Non-Linear Taylor Rule through Threshold Estimation

Bhaduri, Saumitra and Sethudurai, Raja

Madras School of Economics

8 March 2013

A Note on the Empirical Test of Herding: A Threshold Regression Approach

Abstract:

The paper applies a threshold regression model developed by Hansen [2000] to standard herding model in order to capture a non-linear effect of extreme market movement on the trading behaviour of the participants. Using the model with threshold effect, the paper finds little evidence for market-wide herding for the Indian equity market.

1. Introduction:

The efficient market hypothesis assumes that investors form rational expectations of future prices and discount all market information into expected prices. However, these rationality assumptions underpinning the efficient market hypothesis are often challenged in reality as the observed stock markets display "herd behaviour" wherein group of individuals act to imitate the decisions of others or market without paying any attention to their own belief or information[1].

Barring a few exception, most of the empirical models of herding are based on Christie and Huang (1995) (hereafter referred to as CH) and Chang et al. (2000) (hereafter referred to as CCK) model which uses the cross sectional standard deviation (CSSD) and cross sectional absolute standard deviation (CSAD) across stock returns as a measure of average proximity of individual returns to the realized market return[2]. CH and CCK focus their analysis of herding for periods of extreme market movements, as they argue that traders are more likely to herd at times of heightened uncertainty and extreme market turbulence.[3,4]

---

[1] Bhikchandani and Sharma, 1992, Scharfstein and Stein, 1990 and Devenow and Welch, 1996, Chan, Cheng and Khornana 2000, Hwang and Salmon, 2004 and Demirer and Kutan, 2006, Gleason, Mathur and Peterson, 2004, Weiner and Green, 2004 Wermers, 1999.

[2] Hwang and Salmon (2004) have used other measure of herding such as cross-sectional dispersion of the factor sensitivity of assets within a given market.

[3] However, herd behavior may be present when markets are quiet, because during these times the role of the market portfolio may be replaced by other factors that serve as herding objectives (Hwang and Salmon, 2004).

Most of the empirical models of herding use the rational asset- pricing model (CAPM) to arrive at a test for herding under extreme market conditions. These models postulate that under herding individual returns will converge to the aggregate market return under extreme condition resulting in decreased dispersion of individual returns from the market return.

Therefore, empirically, herding is tested during the trading intervals characterized by large swings in average prices, in which a lower than expected level of cross sectional variation would indicate herding. Though the theoretical model provides robust conclusions, most of the empirical models using this approach suffer from the subjectivity involved in defining the extreme market movements. Therefore, the goal of this paper is to address this limitation by applying a threshold model which addresses this issue. The paper applies threshold regression method developed by Hansen [2000] to standard CSAD regressions to capture a non-linear effect of extreme market movement on the investor behaviour.

The remainder of the paper is organized as follows: Section two presents the methodology proposed in the paper to test the herding behaviour in the stock market. Section 3 describes the data while section 4 reports the empirical results .Section five concludes the paper.

---

[4] The cross-sectional standard deviation (CSSD) is expressed as:

$$CSSD_t = \sqrt{\frac{\sum_{i=1}^{N}(R_{i,t} - R_{m,t})^2}{(N-1)}}$$

While the cross-sectional absolute deviation is expressed as:

$$CSAD_t = \frac{1}{N}\sum_{i=1}^{N}\left|R_{i,t} - R_{m,t}\right|$$

N is the no. of firms in the portfolio. $R_{i,t}$ Is the observed stock return of firm i at time t. $R_{m,t}$ Is the cross-sectional average stock of N returns in the portfolio at time t.

2. The Empirical model and testing procedure:

Rational asset pricing models and herding behavior propose distinct predictions regarding the behavior of the cross-sectional standard deviation of returns during periods of markets stress. Rational asset pricing models predict that during extreme market movements, large changes in the absolute value of the market return translate into an increase in dispersion due to the differing sensitivities of individual securities to the market return. In contrast, the herding behavior suggests that dispersions would reduce in presence of large market movements. Conventionally, the test for herding, or alternatively for rational asset pricing, uses the following empirical specification:

$$CSSD_t = \alpha + \beta^L D_t^L + \beta_t^U D_t^U + \varepsilon_t$$

where the CSSD is cross-sectional standard deviation at time *t*, and is defined as

$$CSSD_t = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(r_{it} - r_{mt})^2}$$

and D^L=1 if the market return on day *t* lies in the extreme lower tail of the distribution and zero otherwise; D^U=1 if the market return on day *t* lies in the extreme upper tail of the return distribution and zero otherwise.

