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SciVerse ScienceDirect
Procedia Computer Science 18 (2013) 1764 – 1773
Procedia Computer Science

International Conference on Computational Science, ICCS 2013

Securities Transaction Tax and Stock Market Behavior in an Agent-based Financial Market Model

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Abstract

As highly related to the investors' earnings expectations and trading decision-making behavior, securities transaction tax (STT) has long been regarded as a typical regulatory mechanism exploited by policy makers. However, neither theoretical analysis nor empirical studies reach consensus about the role and policy effect of the securities transaction tax. Within the framework of agent-based computational finance, this paper presents a new artificial stock market model with heterogeneous agents, which allows us to assess the impacts of varying STTs on market behavior to come to robust conclusions. First we investigate the dynamics of benchmark market with no tax levied, and then market behaviors with different STTs are thoroughly checked. The results show that a modest transactions tax does contribute to stabilize markets by reducing market volatility, but its negative effects on market efficiency cannot be ignored at the same time. The findings suggest that regulatory authorities should introduce STT discreetly to strike a balance between stability and efficiency.

Selection and peer review under responsibility of the organizers of the 2013 International Conference on Computational Science

Keywords: Computational finance; Security transaction taxes; Heterogeneous agents model; Regulatory policies

1. Introduction

Securities transaction tax (STT) has been considered as an important regulation device, however, neither theoretical analysis nor empirical studies reach consensus about its impacts on financial markets. There are two disparate opinions concerning how an STT may affect the dynamics of financial market. The well-known advocators are Keynes (1936) [1] and Tobin (1978) [2] who deemed as the pioneers of introducing STTs on securities markets. By throwing some sand in the wheels of speculation, they propose to impose transaction tax on financial markets for the sake of penalizing speculators engaged in short-term trading and hence reducing

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Selection and peer review under responsibility of the organizers of the 2013 International Conference on Computational Science
doi:10.1016/j.procs.2013.05.345

instability in stock markets. After the 1987 stock market crash, many scholars follow their trace of research. Summers(1989)[3]and Stiglitz(1989)[4] claim using general types of STTs to curb speculative trading. Shiller (1989, 2000) [5-6] points out that there are two kinds of investors, that is, noise traders and well-informed traders. He advocates to downscaling the noise trading and herding effects to strengthen the stability of markets. Westerhoff and Dieci (2006) [7] obtains similar findings and their model indicates that if a small STT is levied on a market, then speculators leave the market, thereby making it less volatile.

Contrary to the aforementioned view, some economists challenged the assertion that STTs play vital role in stabilizing securities market. To begin with, Umlauf (1993) [8] proves that volatility does not decline in line with the introduction of taxes by analyzing data from Swedish stock market. Heaton and Lo (1995) [9] further point out traders' actions will reinforce market volatility when the trading volume is decreasing. Jones and Seguin (1997) [10] argue that a reduction in transaction costs is associated with a decline in stock return volatility, and Baltagi et al.(2006)[11] find that the market volatility increases after the tax rate increases in an emerging market. Those works consistent with Umlauf (1993) findings. Contributions by Habermeier and Kirilenko (2001)[12] and Aliber et al. (2003) [13] also support this view.

As we can see that international experiences with STTs are quite varied, and disagreements about the impacts of an STT are largely associated with different samples used by various researchers. As we know, the underlying market structures vary from markets to markets, and traders' behaviour may differ with location and time-varied, which will undoubtedly intervene on the impacts exerted by STT. In this sense, empirical study cannot give the full picture about the impacts of an STT due to these limitations.

Compared with traditional empirical approach, agent-based financial market model can create a comprehensive market that is able to replicate the whole episodes of real market, rather than treating market as a segment. An early example is given by Zeeman (1974) [14]. Now Agent-based Computational Finance (ACF) method has become one promising tool to analyze the effectiveness of policy measures, see Lebaron (2006) [15], Hommes (2006) [16], Lux (2009)[17] , Demary(2008)[18] and Westerhoff et al. (2003, 2006, 2008) [19-21]. However, there are few studies about STT and stock market behaviour from the point of ACF.

This paper aims to contribute to the issue. Our paper builds on the model of Westerhoff (2008) [21], which is in essence an exchange rate market model with only two types of market participants. Although the model is rather simple, it mimics the dynamics of financial markets quite well. His work gives us a reasonable prototype model for further research.

