During the latter part of the 1990s, due to the wonderful image about the high tech company, investors aggressively chased internet stocks and were poorly diversified for the idiosyncratic risk in their investments. After the market crashed, investors turned to be conservative and well-diversified for the idiosyncratic risk in their investments.

However, the degree of how investors are motivated to diversify the idiosyncratic risk in their investments is difficult to measure. Therefore, some proxies must be used to capture such variable. We propose the idiosyncratic risk as proxy. In a bull market, investors turn to be aggressive, over-confident, and less concerned about risk diversification so investors are less diversified and thus the idiosyncratic risk is high. Since investors are less inclined to hold diversified portfolio, a positive relation between idiosyncratic risk and expected stock return is observed. On the other hand, in a bear market, stock return is more correlated to the market because investors have incentive to diversify and hence lower idiosyncratic risk.

Based upon above arguments, we posit the following hypothesis.

Hypothesis: there is a threshold value of idiosyncratic risk that the relation between idiosyncratic risk and expected stock returns is significantly positive when the idiosyncratic risk is above the threshold value. Alternatively, the relation between idiosyncratic risk and expected stock returns is weak or insignificant when the idiosyncratic risk is below the threshold value.

3.2. Panel threshold regression method

Tong(1978)firstly proposed the threshold Auto-regression applying on the non-linear time series model to describe the variables of non-symmetric. Then, Tong and Lim (1980) modified this model using threshold variables on different periods to discriminate the variables of Auto-regression. This method was developed by Hansen (1999, 2000), and used widely in finance and economic research. He uses panel threshold regression method to test whether financial constraints affect investment decision. Hence this paper will use threshold regression to test the relationship between the idiosyncratic risk and the expected stock returns by one single threshold variable with multiple threshold values.

Because traditionally Ordinary Least Square is difficult to estimate the non-linear relationship, Hansen(1999) proposed that two-step estimation procedure can be used. To test our hypothesis, we firstly estimate the idiosyncratic risk using the Fama-French 3-factor model, i.e.,

$$R_{it} - R_{ft} = \beta_0 + \beta_1(R_{mt} - R_{ft}) + \beta_2(SMB)_t + \beta_3(HML)_t + \varepsilon_{it} \qquad (1)$$

The idiosyncratic volatility of stock is computed as the standard deviation of the regression residuals, i.e., $\sqrt{Var(\varepsilon_{it})}$. To reduce the impact of infrequent trading on idiosyncratic volatility estimates, we require a minimum of 15 trading days in a month for which CRSP reports both a daily return and non-zero trading volume. Secondly, we construct a threshold regression with the expected stock return as the endogenous variable and idiosyncratic volatility as one of the explanatory variables to test the relationship between idiosyncratic risk and the cross-section of expected stock returns. Threshold regression method is developed for non-dynamic panels with individual special fixed effects. It will be used to test the relation between idiosyncratic risks and expected stock returns. The regression model can be specified as:

{ $R_{it}, q_{it}, x_{it} : 1 \le i \le n, 1 \le t \le$ T}, where the subscript i indexes the individual stocks and the subscript t indexes time. The threshold variable q_{it} is a scalar and the thresholds are ordered so that $\gamma_1 < \gamma_2$ in the case that the number of thresholds is more than one. The threshold variable is idiosyncratic risk and we will conduct test described below to determine the number of thresholds.

3.2.1. Single-threshold regression

$$R_{it} = \beta'_{0t} + \beta'_{1t}[IVOL_{it}]I(q_{it} \le \gamma) + \beta'_{2t}[IVOL_{it}]I(q_{it} > \gamma) + \beta'_{kt}\sum_{K=3}^{K} X_{kit} + u_{it} \, (2)$$

In Equation (2), R_{it} is the stock return, $IVOL_{it}$ is the idiosyncratic risk, and X_{it} are the explanatory variables including the threshold variables. $I(\cdot)$ is the indication function, and γ is the threshold value. Finally, u_{it} is the unobserved scalar random variable (errors).

The hypothesis of no threshold effect in (2) can be represented by the linear constraint

$$H_0: \ \beta_1 = \beta_2$$

Under the null hypothesis of no threshold, the model is

$$R_{it} = \mu_i + \beta'_1 x_{it} + e_{it}$$

After the fixed-effect transformation is made, we obtain

$$R^*_{it} = \beta'_1 x^*_{it} + e^*_{it}$$

The regression parameter β_1 is estimated by ordinary least squares (OLS), yielding estimated $\tilde{\beta}_1$, residuals $\tilde{e}_{it}^{\,*}$ and sum of squared errors $S_0 = \tilde{e}_{it}^{\,*\,\prime}\,\tilde{e}_{it}^{\,*}$. The likelihood ratio test of H_0 is based on

$$F_1 = (S_0 - S_1(\hat{\gamma}))/\hat{\sigma}^2$$

If F_1 rejects the null of no threshold, we need to further test to discriminate between one and two thresholds.

$$\hat{\sigma}^2 = S_2^r(\gamma_2^r)/n(T-1)\,; \quad F_2 = \left[S_1(\hat{\gamma}_1) - S(\hat{\gamma}_2^r)\right]/\hat{\sigma}^2 .$$

The hypothesis of one threshold is rejected in favor of two thresholds if F_2 is large.

