In Search of Prudential Leverage Regulation Regimes

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Abstract. In year 2009, Thurner, Farmer and Geanakoplos construct an agent-based model of leverage asset purchases with margin calls. The interesting research shows that leverage could cause fat tails and clustered volatility. In this paper, we study the effects of leverage regulation regimes on financial markets based on their model, by introducing two types of leverage regulation policy: risk-based policy and incentive-based policy. Besides examining fat tails and clustered volatility stylized facts, we analyze macroeconomic indicators such as bankruptcy ratio, total social wealth and the efficiency of banking system for identifying prudential leverage regulation regimes.

Keywords: leverage regulation, risk-based policy, incentive-based policy.

1 Introduction

In recent years, the financial crisis has engendered lots of debates on the prudential regulation of bank leverage, since the 2007 financial crisis was blamed in part on excessive leverage. Michael Simkovic(2009)[1]explains that hidden leverage is the root of financial crises in one of the oldest and most fundamental problems of commercial law. Leverage is used usually in investments or corporate finance, which means using debt to finance an activity. It is a general term of risk evaluation is measured as the ratio of total assets owned to the wealth of the borrowers. Is it necessarily to regulate leverage? How to regulate leverage effectively to benefit financial market? In this paper, we examine leverage regulation effects on financial market from the view of banks' local control strategies.

The existing literature on leverage can be divided into three strands.

1. Impact analysis. These papers mainly discuss the consequence of using leverage. Fostel and Geanakoplos(2008)[2]show that leverage cycles can cause contagion and financial crisis in an anxious economy through providing a pricing theory for emerging asset classes. Thurner, Farmer and Geanakoplos (2009) [3]construct an agent-based model of leverage asset purchases with margin calls. The research shows that leverage causes fat tails and clustered volatility and causes financial crisis under special conditions. Feldman(2010)[4]reveals that the portfolio managers taking on excessive leverage when they become risk averse

K. Glass et al. (Eds.): COMPLEX 2012, LNICST 126, pp. 325–338, 2013.

could create harder hit global crisis. Above researches support the viewpoint that it is imperative to regulate the leverage.

2. Leverage computation. Friedman and Abraham(2009)[5]compute leverage in response to the payoff gradient and study the equilibrium and dynamics. Peters(2009)[6]analyzes the optimal leverage for self-financing portfolios by considering time-irreversibility and non-ergodicity. These methods try to explore a reasonable or optimal leverage from the view of borrowers for maximizing their return, not from the side of lenders (such as banks).

3. Leverage regulation. It is important for financial institution and government since excessive leverage can cause crisis of a country or even the whole world. Leverage regulation involves two questions: when and how to regulate. Hodas, Tagliabue, Schmidt and Barofsky(2009)[7] build a model on the work of Thurner, Farmer and Geanakoplos, they present an economy consisting of a banking sector and an equity market,with traders transferring money between the two. Their research mainly analyzes the banks behaviours and set the leverage on the basis of banks balance sheet. Feldman(2011)[8]uses an agent based model to find that regulating leverage by using margin calls could lead to less but harder financial crisis hits. Feldman compares four regulatory regimes: no regulation, fixed leverage, the amount of risky asset limiting and constrained based on detrended price. None of them considers funds' performance. Christensen, Meh and Moran(2011) [9], Raberto, Teglio and Cincotti(2012)[10] focus on stduying banking regulation. The former paper finds that countercyclical bank leverage reguation is likely to stabilize the economy and there exists strong interations between monetary policy and bank regulation policy. The latter shows that the dynamic regulation of capital requirements is more effective than fixed tight one.