This paper is to extend this model in two ways. Firstly, we introduce more trading strategies into the model to mimic heterogeneous trader behavior in real stock market. Further, an exogenous fundamental noise is added to the law of motion with the assumption of IID normal innovations of the fundamental value in order to better mimic real market and to investigate market behavior via varying tax rates given more complex market conditions. The remainder of the paper proceeds as follows: Section 2 describes our model which is used as simulation platform. Section 3 discusses the simulation results, including calibration and results analysis. By choosing different values of key parameters, we postulate three scenarios to verify the statistical dynamics and properties of market. The last section provides some concluding remarks.

2. The Model

Our model is ignited by the previous contributions, especially by the type of models surveyed in Westerhoff et al. (2003, 2006, 2008). To make up the deficiencies, such as rare trading strategies and ignoring the fundamental value, here we expand the selective strategies of agents and extend it into one that can be applied to stock markets. In our model, agents have five sorts of trading strategies: contrarians, random traders, momentum traders, fundamentalists and exit strategy. The agents incline to select those strategies which did well in the past. Let us turn to the details of the model.

2.1 Market Structure Assumption

Similar to the traditional artificial financial market, our model is indefinitely dynamic model, and there is only one risk asset in the market, the total number of risk asset is fixed without changes over time.

We simulate the price adjustment process by a so-called price impact function (Farmer and Joshi 2002) [22]. The price in this market is adjusted in response to excess demand as usual. If excess demand is positive, prices rise, otherwise, price will drop. The log of the price of the asset in period t + 1 is given as

$$p_{t+1} = p_t + \beta(W_t^C D_t^C + W_t^F D_t^F + W_t^R D_t^R + W_t^T D_t^T) + \alpha_t^p \quad (1)$$

where a is an impact coefficient to the excess demand, D^C, D^R, D^T and D^F stand for orders generated by contrarians, random traders, trend-followers and fundamentalists, and W^C,W^R ,W^T and W^F denote their fractions respectively. In order to make our model closer to the real markets, we add a random term α_t^P to (1). α_t^P represents other random factors such as price halting, specific market regulations, and so on. Here, we assume that α_t^P is an IID normal random variable with zero mean and constant standard deviation σ^P.

We will set the fundamental value of security in order to analyze the price deviation. Westerhoff (2006, 2008) argue that the fundamental value of exchange rate changes scarcely, therefore he assumes that the basic value is constant, that is, $f_t = c$. However, security price in stock market is changing in seconds and is easily affected by external factors, thus leading to large fluctuations in daily prices. Accordingly, we make several modifications to the model, bringing in external noise and setting the form of fundamental value as random walk, specific setting is illustrated as

$$f_t = f_{t-1} + \varepsilon_t, \qquad \varepsilon_t \sim IIDN(0, \sigma_\varepsilon^2) \quad (2)$$

2.2 Investor Behavior Assumption

There are many types of heterogeneous agents in computational finance literatures, and the most common are the fundamental analysts and technical analysts. Hommes(2006)sheds a detailed light on these two agents, he deems that fundamental analysts form the expected price of assets and their trading activities are based on market fundamental value, while technical analysts, so called chartists, do not care about those factors. In order to make our model closer to the real market, we subdivide technical analysis into momentum and contrarian strategies, and introduce exit and random strategies at the same time.

The specific economic implications of all sorts of trading strategies are as follow

2.2.1 Momentum trading strategy

Momentum trading strategy (also known as trend-following), which indicates that this type of investors try to exploit trading information about past price pattern to forecast market trend in future. Trend-followers tend to buy assets when the prices go up and vice versa. Therefore, orders due to momentum trading rules may be illustrated as

$$D_t^T = \beta^T (p_t - p_{t-1}) + \alpha_t^T \quad (3)$$

where β^T denotes how strongly the agents react to the price trend. The higher β^T is, the more sensitivity to price trend. α_t^T is an IID normal random variable with mean zero and constant standard deviation σ^T, which denotes other random factors.

2.2.2 Contrarian trading strategy

Contrarians is counter to the momentum traders. When stock price is rising, they will say market would stop rising soon and fall down, so it is better to sell now, and vice versa. Orders induced by contrarian trading rules may be formalized as

$$D_t^C = \beta^C (p_{t-\tau} - p_t) + \alpha_t^C \tag{4}$$

$(P_{t-\tau} - P_t)$ describes the transactions triggered by an extrapolation of the current price trend. β^C is a reaction parameter to the contrarian trend. τ refers to the time window traders use in the contrarian trading strategy, e.g. they may select from 1, 5, 10, 20 days randomly. α_t^C stands for other factors that may affect the orders, and $\alpha_t^C \sim N(0, \sigma^C)$