The asymptotic (1-∂)% confidence intervals for γ_2 and γ_1 are the set of values of

γ such that $LR_2^r(\gamma) \le C(\partial)$ and $LR_1^r(\gamma) \le C(\partial)$, respectively, where Asymptotic (1-∂)% confidence intervals for γ_2 and γ_1 are the set of values of γ such that $LR_2^r(\gamma) \le C(\partial)$ and $LR_1^r(\gamma) \le C(\partial)$, respectively, where LR_2^{γ} and LR_1^{γ} are defined as: $LR_2^r = \left[S_2^r(\gamma) - S_2^r(\hat{\gamma}_2^r)\right] / \hat{\sigma}^2$, and $LR_1^r = \left[S_1^r(\gamma) - S_1^r(\hat{\gamma}_1^r)\right] / \hat{\sigma}^2$.

3.2.2. Double-threshold regression

$$R_{it} = \beta_{0t}^{'} + \beta_{1t}^{'}[IVOL_{it}]I(q_{it} \le \gamma_1) + \beta_{2t}^{'}[IVOL_{it}]I(\gamma_1 \le q_{it} \le \gamma_2) + \beta_{3t}^{'}[IVOL_{it}]I(q_{it} > \gamma_2) + \beta_{kt}^{'}\sum_{K=4}^{K} X_{kit} + u_{it} \quad (3)$$

When the model tests only one threshold effect, the bootstrap and likelihood test have to be repeatedly used to estimate the significance of double threshold. If the double threshold is rejected, there is single threshold. If not, the testing of multi-threshold needs to be processed until we can find the exactly threshold number.

3.3. Variable Definition

The measurements of key variables *constructed for the measurement of the threshold variable* idiosyncratic volatility areused to find the standard deviation of the residuals by Fama-French 3-factor model. *Variables used and obtained from the first stage estimates* are explained below:

(1)Stock Returns (R_{it}): measured by the natural logarithm of the price ratio;
(2)Market Returns (R_{mt}): measured by the CRSP value-weighted returns;
(3)Risk-free Rate (R_{rf}): measured by three-month T-bill rate obtained from the Federal Reserve Bank of St. Louis;
(4)SMB: Fama-French's small minus big risk factor;
(5)HML: Fama-French's high minus low risk factor;

Other control variables include Ln(ME): natural logarithm on the market value of equity; Ln(BE/ME): natural logarithm of BE over ME, where ME is the market value of equity and BE is the book value of equity; Ln(turn): natural logarithm of stock turnover rate, measured by common share traded to common share outstanding; Ln(LEV): natural logarithm of financial leverage, measured by the debt to asset ratio.

4. Empirical results

The stocks which are traded in Taiwan Stock Exchange from January 1994 to December 2013(except for the over the counter stocks, ADR and F-stock) are sampled to explore the relationship between idiosyncratic risk and expected stock returns. All data for the first stage estimates will be obtained from the TEJ database and Taiwan first Bank. Variables for the second stage estimates are obtained from the TEJ database. Since the Hansen threshold regression is only suitable for the balanced panel data, companies with incomplete data are deleted.

The descriptive statistics of variables are shown in Appendix 1. There are 20-year, 5-year and 6-month periods from 1994-2013. The stock return is a dependent variable and the idiosyncratic risk is a threshold variable while the market value, book value over market value of equity, turnover rate and financial leverage are control variables. The stock return is influenced by idiosyncratic risk, market value, book value over market value of equity, turnover rate and financial leverage. The highest stock returns period is 37.33%(2009-2013), and largest volatility is 92.25%, which may be influenced by the recovery from the financial crisis. The volatility of idiosyncratic risk is 8~11 in 20-year and 5-year, but the volatility decline to 2.28, 2.41 during internet bubble and financial crisis period. The results show that investors have strong incentive to diversify during a bear market.