While, the purpose of this paper is to focus on bank's leverage strategies. We introduce a framework for examining the effects of banks' leverage regulation policies by using an agent-based financial market model constructed by Thurner, Farmer and Geanakoplos (2009)[3] in which leverage is allowed. We explore a variety of banks' leverage regulation regimes that adjust each fund's leverage level dynamically based on their performance or market volatilities, and try to search prudential leverage regulation regimes which could reduce excessive volatility, the damage of defaults and stabilize the financial market. In the finanial makert model of Thurner et al., there are two types of traders in the model: noise trader and hedge funds. Hedge funds are value investing and can borrow from a bank under leverage. The loan is a collateralized one in which the debt is guaranteed by an asset. The asset price is determined through market clearing mechanism, i.e. the equilibrium between the market demand and supply. A rational investor will buy assets at a low price and sell at a at a high price. But a fund with collateralized loan may be forced to sell as the value of the collateralized asset falls. When a group of fundsselling occurs together,it may cause defaults or crashes.When a fund invest with borrowed money, it can potentially earn more due to larger scale of investment, but also can lose more because of default. That is to say, leverage can magnify the expected revenue, but also cause bankruptcy of hedge funds. Therefore the using of leverage is followed with risk. Especially, this risk can be much more complex as that the financial market is unstable and the financial derivatives are expanding rapidly. In addition, the banks may face expanding risk for the bad debt that the funds bankruptcies bring about. To maintain safety itself and keep profit, a bank has to limit the borrowing, i.e. setting a reasonable leverage limit. The banks leverage policy has great influence on financial market. If the leverage is over high, then there are more bankruptcies. If leverage is too low, the market is less flexible. Intuitively, a bank sets leverage on the basis of funds' performance and market volatility. Banks evaluate funds' performance by their revenue, and assess risk based on the fluctuations in prices. Thurner et al.(2009) consider banks' leverage regulation according to market volatility. But for all the funds, they use the same leverage level. We argue that homogeneous leverage can make the high-risk funds to borrow excessively, even cause defaults.

In this paper, we explore leverage regulation regimes of banks in three main perspectives. The first one is Homogenous or heterogeneous policy. All the funds have the same leverage under the homogenous policy, but each fund has its own individual leverage level under heterogenous policy. Heterogenous policies are more realistic and could perform well. The second perspective considers long term and short term policy. The difference between these two policies is the length of time that a policy considers. The third perspective is incentive based and risk based policy, in the former, leverage level is constrained on each funds' performance, and in the latter, leverage is constrained mainly on market volatility.

This paper is organized as follows. Section 1 is introduction. In Section 2 we describe the model and different leverage policies. Section 3 shows the computer experiments and results, we use comparative analysis method to study the consequences that different policies cause. Section 4 concludes the paper.

2 Model and Policies

2.1 Leverage Asset Purchases Model

We build our model on the basis of a leverage asset purchases model proposed by Thurner, Farmer, Geanakoplos (2009). In this model, agents consist of two types of traders including noise traders and hedge funds and commercial banks, investors. Hedge funds can borrow from the commercial banks to buy. Commercial banks compute a leverage according to the funds transaction data to limit their borrow amount. When a funds wealth goes below a threshold, it has to get out of the market for waiting. The banks have no capital limit and will not default. Investors value the funds' performance to determine investing or withdrawing money at every timestep.

In their model, Noise traders buy and sell assets randomly. The hedge funds are value investors, their demands are depended on a mispricing signal

$$m(t) = V - p(t) \tag{1}$$

In the equation (1), V is the perceived fundamental value, which is held constant as 1. $p(t)$ is the asset price. Hedge fund i computes its demand $D_i(t)$ based on the mispricing at time t. As the mispricing increases the dollar value of the fund's position increases linearly until it reaches the maximum leverage, at which point it is capped. The hedge funds' demand can be written as following :

$$\begin{array}{rl} m < 0 & : \quad D_i = 0 \\ 0 < m < m_{crit} & : D_i p = \beta_i m W_i \\ m \geq m_{crit} & : D_i p = \lambda_i^{Max} W_i \end{array} \tag{2}$$

In the equation (2), β_i is the aggressiveness of the hedge fund i. m_{crit} is λ_i^{Max}/β_i, this is the critical mispricing that can limit the leverage. λ_i^{Max} is the leverage ratio that the banks based on to provide loans. If the price decreases, the fund may have to sell assets even though the mispricing is high.

And we compute the risky assets ratio of hedge fund i, $\lambda_i(t-1)$ in the same way in [3]:

$$\lambda_i(t) = \frac{D_i(t) \cdot p(t)}{W_i(t)} = \frac{D_i(t) \cdot p(t)}{D_i(t) \cdot p(t) + C_i(t)} \tag{3}$$

The risky assets ratio can not exceed the leverage ratio λ_h^{Max}, Otherwise, funds have to sell assets for repayment.

This model is a simplified framework for the real financial market, it ignores many elements, such as the banks' economic behavior, banks capital limit, investors profit model. But it can be used to focus on studying banks' local strategies without other influencing factors.

2.2 Leverage Regulatory Regimes

A fund can be valued from its profit and risk. Accordingly, a bank can set a leverage for a fund from these two aspects. In this paper, we explore different types of leverage policies as below.