2.2.3 Fundamental trading strategy

Fundamental traders firmly believe asset price will revert to its fundamental value sooner or later, and they place orders on the mispricing in stock market and usually create a stabilizing mean reversion effect. Accordingly, fundamental analysis implies buying (selling) the asset when the price is below (above) its fundamental value. Orders triggered by fundamental trading rules may be defined as

$$D_t^F = \beta^F (f_t - p_t) + \alpha_t^F \tag{5}$$

where β^F is a positive reaction parameter and f_t is the fundamental value of assets. Meanwhile, agents are aware of the asset's true fundamental value and we introduce a random term in the demand function. α_t^F is an IID normal random variable with mean zero and constant standard deviation σ^F.

2.2.4 Random trading strategy

Particularly, we embed the random trading strategy into the model for the reason that there are many naive traders or liquidity traders existing in international stock markets especially in emerging markets. Random traders are characterized with zero intelligence and with random buy or selling decisions. Orders arisen from random trading rules are computed as

$$D_t^R = \alpha_t^R \tag{6}$$

with $\alpha_t^R \sim N(0, \sigma^R)$,

The last option for trader is exit, which indicates one agent has no interest in trading activity or loses all money beat by the market. Excess demand therefore is zero.

2.3 Trading Strategies Selection Assumption

Now every agent has five options totally. We presume that selection decision depends on the strategies' attractiveness. The more attractive a strategy, the more agents will follow it. According to Demary (2010, 2011)[23-24] and Westerhoff (2008), the following fitness functions capture the attractiveness of the five strategies respectively

$$A_t^T = (\exp[p_t] - \exp[p_{t-1}])D_{t-2}^T - tax(\exp[p_t] + \exp[p_{t-1}]\left|D_{t-2}^T\right| + dA_{t-1}^T \tag{7}$$

$$A_t^C = (\exp[p_{t-\tau}] - \exp[p_t])D_{t-\tau-1}^C / \tau - tax(\exp[p_t] + \exp[p_{t-\tau}]\left|D_{t-\tau-1}^T\right| / \tau + dA_{t-1}^C \tag{8}$$

$$A_t^F = (\exp[p_t] - \exp[p_{t-1}])D_{t-2}^F - tax(\exp[p_t] + \exp[p_{t-1}]\left|D_{t-2}^F\right| + dA_{t-1}^F \tag{9}$$

$$A_t^R = (\exp[p_t] - \exp[p_{t-1}])D_{t-2}^R - tax(\exp[p_t] + \exp[p_{t-1}]\left|D_{t-2}^R\right| + dA_{t-1}^R \tag{10}$$

$$A_t^0 = 0 \tag{11}$$

It's worth noting is that the attractiveness of a strategy depends on two components. Firstly, it relies on the performance (net income after taxed) of the specific rule during current period. Secondly, it has a memory of itself. The memory parameter $d \in [0,1]$ measures how fast current fitness is discounted for strategy selection. For b=0, the fitness equals current profits. But the larger the memory of the agents, the more strongly the fitness depends on its past performance.

A_t^o is the fitness of being inactive (exit strategy) , which is set to zero.

Finally, we set the relative weights of the strategies as follows

$$W_t^T = (\exp(eA_t^T)/(\exp(eA_t^C) + \exp(eA_t^F) + \exp(eA_t^0) + \exp(eA_t^T) + \exp(eA_t^R)) \tag{12}$$

$$W_t^C = (\exp(eA_t^C)/(\exp(eA_t^C) + \exp(eA_t^F) + \exp(eA_t^0) + \exp(eA_t^T) + \exp(eA_t^R)) \tag{13}$$

$$W_t^F = (\exp(eA_t^F)/(\exp(eA_t^C) + \exp(eA_t^F) + \exp(eA_t^0) + \exp(eA_t^T) + \exp(eA_t^R)) \tag{14}$$

$$W_t^R = (\exp(eA_t^R)/(\exp(eA_t^C) + \exp(eA_t^F) + \exp(eA_t^0) + \exp(eA_t^T) + \exp(eA_t^R)) \tag{15}$$

$$W_t^0 = (\exp(eA_t^0)/(\exp(eA_t^C) + \exp(eA_t^F) + \exp(eA_t^0) + \exp(eA_t^T) + \exp(eA_t^R)) \tag{16}$$

Here, *e* is a parameter that explains how sensitive the mass of traders is to selecting the most attractive strategy. The higher *e*, the more agents will select the strategy with the best performance. For *e* = 0, there is no difference for every option, and all traders select their rules random without regard of fitness. In this sense, *e* reflects the rationality of the agents.