In addition, Lnbeme is positive only on 1999-2003, 2008/7-2008/12 and it stands for the book value larger than the market value. Lnturn is the lowest during internet bubble and financial crisis, which show the poor liquidity. From the Jarque-Bera test, all variables reject the normal distribution.(Seeappendix 1)

According to the threshold regression and the data from 1994-2013, there are 3920 samplesin 20-year, we can find three threshold values and four intervals existing positive relationship under 95% confidence level(See Appendix 3). If we further divide the period into several 5-year periods, including of 1994-1998, 1999-2003, 2004-2008, 2009-2013, there are 1015samples in each 5-year period. In addition, in some specific periods, there are 3348 samplesin the internet bubble period and 1149 samples in the financial crisis period. The threshold regression of each period is shown in Appendix 2.

Appendix 2 shows that the idiosyncratic risk has different impact levels on expected stock returns in each period. Appendix 3 shows the result of the threshold regression. We test the period of 1994-2013, 1994-1998, 1999-2003, 2004-2008, 2009-2013,2000 and 2008 and there is significant threshold effect in each period to make the slope of idiosyncratic risk and expected stock return change. The likelihood ratio trend graphs are shown in appendix 4.

Table1 shows the result of the threshold regression. We test the periods of 20-year, 5-year and 6-month and there is significant threshold effect in each period. In the 20-year and 5-year period, the bear market effect is diluted due to the long period so the relationship of idiosyncratic risk and expected stock returns is positive, except for the internet bubble period (1999-2003; 2000/4-2000/9), because the bear market effect makes the relationship insignificant. However, in financial crisis period (2008/7-2008/12), the relationship is also observed to be positive. This may be due to that the data for this period is not as complete as those for internet bubble period. Because we use the balanced panel data, for further re-examine the threshold effect, we delete the stocks with incomplete data and more stocks are deleted based on this criterion during financial crisis period.

Table 1: threshold regression test

	20-year	**5-year**				**6-month**	
	94-13	94-98	99-03	04-08	09-13	00	08
Threshold value	3	3	3	3	3	3	3
IVOL period							
1	+	+	.	+	+	.	+
2	+	+	.	+	+	.	+
3	+	+	+	+	+	+	+
4	+	+	+	+	+	+	+

Ps. .stands for no significate under 95% confidence level.

The results align with our expectation. When investors have strong incentive to diversify the idiosyncratic risk in their investments during bear market, a weaker or no relation exists. In other words, when investment diversity declines, a positive relation exists. Therefore, the diversified degree could change with economic cycle and time. These results support Merton (1987) argument, the relationship between idiosyncratic risk and expected stock returns are often positive.

For further testing, we also conduct the OLS test and the results are shown in Table2.The results using threshold regression and OLS for the periods of 2000 and 2008are compared in Figure1 and Figure2.

Table 2: OLS test

	20-year	5-year				6-month	
	94-13	94-98	99-03	04-08	09-13	00	08
IVOLCoef	+	+	+	+	+	+	+
Non-linear test	0	1	1	1	1	1	1

Ps. +stands for positive relation under 95% confidence level.In non-linear test, 1 stands for rejecting the non-linear hypothesis under 95% confidence level, otherwise is 0.

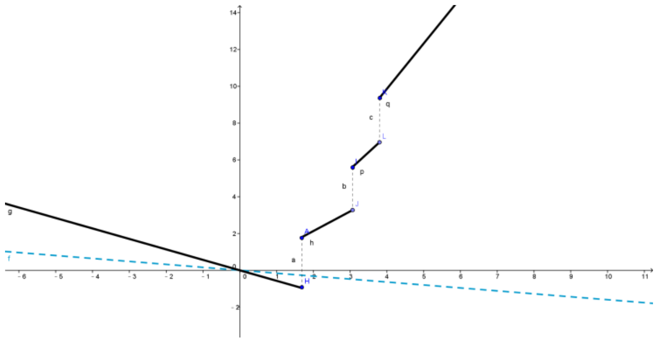

Figure 1: Comparison threshold regression with OLS in 2000/4-2000/9

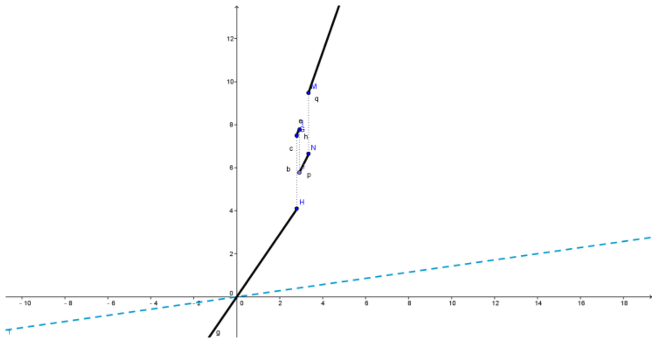

Figure 2:Comparison threshold regression with OLS in 2008/7-2008/12

The solid line shows the results by threshold regression and dotted line shows the results by OLS in Figure1 and Figure2.Figure 1 shows the results during the internet bubble period and Figure 2 shows the results during the financial crisis period. We can see the difference between threshold regression and traditional linear regression from the two significant financial events. In threshold regression, we can find 4 intervals, the stock returns will change with idiosyncratic risk. But the coefficient of expected stock returns and idiosyncratic risk are constant in OLS model