Risk-Based Policies. A risk-based policy assesses a hedge fund through its market risk. In this paper, we consider three different Risk-based policies.

Regime I: This regime monitors the volatility of asset price to set the leverage which is negative correlation with the volatility. Asset price volatility can be described as variance of the price within a time window. As the price determined in the market is same to all the hedge funds, the leverage is homogeneous to all the funds. Regime I has two parameters k and τ which we will discuss in following analysis. In the equation (4), σ_τ^2 reveals the market risk, it is the price volatility within the observation period of time steps τ . λ is a variable ranges from 1 to 16. Regime I is a baseline model which we quote from the model of Thurner, Farmer, Geanakoplos (2009).

$$\lambda_i^{Max}(t) = \max[1, \frac{\lambda}{1 + k\sigma_\tau^2}] \tag{4}$$

Regime II: This regime considers variation of market risk, the risky asset ratio and the leverage at one previous time step. RegimeII is heterogeneous as the risk assets ratios of different funds are different. It is also a short term policy, in another word, it is a point to point policy.

$$\lambda_i^{Max}(t) = \max\{1, \lambda_i^{Max}(t-1) + \theta_{t-1} * \max\{0, [\lambda_i^{Max}(t-1) - \lambda_i(t-1)]\}\} \quad (5)$$

In equation (5), the variation of market risk can be computed as the gradient of σ_τ^2 , which is

$$\theta_{t-1} = \frac{-\sigma_{t-1}^2 + \sigma_{t-2}^2}{\sigma_{t-2}^2} \quad (6)$$

Regime III: This policy is similar to Regime II, the difference is that it computes a arithmetic average of the risk gradient. So this policy is a long term policy, and also a heterogeneous one.

$$\lambda_i^{Max}(t) = \max\{1, \lambda_i^{Max}(t-1) + \overline{\theta}_{t-1} * \max\{0, [\lambda_i^{Max}(t-1) - \lambda_i(t-1)]\}\} \quad (7)$$

In the equation(7), the risk parameter is

$$\overline{\theta}_{t-1} = average(\theta_1, \theta_2 \ldots \theta_{t-1}) \quad (8)$$

Incentive-Based Policy. An incentive-based policy assesses a hedge fund based on its ability of making money. In this paper, we consider two different incentive-based policies: long term and short term. Since each hedge fund has different profit situations, incentive-based policies are all heterogeneous policies.

Regime IV: This policy determine the current leverage according to the risky asset ratio, the leverage level and rate of return at the previous time step. Regime IV is a short term policy.

$$\lambda_i^{Max}(t) = \max\{1, \lambda_i^{Max}(t-1) + r_i(t-1) * \max\{0, [\lambda_i^{Max}(t-1) - \lambda_i(t-1)]\}\} \quad (9)$$

In the equation(9), the yield rate is computed as

$$r_i(t) = \frac{D_i(t-1)(p(t) - p(t-1))}{W_i(t-1)} \quad (10)$$

Regime V: We get Regime V on the basis of Regime IV. The difference is that leverage adjustment is based on a fund's yield curve over a long period. In our model, we assign the time window as $t-1$ at the time step t, so this policy is a long term one.

$$\lambda_i^{Max}(t) = \max\{1, \lambda_i^{Max}(t-1) + \overline{r_i(t-1)} * \max\{0, [\lambda_i^{Max}(t-1) - \lambda_i(t-1)]\}\} \quad (11)$$

In the equation (11), $\bar{r}_i^{NAV}$ is the geometric average of the yield rate over the time window. It is

$$\bar{r}_i(t) = \sqrt[n]{\prod_{t=1}^{n}(1 + r_i(t))} - 1 \quad (12)$$

3 Simulation Experiments and Result Analysis

In our simulations, there are 10 hedge funds, each one with an initial wealth W_0. A fund has to get out of the market when its wealth goes down to a level, then after a while (100 time periods), a new fund with initial wealth will enter the market. For hedge fund i, its aggressiveness is $5i$. We set the parameters as follows, the other parameters that we not list here are the same with the model in [3].