3. Simulation Results

3.1 Model Calibration and Comparative Study

This paper develops the simulation platform using Matlab software (program available upon request). We aim to shed lights on how an STT may affect market via varying tax rates. In our model, market parameters (beforehand make sufficient sensitivity analysis for every variable) are tuned in such a way to make sure the artificial market is a good proxy for real stock market. One simulation step is roughly corresponding to a trading day in real markets. For the sake of assuring whether our model is fitting with properties of real financial market, we should also make comparative analysis of the dynamics and of statistical properties of these data. Following these principles, we set parameters below (as benchmark market setting): σ^C=0.05； σ^F=0.01； σ^R=0.01； σ^p=0.01； σ^η=0.01； σ^T=0.05； e=800； d=0.92； β=0.5； β^C=0.2； β^F=0.2； β^T=0.2； tax=0.0%. Fig.1 and Fig.2 show the dynamics of simulation series for T=1500 periods. From the pictures we can see certain stylized facts similar to that of real financial markets. We observe bubbles and crashes, intricate price motion, volatility clustering and mean reversion and etc. To further investigation, we introduce Shanghai Composite Index (SHCI) from November 3, 2005 to January 6, 2012 as the representative data of actual stock market, and then analyze the statistical and dynamic properties of the two time series from artificial market and real market. Table 1 reveals the statistical properties.

Table 1 indicates that excess kurtosis and fatter tail shows up in both data collected from real market and the simulation study, besides, the estimates of Jarque-Bera statistics is far greater than the value at the 5% level, suggesting that the null hypothesis of returns series subject to normal distribution should be rejected. Furthermore, we find that both of the two time series belong to the stationary time series and display the properties of linear autocorrelation and nonlinearity (See Figure 3-Figure 4, Fig. for SHCI omitted). In all, our agent-based model is capable to resemble actual markets quite closely and precisely.

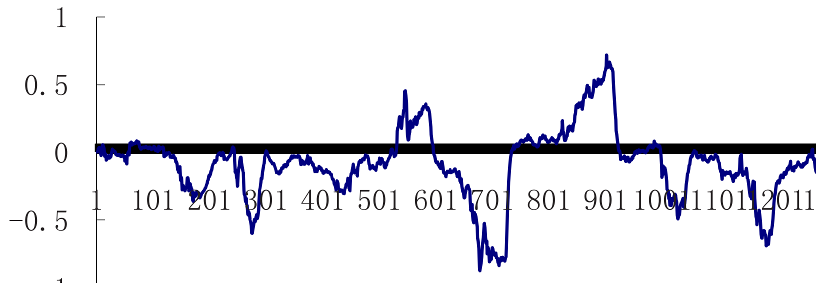


Fig. 1. Time series of the log of price in simulation market

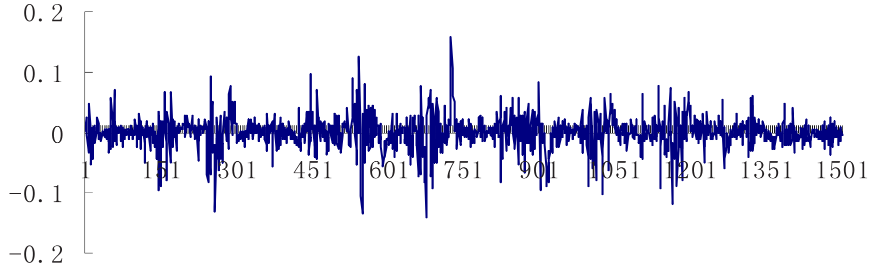


Fig 2.Time series of return rate in simulation market

Table 1 Statistical properties of SHCI returns series and simulation returns series

Sample	Mean	Variance	Skewness	Kurtosis	JarBra
SHCI	0.0002	0.0083	-0.4235	5.72328	508.3756
Model	0.0002	0.1459	-1.0021	15.4276	9903.917