From Table2, the relationship is linear only on 20-year and others are non-linear under 95% confidence level, so the linear model effect is limited. The expected stock returns and idiosyncratic risk influence each other. Furthermore, market cycle also influences the motivation of investors to diversify the idiosyncratic risk in their investments, so the traditional linear model cannot reflect real condition. However, in threshold regression, the coefficient is different in each interval and the relationship of expected stock returns and idiosyncratic risk changes with the time and market economic so it could better reflect real condition.

5. Conclusions

This paper uses Taiwan stock market data from 1994~2013 and employs the threshold regression to show that there is non-linear relationship between idiosyncratic risk and expected stock returns. If we use OLS only, a positive relation exists. However, if we employ the threshold regression to uncover the underlying relationship between idiosyncratic risks and expected stock returns in Taiwan stock market, a weaker or negative relation exists. The Idiosyncratic risk as proxies can be used to capture the degree of investment diversity under different market conditions. The results show that the threshold regression can discriminate several intervals, where the relationship between idiosyncratic risk and expected stock returns changes with idiosyncratic risk. Our results support Merton (1987) argument, the relationship between idiosyncratic risk and expected stock returns are often positive. Investors are not well-diversified for the idiosyncratic risk in their investments and the behavior of investors changes with the time and market economy condition. When investors have weak incentive to diversify the idiosyncratic risk in their investments during bull market, a positive relation exists. On the other hand, when investors have strong incentive to diversify the idiosyncratic risk in their investments during bear market, a weaker or no relation exists. The results shed light on the disputes in existing literatures and help to reconcile the conflicting results found in the literatures.

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Appendix1: Descriptive statistics of variables

Variable	Statistics	1994~1998	1999~2003	2004~2008	2009~2013	1994~2013	2000/4~2000/9	2008/7~2008/12
Ret	Mean	5.32	9.62	5.93	37.33	12.15	-7.99	-7.17
	Std.Dev	44.37	71.86	72.51	92.25	55.6	13.39	15.73
	Q1	-24.02	-33.4	-32.44	-14.89	-23.14	-16.31	-17.4
	Medium	-3.85	-4.51	-3.82	11.69	2.88	-7.96	-5.85
	Q3	23.2	30.13	27.73	56.39	31.8	0.00	2.17
	Jarque-Ber	3158.28***	43607.9***	53667800***	52403.8***	48929.6***	6452.67***	3789.39***
Lnme	Mean	9.08	8.09	7.98	8.23	8.84	8.38	7.76
	Std.Dev	1.12	1.49	1.59	1.5	1.47	1.42	1.52
	Q1	8.34	7.05	6.84	7.16	7.89	7.36	6.69
	Medium	8.99	7.92	7.83	8.06	8.73	8.21	7.59
	Q3	9.71	8.89	8.87	9.1	9.69	9.16	8.63
	Jarque-Ber	27.57***	240.5***	468.4***	663.42***	120.68***	463.67***	970.83***
Lnbeme	Mean	-0.78	0.05	-0.17	-0.34	-0.19	-0.42	0.09
	Std.Dev	0.48	0.75	0.66	0.61	0.67	0.89	0.65
	Q1	-1.1	-0.41	-0.59	-0.69	-0.62	-0.96	-0.31
	Medium	-0.76	0.09	-0.14	-0.29	-0.17	-0.28	0.13
	Q3	-0.46	0.51	0.27	0.09	0.27	0.22	0.53
	Jarque-Ber	4.59	125.42***	126.82***	2255.36***	18.92***	197.85***	165.18***