Parameters of market:

- The amount of assets: $N = 1000$;
- Perceived fundamental value: $V = 1$;

Parameters of hedge fund i:

- Initial wealth(Cash) of i: $W_i(0) = C_i(0) = 2$;
- Initial demand of i: $D_i(0) = 0$;
- Aggressiveness of i: $\beta_i = 5 \cdot i$;
- Bankruptcy level of i: $W_i(t)/10$;
- The waiting time that need to return to the market: $T_wait = 100$;

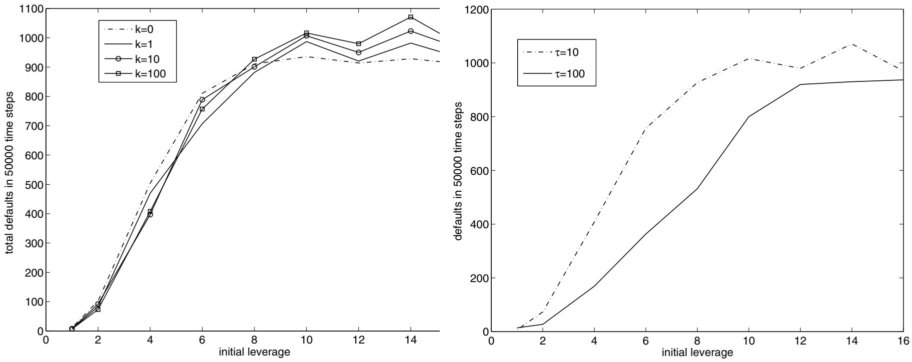
Parameters that we vary to discuss:

- Initial leverage: range from 1 to 16 for each regime;
- Volatility monitoring parameter k of Regime I: 0, 1, 10, 100;
- Volatility monitoring parameter τ of Regime I:10,100;

As mentioned before, our analytical framework of leverage policies in three aspects: homogenous and heterogeneous, long term and short term, incentive-based and risk-based. Under each policy, we simulate the model 5 times for each initial leverage limit ranging from 1 to 16, then get the average as the results. For the whole market, we analyze the total wealth, bankruptcy rate, fat tails and clustered volatility. Furthermore, we examine the effects of bank's local leverage regulation policies from banks' perspective, including the mortgage amount and bad debts of banks.

3.1 Default

In Regime I, there are two volatility monitoring parameters. We firstly discuss how the two parameters affect the funds' default. Fig. 1 illustrates correlation between these parameters and funds' default rate. In Fig. 1(a), $k = 0$ corresponds to constant maximum leverage. The default rate under Regime I has no great differences over different k. When the initial leverage exceeds 8, the default rate amplifies along with the increasing of k. In our paper, we set $k = 100$, under which the default rate is less with initial leverage below 8 and greater with initial leverage above 8. Fig. 1(b) measures the default rate over initial leverage under different τ. It shows that the default rate decreases as τ increases. We conjecture that this phenomenon shows that long term policy can reduce the default ratio. τ is the time window of computing the variance of asset price, when τ increases, computational cost increases. We assign τ to a neutral value 10.



(a) (b)

Fig. 1. Discuss the defaults of Regime I with different parameters k and τ.(a)The effects of k with different initial leverage limit(in 50000 time steps).(b)The effects of τ.

Fig. 2 shows the defaults of the 5 regimes and the situation with no leverage regulation. From this figure, the policy of no leverage (dotted line) has the most defaults in most instances. Regime I (solid line) takes the second place, i.e. the homogeneous leverage policy faces more bankruptcies than heterogeneous ones, and the odds are very large from the figure. Comparing the risk-based policies with the incentive-based policies(with the same time window), risk-based policies have less defaults. Moreover, the long term policy has less defaults than the short term policy in both risk-based policies and the incentive-based policies.

This result shows that leverage regulation is necessary and the funds' performance should be involved when determining leverage. And the long term policies and risk-based policies are more effective to reduce defaults. But the long term policies may amplify the computational cost and regulation cost, policy makers should consider the costs in the real market when they implement regulation regimes.

3.2 Wealth in the Market

The purpose of trading is to gain wealth. A fund borrows money to maintain its long position. Wealth is a symbol of market activity. We compute the total wealth of all funds within 50000 time steps. Fig. 3 shows the total wealth of funds under 5 regimes. The homogeneous policy (Regime I) which has the most