The dummy variables act to capture differences in investor behavior during extreme up or down versus relatively normal markets. Therefore, the significantly negative coefficients on dummies would indicate herd behaviour. Typically extreme market movements are defined arbitrarily as consisting of the upper and lower 1%, 2% and 5% tails of the market distribution.

However, to avoid the subjective definition of extreme behaviour and also to account for non-normality of returns and the fat tails of return distributions that affect standard deviation metrics more than they affect absolute deviation measures, CCK proposes an alternate model to identify herding. The CCK model predicts that market participants are more likely to herd during market stress, as characterized by periods of large price movements. Thus, one would expect a less than proportional increase in $CSAD_t$ for extreme values of return (R_{mt}).

$$CSAD_t = \alpha + \gamma_1 \mid R_{mt} \mid + \gamma_2 R_{mt}^2 + \varepsilon_t$$

The coefficient γ_2 captures the non-linear relationship that may exist between $CSAD_t$ and R_{mt}.

In contrast to the conventional approach we apply a threshold regression method developed by Hansen [2000] to standard CSAD regressions, in order to capture a non-linear effect of extreme market movement on the herding behaviour. The threshold model allows splitting up of the sample into different regimes and tests the herding for each of these regimes respectively. Further, the paper also tests herding in up-market and down-markets conditions separately, where the down-market (up-market) is defined as comprising all observations for which the return is less than zero (greater than zero). This specification allows us to capture potential asymmetries in the herding behaviour.

We test the null hypothesis of a linear regression against a threshold model as follows.

$$CSAD_t = \beta_1^{'} \mid R_{mt} \mid + u_t \qquad q_t \le \gamma \qquad (1)$$
$$CSAD_t = \beta_2^{'} \mid R_{mt} \mid + u_t \qquad q_t > \gamma \qquad (2)$$

Where $CSAD_t$ and q_t are the dependent variable and the threshold variable respectively, while $|R_{mt}|$ is the independent variable capturing the absolute market return. The threshold variable, which is $|R_{mt}|$ in our model, is used to split up the sample into two groups called "regimes". The model allows the regression parameters to differ depending on the value of q. The random variable u_t is the regression error.

The model (1)-(2) can be written in a single equation form with the introduction of the dummy variable d_t=I ($|R_{mt}|\le\gamma$) where I (•) denotes the indicator function. If we set the variable $|R_{mt}(\gamma)|=|R_{mt}|.d_t$, then equations (1)-(2) are equal to

$$CSAD_t = \beta^{'} \mid R_{mt} \mid + \theta \mid R_{mt}(\gamma) \mid + u_t \qquad (3)$$

where $\beta=\beta_2$ and $\theta=\beta_1-\beta_2$.

Equation (3) allows all regression parameters to differ between the two regimes. Hansen [2000] develops an algorithm based on a sequential OLS estimation which searches over all values $\gamma=q_{\{t\}}$ t=1,...,T. The procedure also provides estimates of β and θ. The null hypothesis of rational asset pricing model is captured as $\beta_1>\beta_2>0$ against the alternative of herding behaviour as $\beta_2<\beta_1$. A heteroskedasticity-consistent F-test bootstrap procedure is used to test the null of linearity. Since the threshold value is not identified under the null, the p-values are computed by a fixed bootstrap method. The independent variables are supposed to be fixed, and the dependent variable is generated by a bootstrap from the distribution N(0, e_t)) where e_t is the OLS residual from the estimated threshold model. Hansen [2000] shows this procedure yields asymptotically correct p-values. Therefore, if the hypothesis of linearity is rejected with $\beta_1=\beta_2$, one can split the original sample according to the estimated threshold value and further test for herding using the restriction $\beta_2 < \beta_1$.

3. Data and Sample

Christie and Huang (1995) argued that the herding behavior is often a short-term phenomenon and can only be captured with a high frequency data. Further, Tan et al (2008) while analyzing herding behavior in the Chinese stock market also concluded that the level of herding is more pronounced using daily data than using weekly and monthly data. Therefore, following the existing literature the paper uses daily stock price data to test herding behaviour for the Indian equity market.

The daily data on stock prices, market capitalization for all firms listed on BSE-500 has been collected over the period from January 1, 2003 to 31 March, 2008, constituting 1301 observations[5].

[5] Though the number of observations in 2008 is only 61, we still include this year in order to capture the recent stock market crash.

Since, there have been new firms included in BSE-500 in the sample period for which only partial data was available we have considered a consistent set of firms in our analysis leading to a balanced sample of 349 firms. The data is obtained from Capitaline database. The stock return for all firms is calculated as $R_t = 100 * (\log(P_t) - \log(P_{t-1}))$.