Appendix1: Descriptive statistics of variables

Variable	Statistics	1994~1998	1999~2003	2004~2008	2009~2013	1994~2013	2000/4~2000/9	2008/7~2008/12
Lnturn	Mean	5.41	4.79	4.75	4.61	4.85	1.99	1.7
	Std.Dev	1.01	1.22	1.16	1.15	1.06	1.38	1.19
	Q1	4.9	4.08	4.07	3.91	4.24	1.13	0.98
	Medium	5.56	4.94	4.89	4.73	4.94	2.08	1.73
	Q3	6.06	5.68	5.61	5.43	5.63	3.01	2.51
	Jarque-Ber	2725.26***	222.43***	965.08***	730.77***	479.81***	87.69***	237.2***
Lnda	Mean	3.63	3.76	3.7	3.62	3.69	3.73	3.63
	Std.Dev	0.44	0.43	0.53	0.56	0.5	0.45	0.57
	Q1	3.36	3.54	3.45	3.33	3.46	3.51	3.33
	Medium	3.71	3.82	3.82	3.73	3.8	3.83	3.76
	Q3	3.94	4.04	4.05	4.01	4.01	4.02	4.01
	Jarque-Ber	132.46***	1418.8***	3072.05***	3385.22***	4250.03***	1195.62***	2407.66***
IVOL	Mean	8.21	11.48	9.96	9.23	8.74	2.32	2.41
	Std.Dev	4.26	6.62	6.33	6.51	5.35	0.87	0.9
	Q1	5.22	7.19	5.88	5.1	5.26	1.71	1.78
	Medium	7.36	10.08	8.51	7.6	7.6	2.23	2.29
	Q3	10.11	14.26	12.19	11.34	10.68	2.83	2.92
	Jarque-Ber	3006.82***	32217***	35847.9***	81050***	55387.1***	389.04***	1167.1***

Ps. *10% **5% ***1% significant

Appendix 2:Threshold regression model of each period

Period	Threshold value	Threshold regression model
1994-2013	9.2998; 13.1409; 18.1312.	$R_{it}=u_{it}+1.3097IVOL_{it}I(q_{it}\le 9.2998)+2.1323IVOL_{it}I(9.2998<q_{it}\le 13.1409)+3.8355IVOL_{it}I(13.1409\le q_{it}\le 18.1312)$ $+3.0971IVOL_{it}I(q_{it}>18.1312)+8.9478Lnme_{it}-19.5304Lnbeme_{it}-1.1171Lnturn_{it}-6.1631Lnda_{it}+0.6120Beta_{it}+e_{it}$
1994-1998	8.2245; 12.8560; 14.5640.	$R_{it}=u_{it}+3.3046IVOL_{it}I(q_{it}\le 8.2245)+2.2308IVOL_{it}I(8.2245<q_{it}\le 12.8560)+3.5064IVOL_{it}I(12.8560<q_{it}\le 14.5640)$ $+2.4602IVOL_{it}I(q_{it}>14.5640)+25.7833Lnme_{it}-45.6101Lnbeme_{it}-1.7421Lnturn_{it}+4.4983Lnda_{it}+0.5121Beta_{it}+e_{it}$
1999-2003	5.8740; 9.0165; 13.1951.	$R_{it}=u_{it}-1.3933IVOL_{it}I(q_{it}\le 5.8740)-0.0509IVOL_{it}I(5.8740<q_{it}\le 9.0165)+1.7313IVOL_{it}I(9.0165\le q_{it}\le 13.1951)$ $+3.4128IVOL_{it}I(q_{it}>13.1951)+15.5492Lnme_{it}-52.8508Lnbeme_{it}+6.4336Lnturn_{it}+15.5520Lnda_{it}+0.2020Beta_{it}+e_{it}$
2004-2008	6.4055; 8.0271; 21.1100.	$R_{it}=u_{it}+6.1199IVOL_{it}I(q_{it}\le 6.4055)+4.2307IVOL_{it}I(6.4055<q_{it}\le 8.0271)+3.2918IVOL_{it}I(8.0271\le q_{it}\le 21.1100)$ $+3.8210IVOL_{it}I(q_{it}>21.1100)+4.9378Lnme_{it}-66.3799Lnbeme_{it}-0.6964Lnturn_{it}-8.8158Lnda_{it}+0.3931Beta_{it}+e_{it}$
2009-2013	8.9445; 12.4963; 21.0306.	$R_{it}=u_{it}+2.4780IVOL_{it}I(q_{it}\le 8.9445)+3.7416IVOL_{it}I(8.9445<q_{it}\le 12.4963)+5.3933IVOL_{it}I(12.4963\le q_{it}\le 21.0306)$ $+4.5479IVOL_{it}I(q_{it}>21.0306)+33.7059Lnme_{it}-45.9237Lnbeme_{it}-8.7665Lnturn_{it}-7.2498Lnda_{it}+0.8277Beta_{it}+e_{it}$
2000/7-12	1.6900; 3.0765; 3.8092.	$R_{it}=u_{it}-0.5681IVOL_{it}I(q_{it}\le 1.6900)+1.0661IVOL_{it}I(1.6900<q_{it}\le 3.0765)+1.8307IVOL_{it}I(3.0765<q_{it}\le 3.8092)$ $+2.4642IVOL_{it}I(q_{it}>3.8092)+31.8639Lnme_{it}+4.2787Lnbeme_{it}-1.3764Lnturn_{it}+0.1812Beta_{it}+e_{it}$
2008/7-12	2.7994; 2.9055; 3.3474.	$R_{it}=u_{it}+1.4572IVOL_{it}I(q_{it}\le 2.7994)+2.6926IVOL_{it}I(2.7994<q_{it}\le 2.9055)+1.9818IVOL_{it}I(2.9055\le q_{it}\le 3.3474)$ $+2.8405IVOL_{it}I(q_{it}>3.3474)-23.3606Lnme_{it}-35.8693Lnbeme_{it}+1.0432Lnturn_{it}+0.8704Beta_{it}+e_{it}$