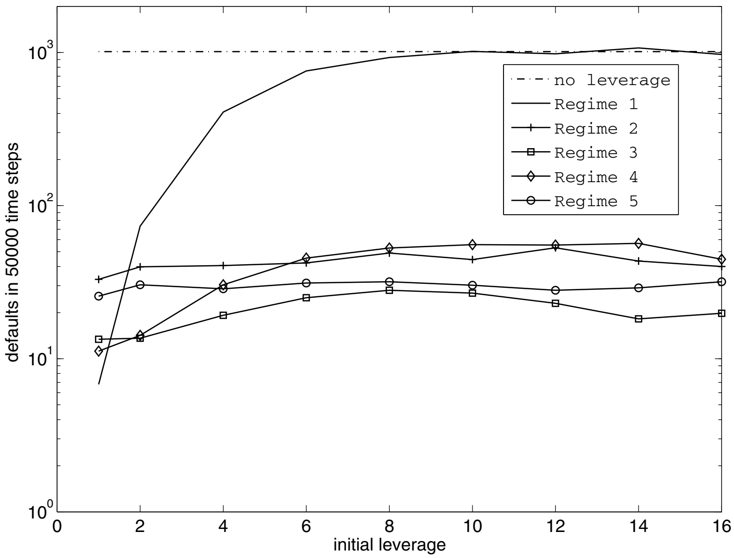


Fig. 2. Comparisons of defaults in 50000 time steps between different leverage policies. We measure the defaults on semi-log scale.

default rate has the least total wealth. Under incentive-based policies(Regime IV and Regime V) and risk-based policies (Regime II and Regime III), the former have higher amount of total wealth. By comparison of two risk-based policies, the long term one has more total wealth,so are the incentive-based policies.

3.3 Fat Tails

In this section , we draw the probability distribution of logarithmic price returns $p(r|m > 0, r(t) = logp(t) - logp(t-1))$, and compare it with the price return of noise traders that can be treated as normal distribution. We only consider the situation of $m > 0$, as when $m < 0$, funds sell all the assets and be not active. Fig. 4(a) illustrates the probability distribution under risk-based policies, Regime I has obvious fat tails on the negative side, Regime II and Regime III have inconspicuous fat tails. Fig. 4(b)show the probability distribution of incentive-based polices, the policies have fat tails with respect to the situation that there are only noise traders.

To compare our 5 regimes, we plot the cumulative distribution $P(r > R|m > 0)$ of r. The fat tail is more obvious as the P is larger. In Fig. 4(c), the incentive-based policies have more fat tails than the risk-based ones. And the long term policies have no much difference with the short term ones. Regime I has the most fat tail.