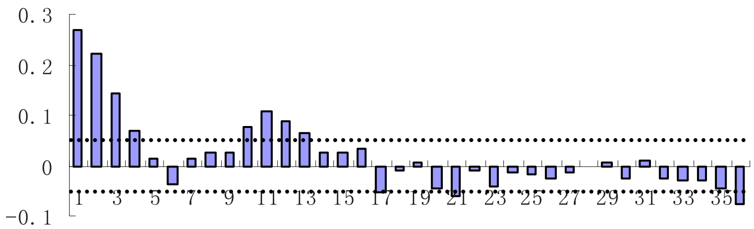


Fig. 3. Auto-correlation diagram for the simulated return series

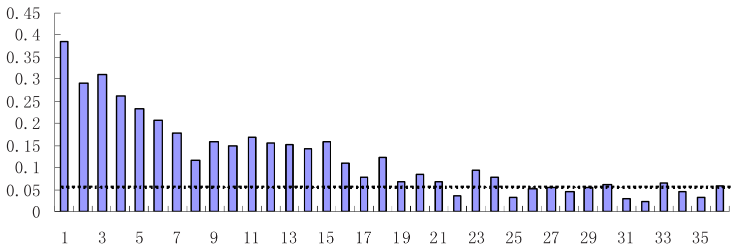


Fig.4. Auto-correlation diagram for the simulated absolute return series

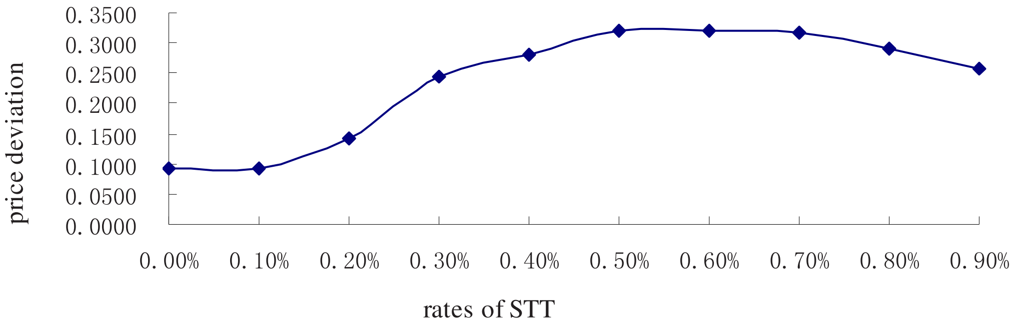
3.2 STTs and market behavior

The main concern is what will happen on market dynamics if an STT is impeded, which include the impacts on market volatility and on the deviation between price and fundamental values. Another important issue about market microstructure is how the investor's trading strategies would change while STTs vary? To shed lights on these questions, we follow parameter setting as in section 3.1, but change the tax rate from 0.0% to 0.9%.

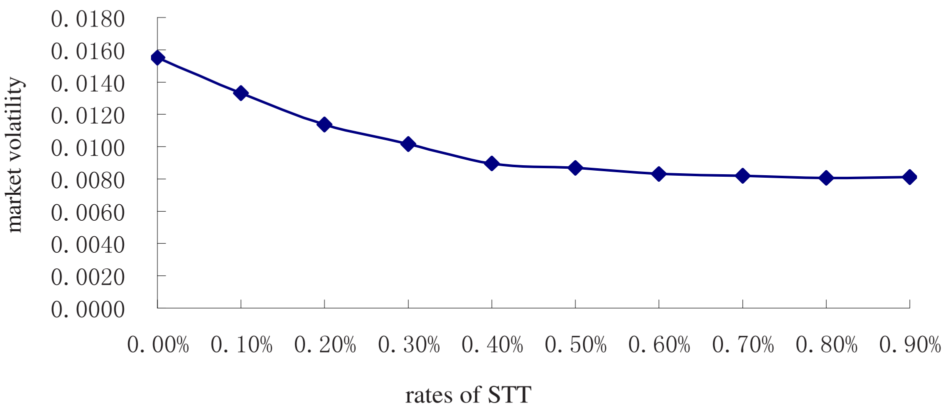
Figure 5 shows that with an increasing tax rate, the exit trading strategy will dominate market while the weights of technical and fundamental analysts drop heavily, the weight of fundamental rules declines below 10% especially when the rate overpass 0.3%, therefore the market is occupied by exit and technical analysts. The direct consequences of the aforementioned changes are less activeness, lower volatilities of market but price deviation will maintained at a high level. The results conform partly to Tobin's view and there also exits divergences. First, the results reveals that levied taxes which increase the transaction costs, impair interests of investors will undoubtedly enhance the stability of market. However, the margin of price deviates from fundamental value is rising, declaring that levying taxes undermines market pricing mechanism, which coincides with the view of anti-Tobin group. Our study demonstrates that faced with a high level of Tobin-tax, both fundamentalists and trend-followers' trading interests are dropping rapidly, a majority of investors will choose to retreat from the market. As a result, we may see the volatility of market is declining at the expense of market efficiency.