Appendix 3:Threshold effect testing andThreshold parameters estimation

1. 20-year

(1) 1994-2013

Table A1: Threshold effect testing(1994-2013)

Threshold effecttesting	Single	Double	Triple
Threshold value	13.1409	18.1312	9.2998
F value	48.6419	17.2967	9.0109
P value	0.0000***	0.0000***	0.0000***
The critical value of F			
10%	2.7909	2.3440	3.0201
5%	4.1473	3.5416	4.2599
1%	8.7372	5.0438	6.0393

Ps. *10% **5% ***1% significant

Table A2: Threshold parameters estimation (1994-2013)

Regressor	Coef	Std	t	prob
Lnme	8.9478	1.6236	5.5111	0
Lnbeme	-19.5304	1.775	-11.0029	0
Lnturn	-1.1171	0.9682	-1.1538	0.2487
Lnda	-6.1631	2.4351	-2.5309	0.0114
Beta	0.612	0.0209	29.2568	0
IVOL(qi≤9.2998)	1.3097	0.481	2.723	0.0065
IVOL(9.2998<qi≤13.1409)	2.1323	0.3259	6.5438	0
IVOL(13.1409 <qi≤18.1312)	3.8355	0.2672	14.353	0
IVOL(qi>18.1312)	3.0971	0.1845	16.7842	0

2. 5-year

(1)1994-1998

Table A3: Threshold effect testing (1994-1998)

Threshold effect testing	Single	Double	Triple
Threshold value	12.8560	14.5640	8.2245
F value	6.4398	4.1870	6.3631
P value	0.0000***	0.0333**	0.0067***
The critical value of F			
10%	2.7979	2.9222	2.7875
5%	3.4583	3.6256	3.6326
1%	5.7927	7.7808	6.1206

Ps. *10% **5% ***1% significant

Table A4: Threshold parameters estimation (1994-1998)

Regressor	Coef	Std	t	prob
Lnme	25.7833	3.7065	6.9562	0
Lnbeme	-45.6101	3.6605	-12.4601	0
Lnturn	-1.7421	1.598	-1.0902	0.276
Lnda	4.4983	4.5134	0.9967	0.3192
Beta	0.5121	0.0398	12.873	0
IVOL(qi≤8.2245)	3.3046	0.8253	4.0039	0.0001
IVOL(8.2245≤qi≤12.8560)	2.2308	0.5191	4.2974	0
IVOL(12.8560 ≤qi≤14.5640)	3.5064	0.5147	6.8126	0
IVOL(qi>14.5640)	2.4602	0.3277	7.5071	0

(2)1999-2003

Table A5: Threshold effect testing (1999-2003)

Threshold effect testing	Single	Double	Triple
Threshold value	5.8740	13.1951	9.0165
F value	20.5813	21.5637	6.5707
P value	0.0000***	0.0000***	0.0100***
The critical value of F			
10%	3.2833	-7.3831	2.9082
5%	4.5852	-5.5137	3.8581
1%	6.6795	-1.7197	6.3614

Ps. *10% **5% ***1% significant

Table A6: Threshold parameters estimation (1999-2003)

Regressor	Coef	Std	t	prob
Lnme	15.5492	5.1081	3.044	0.0024
Lnbeme	-52.8508	5.0572	-10.4506	0
Lnturn	6.4336	2.0771	3.0974	0.002
Lnda	15.552	6.9201	2.2473	0.0247
Beta	0.202	0.0332	6.0909	0
IVOL(qi≤5.8740)	-1.3933	1.0266	-1.3571	0.1749
IVOL(5.8740 ≤qi<9.0165)	-0.0509	0.6737	-0.0756	0.9398
IVOL(9.0165≤qi<13.1951)	1.7313	0.4658	3.7168	0.0002
IVOL(qi>13.1951)	3.4128	0.3057	11.1655	0

(3)2004-2008

Table A7: Threshold effect testing (2004-2008)

Threshold effect testing	Single	Double	Triple
Threshold value	6.4055	21.1100	8.0271
F value	21.2192	9.3754	7.2867
P value	0.0000***	0.0033***	0.0000***
The critical value of F			
10%	2.8492	-2.2731	-1.3734
5%	4.5028	0.1783	-0.2963
1%	8.9281	3.3123	2.7381