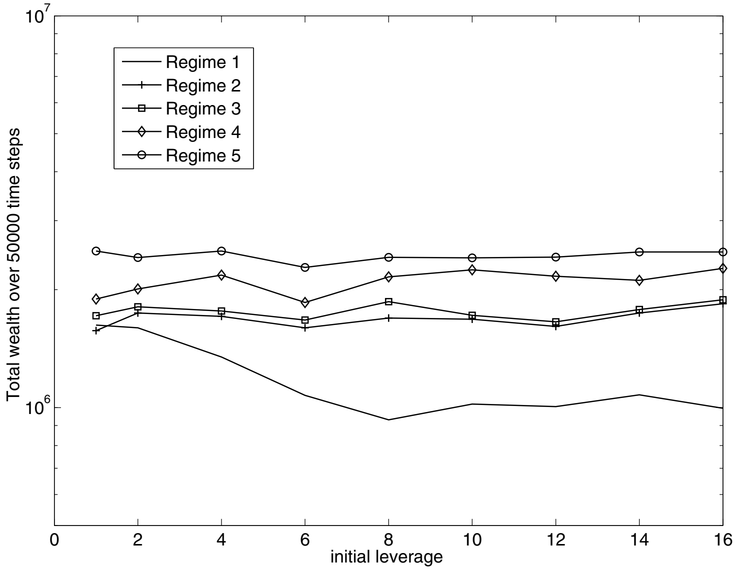


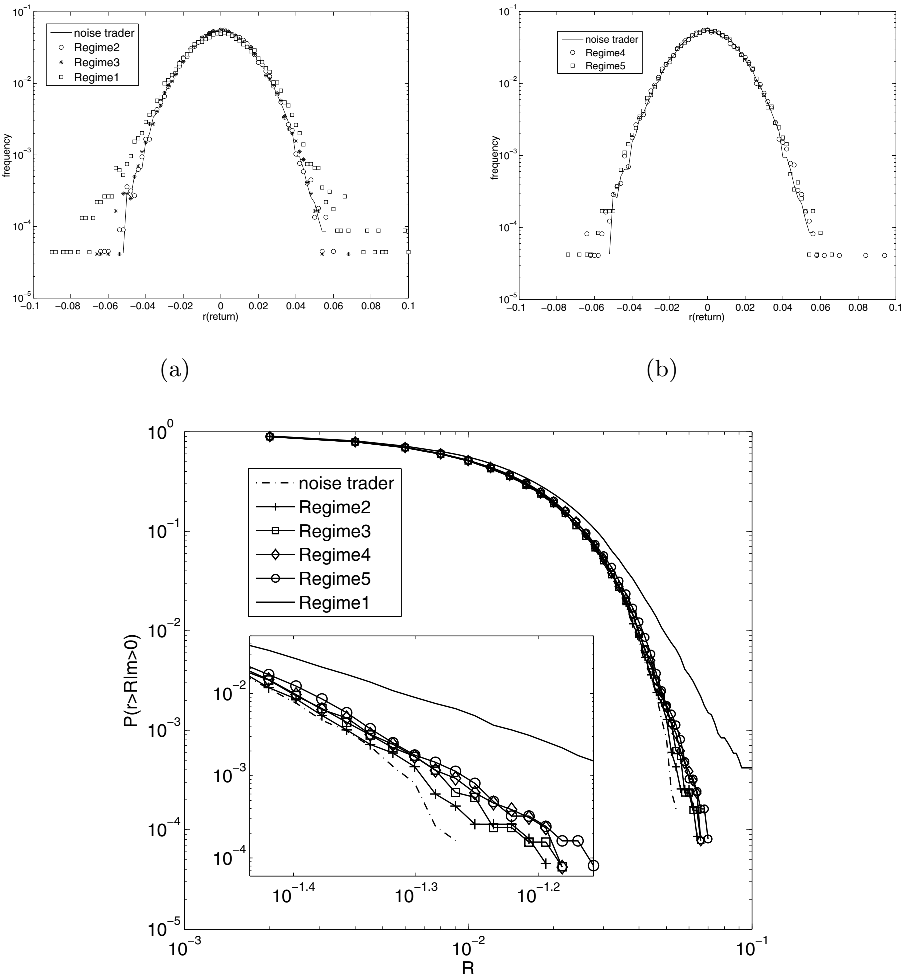
Fig. 3. Market wealth of 5 regimes over different initial leverage.Vertical axis is the total wealth of 10 funds within 50000 time steps.The total wealth use semi-log scale.

3.4 Clustered Volatility

Volatility means the dispersion degree in time series, it reflects the uncertainty of asset price, and can be used to measure risk and yield rate. Volatility has great impact on the financial market and macro-economy, it is significant to measure the volatility accurately. Mandlbrot(1963)[11]described volatility clustering as "large changes tend to be followed by large changes, of either sign, and small changes tend to be followed by small changes". This fact has a quantitative manifestation: while returns themselves are uncorrelated, absolute returns or their squares display a positive, significant and slowly decaying autocorrelation function.

Fig. 5 compares the conditional standard deviations between Regime V and the situation that only have noise traders. The distribution of noise traders is nearly a straight line while the Regime V has obvious fluctuation of the standard deviations. We draw a conclusion that the price under Regime V has clustered volatility.

Fig. 6 displays the autocorrelation coefficient of return under our 5 leverage regulation regimes. We can conclude from the figure that: (a).The incentive-based policies have larger autocorrelation coefficient, i.e.has more obvious clustered volatility. (b).The clustered volatility of short term policies is obvious. (c)Regime I which is homogeneous has the most obvious clustered volatility.



(a) (b) (c)

Fig. 4. The distribution of logarithmic price returns. (a)plots the probability distribution of risk-based policies.(b)plots the probability distribution of incentive-based policies. In(a)and(b), we can see fat tails at the negtive side, the vertical axis is $p(r|m > 0)$, uses semi-log scale. (c)illustrate the cumulative distribution of r under of regimes and noise trader, the vertical axis is $P(r > R|m > 0)$, (c)is log-log scale.