Table 1 contains summary statistics for average daily return for BSE 349 companies. In 2008, the mean value of average daily return is in negative and has a higher standard deviation which confirms the then turbulence in the Indian Market. The minimum average daily return for the total sample (-5.101%) also occurs on 21st January 2008. The second lowest minimum average daily return (-4.734%) was on 17th May 2004 when SENSEX slumped by 842 points due to political uncertainty in the domestic market as National Democratic Alliance government went out of power. The average daily return for the entire sample is 0.06% with a characteristic negative skewness observed in the return data.

4. Empirical Results:

Table 2 shows the results of global OLS regressions of standard CSAD model and test for a threshold effect. Using 1000 bootstrap replications, the *p*-value for the threshold model using $|R_{mt}|$ is significant at 0.001 suggesting a possible sample split based on $|R_{mt}|$. Figure 1 displays a graph of the normalized likelihood ratio sequence *LR*(n)* as a function of the threshold. The LS estimate of γ is the value that minimizes this graph, which occurs at 1.413%. The 95% critical value is also plotted in Figure 2 and the asymptotic 95% confidence interval can be considered as between 0.458% and 1.433%. Therefore, the results show that there are reasonable evidences for a two-regime and nonlinear effect in CSAD[6].

[6] It is important to note that the data does not support any higher level of split and does not generate any threshold effect with lag values of absolute market return.

Table 1: Summary Statistics: Average Daily Return (BSE 349 companies)

	Observations	Mean	Standard Deviation	Minimum	Maximum	Skewness
2003	253	0.152	0.582	-1.626	1.822	-0.289
2004	254	0.057	0.763	-4.734	2.635	-1.662
2005	251	0.092	0.499	-2.355	1.475	-0.969
2006	250	0.050	0.709	-3.311	2.305	-1.361
2007	249	0.083	0.556	-2.207	1.591	-1.106
2008	61	-0.314	1.374	-5.101	3.036	-0.575
Total	**1317**	**0.068**	**0.687**	**-5.101**	**3.036**	**-1.406**

Table 2: Global OLS Estimation, Without Threshold

Dependent Variable (CSAD)	Estimate	Standard Error
Constant	0.719579	0.00745
$\lvert R_{mt} \rvert$	0.295904	0.013674
R^2	0.35	

Note: The null of no threshold is rejected at 1% level. The heteroskedasticity correction used for SE

Figure 1: F-test for testing the null of linearity against a threshold specification using $\lvert R_{mt} \rvert$ as threshold variable.