Ps. *10% **5% ***1% significant

Table A8: Threshold parameters estimation (2004-2008)

Regressor	Coef	Std	t	prob
Lnme	4.9378	3.7226	1.3264	0.1848
Lnbeme	-66.3799	4.0085	-16.56	0
Lnturn	-0.6964	1.4569	-0.478	0.6327
Lnda	-8.8158	3.9701	-2.2206	0.0264
Beta	0.3931	0.0328	11.9691	0
IVOL(qi≤6.4055)	6.1199	0.961	6.3686	0
IVOL(6.4055 <qi≤8.0271)	4.2307	0.6541	6.4685	0
IVOL(8.0271 <qi≤21.1100)	3.2918	0.3544	9.288	0
IVOL(qi>21.1100)	3.821	0.2128	17.952	0

(4)2009-2013

Table A9: Threshold effect testing (2009-2013)

Threshold effect testing	Single	Double	Triple
Threshold value	12.4963	8.9445	21.0306
F value	36.4706	17.4098	17.6895
P value	0.0000***	0.0000***	0.0000***
The critical value of F			
10%	2.6774	-10.5751	-25.8037
5%	3.6905	-8.5624	-20.4399
1%	8.0277	-1.8492	-14.9792

Ps. *10% **5% ***1% significant

Table A10: Threshold parameters estimation (2009-2013)

Regressor	Coef	Std	t	prob
Lnme	33.7059	3.5893	9.3907	0
Lnbeme	-45.9237	3.781	-12.146	0
Lnturn	-8.7665	1.4436	-6.0725	0
Lnda	-7.2498	3.9234	-1.8478	0.0647
Beta	0.8277	0.0191	43.3587	0
IVOL(qi≤8.9445)	2.478	0.621	3.9903	0.0001
IVOL(8.9445 ≤qi<12.4963)	3.7416	0.403	9.2851	0
IVOL(12.4963 ≤qi<21.0306)	5.3933	0.3201	16.8471	0
IVOL(qi>21.0306)	4.5479	0.2058	22.0979	0

3. Specific period

(1)Internet bubble (2000/4-2000/9)

Table A11: Threshold effect testing

Threshold effect testing	Single	Double	Triple
Threshold value	3.0765	1.6900	3.8092
F value	5.1900	7.1447	5.0641
P value	0.0367**	0.0033***	0.0267**
The critical value of F			
10%	2.9044	2.8189	1.0853
5%	4.7328	3.4185	3.4008
1%	7.5806	6.1269	8.5577

Ps. *10% **5% ***1% significant

Table A12: Threshold parameters estimation

Regressor	Coef	Std	t	prob
Lnme	31.8639	2.8126	11.3289	0
Lnbeme	4.2787	2.4445	1.7503	0.0802
Lnturn	-1.3764	0.4658	-2.9547	0.0032
Lnda	0	0	.	.
Beta	0.1812	0.0305	5.9302	0
IVOL(qi≤1.6900)	-0.5681	1.0659	-0.5329	0.5941
IVOL(1.6900 <qi≤3.0765)	1.0661	0.6615	1.6118	0.1071
IVOL(3.0765 <qi≤3.8092)	1.8307	0.5318	3.4427	0.0006
IVOL(qi>3.8092)	2.4642	0.469	5.2547	0

(2)Financial crisis (2008/7-2008/12)

Table A13: Threshold effect testing

Threshold effect testing	Single	Double	Triple
Threshold value	2.7994	3.3474	2.9055
F value	22.0338	11.8360	5.1558
P value	0.0000***	0.0000***	0.0300**
The critical value of F			
10%	2.8249	2.4265	2.5003
5%	3.4924	3.5413	4.2329
1%	6.1503	7.1129	6.5113

Ps. *10% **5% ***1% significant

Table A14: Threshold parameters estimation (2008/7~2008/12)

Regressor	Coef	Std	t	prob
Lnme	-23.3606	2.4121	-9.6849	0
Lnbeme	-35.8693	2.456	-14.6049	0
Lnturn	1.0432	0.3708	2.813	0.0049
Lnda	0	0	.	.
Beta	0.8704	0.0155	56.2005	0
IVOL(qi≤2.7994)	1.4572	0.4444	3.2792	0.001
IVOL(2.7994 <qi≤2.9055)	2.6926	0.4371	6.1605	0
IVOL(2.9055 <qi≤3.3474)	1.9818	0.3571	5.5502	0
IVOL(qi>3.3474)	2.8405	0.2847	9.976	0