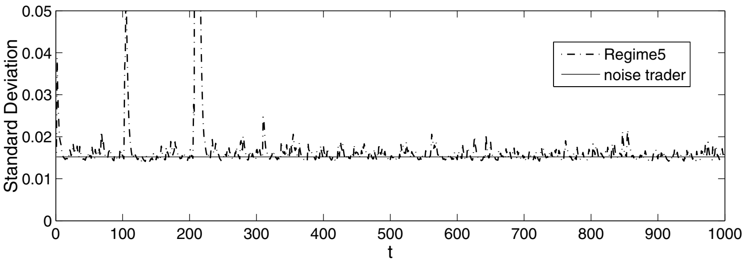


Fig. 5. The Conditional Standard Deviations of noise trader and Regime V

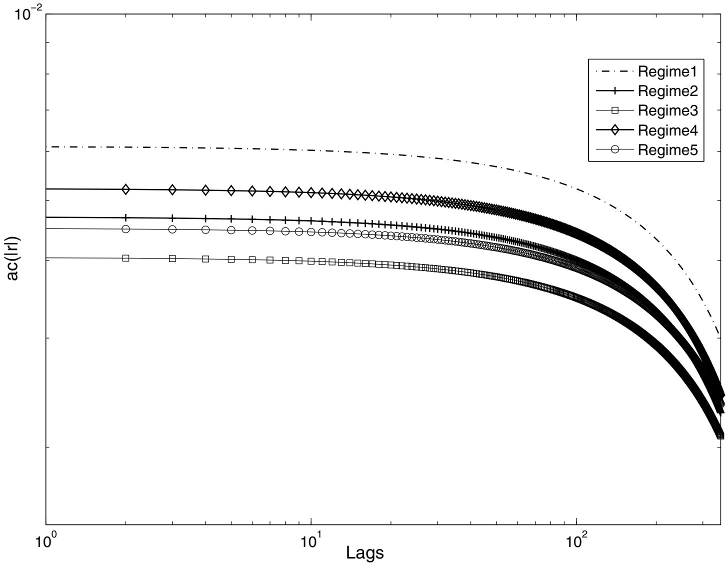


Fig. 6. Autocorrelation coefficient of the absolute values of log-returns of 5 regimes,the lag varies from 0 to 1000

3.5 Bank's Behaviour

In our paper, the function of bank is to provide cash for hedge funds,the banks have no profits. When a fund default, it causes bad debt of relevant bank. In the real market, commercial banks are profits seekers, so a rational bank will certainly consider the default risk when it provides lending and sets funds' leverage limit.

Fig. 7 illustrates the lending amount of banks under 5 different regimes. Regime I has the most loan amount, and banks with incentive-based leverage policies provide more lending than the ones with risk-based polices. Under the incentive-based policies, the long term one has larger lending amount. But under the risk-based policies, short term policy brings larger lending amount.

In Fig. 8, we show unit loss of banks over the initial leverage. The homogeneous policy(Regime I) has the largest rate of bad accounts. While other regimes have little bad accounts under our simulations.

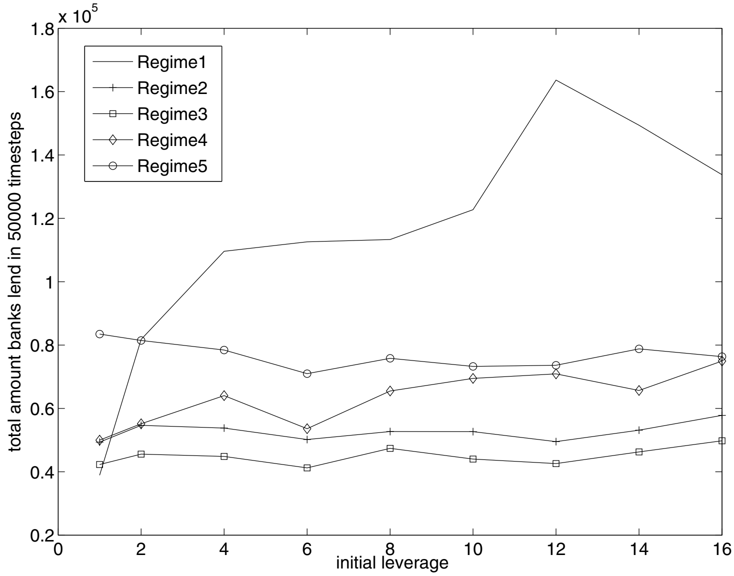


Fig. 7. The total amount of cash that the banks lend to hedge funds within 50000 time steps