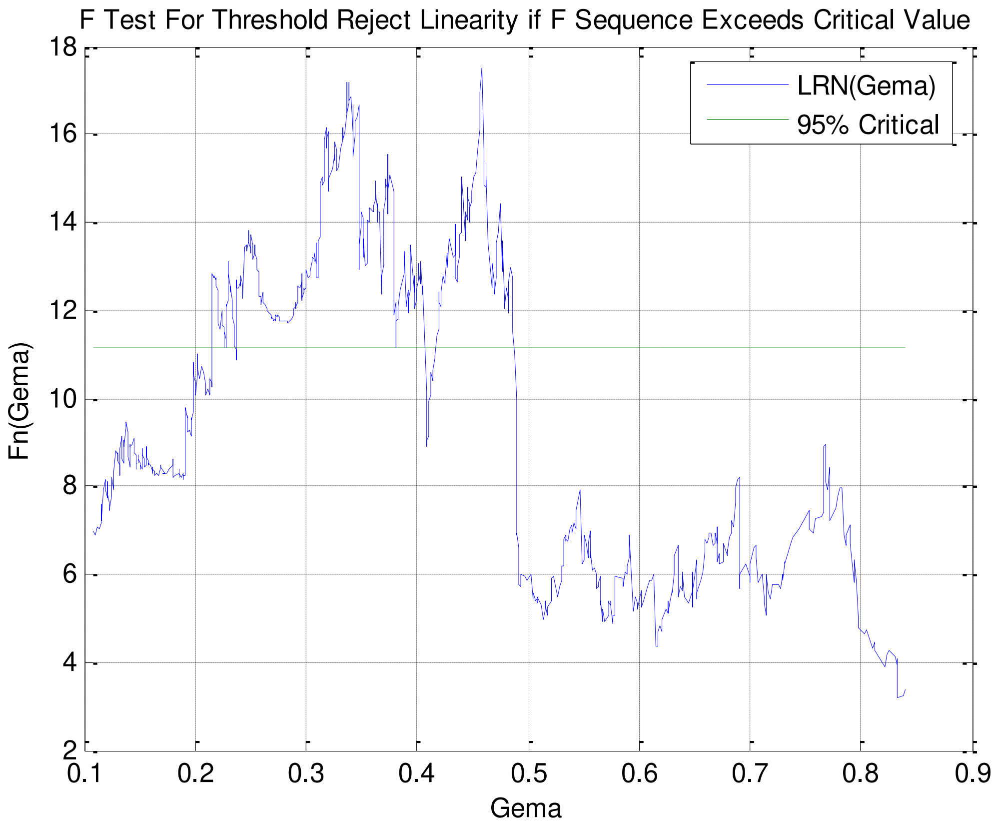
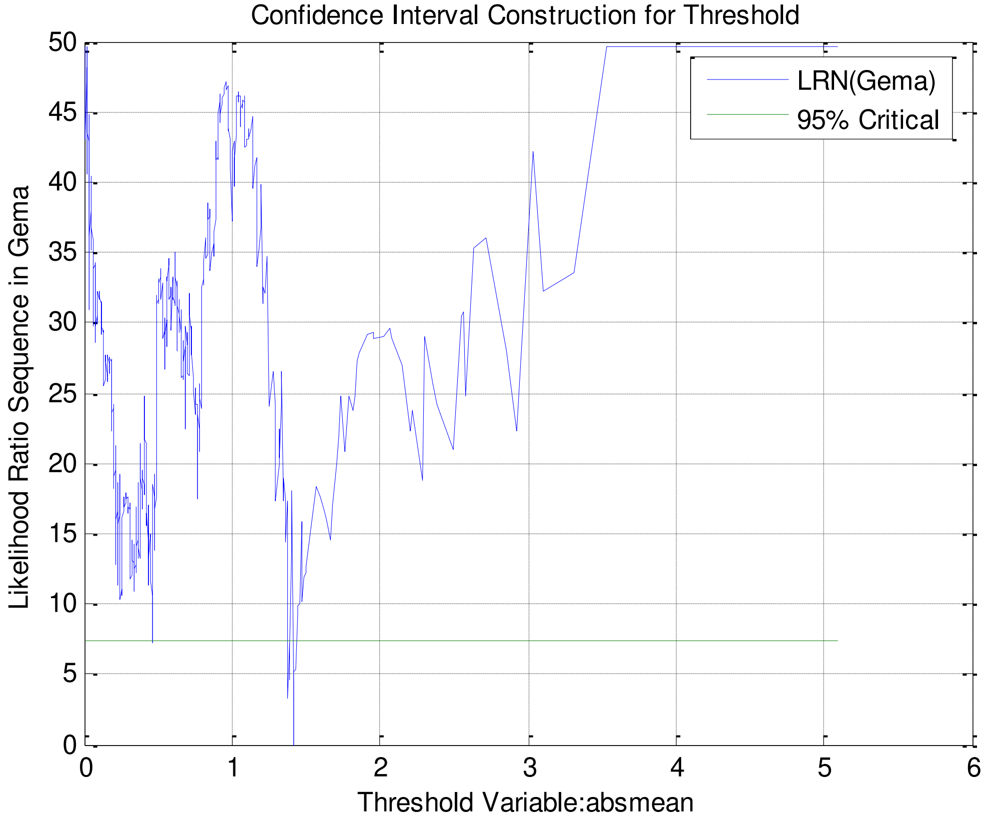


Figure 2: Sample split: Confidence interval construction for the threshold.



Fixing γ at the LS estimate of $|Rmt|$ at 1.413% we split the sample in two regimes where distribution of observations in *normal* ($|Rmt| < 1.413\%$) and *extreme market* movements ($|Rmt| > 1.413\%$) is 95.93% and 4.07% respectively. It is important to note that the extreme tail of the return distribution contains 4% data which is consistent with CH specification of extreme events. Further, the extreme market returns are 23.5 time higher than that of an average daily return of 0.06%.

The coefficient of the absolute market return, as reported in table 3, is positive and significant, indicating that CSAD increases with the absolute market return suggesting that the Indian traders actually trade away from the market consensus during the periods of market stress. In other words, the null hypothesis of rational asset- pricing model, i.e., $\beta_1 > \beta_2 > 0$, is accepted at 1% level.

Table 3: Regression Estimation with the CSAD as dependent variable.