Appendix 4: Likelihood Ratio Trend Graph

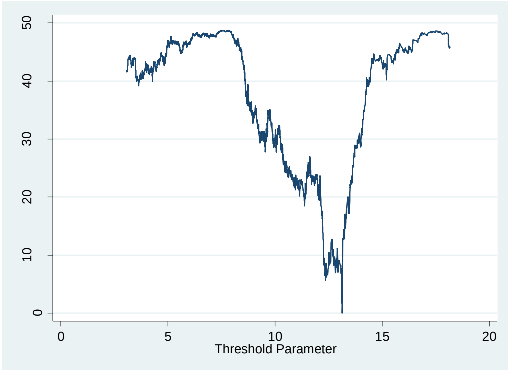
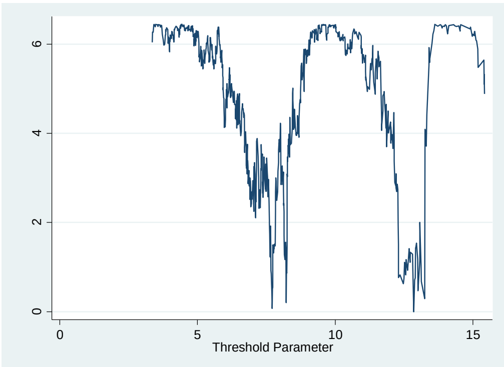


Figure A1: 1994-2013



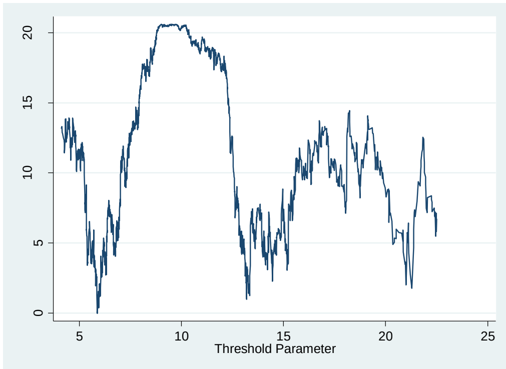
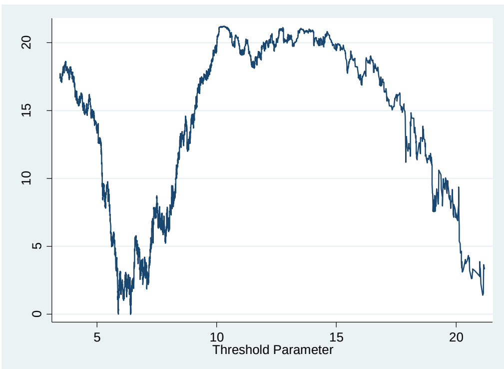


Figure A2: 1994-1998

Figure A3:1999-2003 年



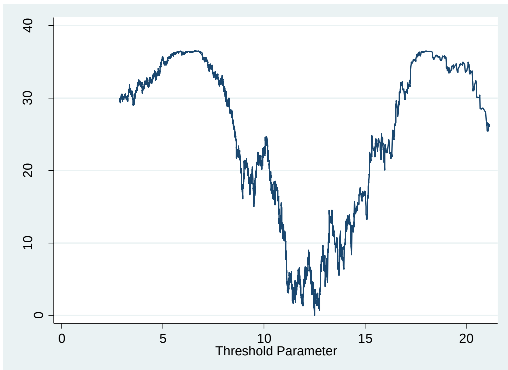
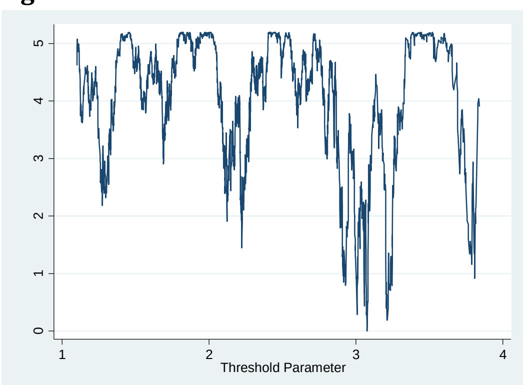


Figure A4: 2004-2008

Figure A5: 2009-2013



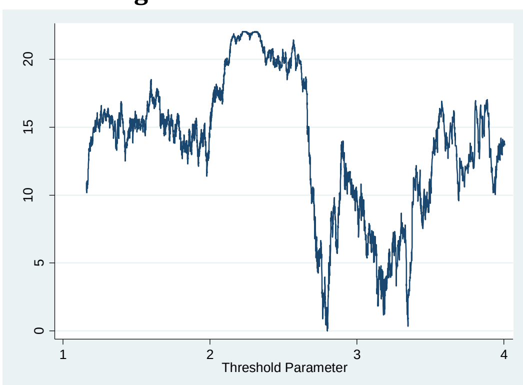


Figure A6:2000/4-2000/9

Figure A7:2008/7-2008/12