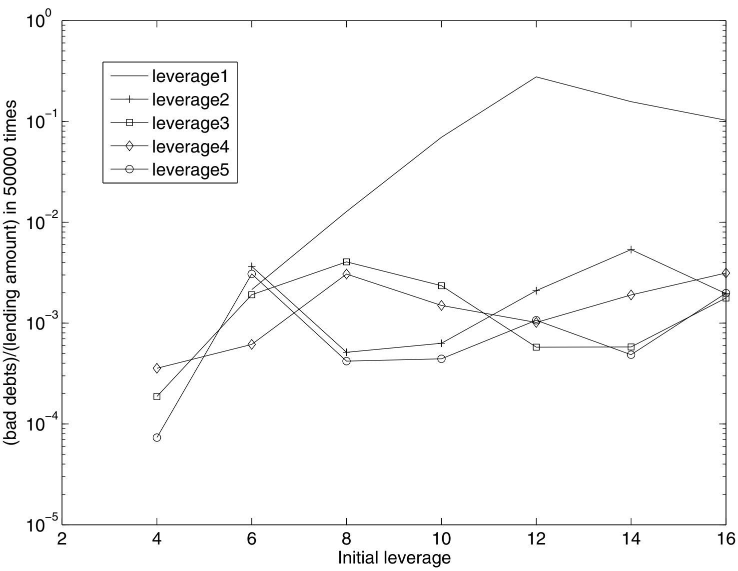


Fig. 8. The Unit lost of cash that the banks lend to hedge funds within 50000 time steps

4 Conclusions

Our paper proposed a framework to examine the effects of banks' leverage regulation regimes based on the model in [3] . We discuss 5 different leverage regulation policies. Through computer simulations, some findings are as follows.

Firstly, leverage regulation is necessary. As in our experiments, no regulation causes multiple more defaults than the risk-based polices and incentive-based polices. In fact, the financial crisis in recent years are induced by the excessive leverage.

Secondly, when banks implementing leverage regulation, it is useful to set the leverage based on the funds performance, as the homogeneous policy could cause worse market situations including more defaults, larger fat tails and more obvious clustered volatility, less market flexibility, i.e., less wealth and less lending amount, and the larger union loss of the banks meanwhile.

Thirdly, the incentive-based policy in this paper is pro-cyclical which brings about more defaults, obvious fat tails and obvious clustered volatility that reduces the stability of the market. But at the same time, the market has larger wealth and lending amount which means higher market flexibility. The two types of polices cut both ways, it may need to consider the purpose of regulations when set leverage in real markets.

Long term polices may have less defaults, larger wealth, smaller fat tails and less obvious clustered volatility that means the long term polices can have stable market and high market flexibility. But Long term polices can also bring about larger cost including computational costs and data acquisition costs. In real life, computational cost matters little with the advanced technologies, but data acquisition matters much. Therefore leverage policies involve many factors including the market conditions, capital of banks, monetary policy, costs and so on.

The main limitations of this paper is the lack of banks behavior, the activities of banks in the model is providing money for funds, and setting leverage level. And there is no capital limit and monetary policy, the funds do not pay interest on the loan. In future work, we extend our framework to simulate banksbehaviors and features and monetary policy. The banks will be a financial entity, and it can provide loan, make profits and have interbank leading.

Acknowledgements. The work is supported by the Ministry of Education of China, Humanities and Social Sciences Fund Project No. 11YJCZH148.

References

1. Simkovic, M.: Secret Liens and the Financial Crisis of 2008. American Bankruptcy Law Journal 83, 253 (2009)
2. Fostel, A., Geanakoplos, J.: Leverage Cycles and the Anxious Economy. American Economic Review 2008 98(4), 1211–1244 (2008)
3. Thurner, S., Farmer, J.D., Geanakoplos, J.: Leverage Causes Fat Tails and Clustered Volatility. SFI Working Paper 09-08-031 (2009)

4. Feldman, T.: Portfolio Manager Behavior and Global Financial Crises. Journal of Economic Behavior & Organization 75(2), 192–202 (2010)
5. Friedman, D., Abraham, R.: Bubbles and crashes: Gradient dynamics in financial-markets. Journal of Economic Dynamics and Control 33(4), 922–937 (2009)
6. Peters, O.: Optimal Leverage from non-Ergodicity. SFI Working Paper, 09-02-004 (2009)
7. Hodas, N., Tagliabue, J., Schmidt, M., Barofsky, J.: The Effect of Leverage on Financial Markets. Market Simulation Working Paper (2009)
8. Feldman, T.: Leverage regulation: An agent-based simulation. Journal of Economics and Business 63, 431–440 (2011)
9. Christensen, I., Meh, C., Moran, K.: Bank Leverage Regulation and Macroeconomic Dynamics. Bank of Canada Working Paper 2011-32 (2011)
10. Raberto, M., Teglio, A., Cincotti, S.: Macroprudential policies in an agent-based artificial economy. In: Workhshop on New Advances in Agent-based Modeling, Paris, France, June 19-20 (2012)
11. Mandelbrot, B.: The variation of certain speculative prices. Journal of Business 36, 394–419 (1963)