In details, it seems that tax rate should be below 0.2% to reach desirable balance between market efficiency and volatility level. At this point, market volatility decreases significantly while the margin of price deviation is not rising obviously, and fundamental strategy still remains dominant.

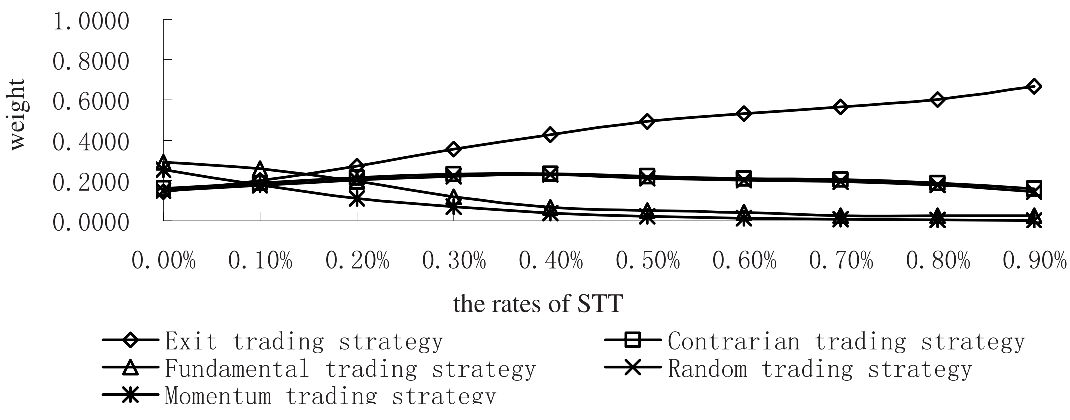
Another interesting finding is that contrarian agents are insensitive to the imposition, in other words, whatever market circumstance is, contrarian trading strategy will be a sound choice. Other studies also verify our finding. For instance, Debondt and Thaler (1985) [25] indicates that contrarian strategy can beat market.


0.3500
0.3000
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
price deviation
0.00% 0.10% 0.20% 0.30% 0.40% 0.50% 0.60% 0.70% 0.80% 0.90%
rates of STT

(a)


0.0180
0.0160
0.0140
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
market volatility
0.00% 0.10% 0.20% 0.30% 0.40% 0.50% 0.60% 0.70% 0.80% 0.90%
rates of STT

(b)


1.0000
0.8000
0.6000
0.4000
0.2000
0.0000
weight
0.00% 0.10% 0.20% 0.30% 0.40% 0.50% 0.60% 0.70% 0.80% 0.90%
the rates of STT
Exit trading strategy
Contrarian trading strategy
Fundamental trading strategy
Random trading strategy
Momentum trading strategy

(c)

Fig 5. The dynamics of the model while transaction tax varies. (a) shows the margin of price deviation, deviation margin is referred to the difference between log of price and fundamental value; (b) depicts market volatilities; (c) presents the weights of investor trading strategies.

4. Concluding remarks

The results indicate that transaction tax in financial market plays a crucial role in stabilizing market, curbing speculations as well as reducing the vulnerabilities of market itself. Introducing an STT will raise transaction costs and deteriorate investors' expected profits as well as interests, finally bring market back into stabilization, which is in accordance with the original intention of Tobin Tax. Unfortunately, levying STTs does not come without adverse effects which include inactive market actions, the declining effectiveness of pricing mechanism and making retreat strategy dominate market. Overall our investigations consistently show that transactions tax does contribute to stabilize markets by reducing market volatility, but its negative effects on market efficiency cannot be ignored at the same time. In conclusion, we suggest the administrations to adopt the policy of moderate tax rates (controlling the level of STT less than 0.2%), which will not sacrifice market efficiency and vitality while controlling market volatility.

The empirical results have significant policy implications. It verifies that the introduction of security transaction tax in financial markets is favourable to penalize the speculative trading as well as prevent financial crisis. Consequently, it suggests the regulatory authorities to take transaction tax into account so as to better control the stability of financial market. However, our study has one drawback as it only involves in one market and neglects the inter-dependence between different financial markets. Further study may aims at multi-markets analysis to gain more comprehensive insights into this issue.

Acknowledgements

Financial supports from the National Natural Science Foundation of China (No.71001036, No. 71171186) and the Scientific Research Fund of Hunan Provincial Education Department (No.10A082) are gratefully acknowledged.

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