	Overall	Threshold	
		<=1.413200	>1.413200
$\lvert R_{mt} \rvert$	0.295904*	0.302667*	0.409984*
Sample Size	1301	1248	53
R^2		0.18	0.70

* Bootstrap p values indicate significance at 1% level.

Table 4 explores the potential asymmetries in the herding behaviour. We test herding for both extreme up-market and down-markets conditions, where the down-market (up-market) is defined as comprising all observations for which the return is less than zero (greater than zero). The result reported in table 4 shows a threshold effect in up market while we do not observe a similar effect during the down market movements.

Regression result presented in table 4 provides strong support for the rational asset- pricing prediction corroborating that there is a positive relationship between CSAD and the absolute market return and specifically the level of dispersion increases at the tail of the market return distribution.

Therefore, the result presented in the paper conforms to the predictions of the rational asset-pricing model as against herding as the dispersions in returns in the Indian equity market increase when the market is subject to greater levels of stress. To check the robustness of the empirical result presented in the paper several alternative specifications have been tested including the standard CCK model with R^2_{mt} and volume as additional explanatory variables. However, most of these unreported exercises corroborate the basic findings of the paper.

Table 4: Regression Estimation with the CSAD as dependent variable.

	Up market (Overall)	Threshold		Down Market (Overall)	Threshold	
		<=0.230213	>0.230213		<=1.504560	>1.504560
$\lvert R_{mt} \rvert$	0.352536*	0.196715	0.430753*	0.269502*	0.26766	0.418527*
Bootstrap P value for Threshold effect	0.0000*			0.821		
Sample Size	744	214	530	557	527	30

* Bootstrap p values indicate significance at 1% level.

5. Conclusion:

The paper investigates herding behaviour in the India equity market by applying a threshold model developed by Hansen [2000]. The results presented in this paper show that the threshold specification does capture the non-linear effect of extreme market movements on the trading behaviour of the participants. However, the threshold effect provides no evidence for market-wide herding in the Indian equity market. Even in the extreme market conditions, participants appear to discriminate between different securities, as predicted by the rational asset pricing paradigm.

References

Bikhchandani S., Sunil. S. (2000). Herd Behavior in Financial Markets . *IMF Working Paper WP/00/48.*

Chang, E.C., Cheng, J.W., Khorana, A., (2000), "An Examination of Herd Behavior in Equity Markets: An International Perspective", Journal of Banking and Finance 24, 1651-1679.

Christie, W. G., and Huang, R. D., (1995), "Following the pied piper: Do individual returns herd around the market? *Financial Analyst Journal*, Vol. 51 (4), pp. 31-37.

Demirer, R. and Kutan, A. M., (2006), "Does herding behavior exist in Chinese stock market?" *Journal of International Financial Markets, Institutions and Money*, **16**, 123-142.

Devenow, A., Welch, I., (1996), "Rational herding in financial economics", European Economic Review 40, 603–615.

Gleason, K.C., Mathur, I, Peterson, M.A., 2004, Analysis of Intraday Herding Behavior among the Sector ETFs, Journal of Empirical Finance 11, 681-694.

Goetzman, W. (1995). "Discussion: On Fads, Crashes and Asymmetric Information," in Richard Sylla and Mike Bordo, Eds. Anglo-American Finance Systems: Institutions and Markets in the 20th Century, Irwin Publishers, 1995.

Hansen B. (2000) "Sample splitting and threshold estimation", *Econometrica*, vol 69, No 1555-1596..

Hong, H., Kubik, J. D., Solomon, A., (2000), "Security Analysts' Career Concerns and Herding of Earnings Forecasts", RAND Journal of Economics 31, 121–144.

Hwang, S., and Salmon, M., (2004), "Market stress and herding," *Journal of Empirical Finance,* Vol. 11, pp.585-616.

Nofsinger, J.R., and R.W. Sias (2002). "Herding and Feedback Trading by Institutional and Individual Investors", Journal of Finance, 54, 2263-2295.

Tan, Lin, Chiang, Thomas C. & Mason, Joseph R. & Nelling, Edward, 2008. "Herding behavior in Chinese stock markets: An examination of A and B shares," *Pacific-Basin Finance Journal*, Elsevier, vol. 16(1-2), pages 61-77, January.

Scharfstein, D.S., Stein, J.C., (1990), Herd Behavior and Investment, American Economic Review 80, 465-479.

Wermers, R., (1999), Mutual Fund Herding and the Impact on Stock Prices, Journal of Finance 54, 581-622.

Weiner, R. J., and Green, M. A., (2004) “Do birds of a feather flock together? Speculator herding in dervatives markets,” *Working Paper* George Washington University