DEVELOPING A HEURISTIC HETEROGENEOUS AGENT MODEL FOR GOVERNMENT INTERVENTION DURING STOCK MARKET CRASHES IN CHINA

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2025

DEVELOPING A HEURISTIC HETEROGENEOUS AGENT MODEL FOR GOVERNMENT INTERVENTION DURING STOCK MARKET CRASHES IN CHINA

by

HUANG PING

Thesis submitted in fulfilment of the requirements
for the degree of
Doctor of Philosophy

March 2025

ACKNOWLEDGEMENT

I am deeply grateful for the opportunity to further my academic research in a field I am passionate about. First and foremost, I would like to express my deepest appreciation to my supervisor, Dr. Chin Phaik Nie, for her patient guidance and continuous support throughout this research. I am equally thankful to my co-supervisor, Prof. Hooy Chee Wooi, for his constructive and valuable suggestions for the thesis. Both supervisors have been incredibly patient and provided detailed feedback despite their busy schedules.

I extend my gratitude to Dr. Sek Siok Kun, Dr. Mohd Tahir Ismail, and Prof. Amine Tarazi for their insightful suggestions, which have significantly improved the quality of the thesis. I am particularly grateful to Dr. Zhou Zhong-Qiang for sharing the nonlinear least squares code used for estimating the HAMs, which greatly facilitated my work. My sincere thanks also go to Prof. Cars Hommes from the University of Amsterdam for providing the open-source *E&F Chaos* software package on his personal homepage, which greatly aided the system dynamic simulations and scenario-response analysis in my thesis. I would like to thank my classmates Chen Siyu, Pu Tingqian, Jiang Zhengyou, Huang Mingzhi, Cai Yun, and Li Jiaqi for their help and support both academically and in daily life.

Last but not least, I would like to express my deep appreciation to my family and friends for their continuous support and understanding throughout my academic journey.

For my son, Zixi, with wishes for his everlasting health and happiness.

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LIST OF ABBREVIATIONS

SSE	Shanghai Stock Exchange
SZSE	Shenzhen Stock Exchange
CSI	China Securities Index
OECD	Organization for Economic Co-operation and Development
EV	Excess Volatility
BH	Behavioural Heterogeneity
HDM	Heuristic Decision-making
ASGI	Animal Spirits and Government Intervention
HAM	Heterogeneous Agent Model
H-HAM	Heuristic Heterogeneous Agent Model
HG-HAM	Heuristic Government Heterogeneous Agent Model
CSMAR	China Stock Market and Accounting Research
NLS	Nonlinear Least Squares
DGP	Data Generated Process

LIST OF SYMBOLS

P_t	stock price at time t
P_t^*	stock fundamental value
P_t^m	m-day moving average price
x_t	deviation for the price from fundamental value at time t
x_g	threshold of government intervention
$f_{1,t}$	fraction of mean-reverting investors at time t in the stock market
$f_{2,t}$	fraction of trend-following investors at time t in the stock market
$f_{3,t}$	fraction of government at time t in the stock market
$f_{3,g}$	government fraction at intervention threshold
ψ_1	belief coefficient of mean-reverting investors
ψ_2	belief coefficient of trend-following investors
ψ_3	belief coefficient of government
β	intensity of choice
ω	memory parameter
Ψ_t	market's average sentiment
δ	difference in belief strength between mean-reverting and trend-following investors

PEMBANGUNAN MODEL EJEN HETEROGEN HEURISTIK UNTUK CAMPUR TANGAN KERAJAAN SEMASA KEJATUHAN PASARAN SAHAM DI CHINA

ABSTRAK

Pasaran saham China didominasi oleh pelabur runcit yang tidak berpengalaman dan tahap spekulasi yang tinggi, disertai campur tangan aktif kerajaan untuk mengurus risiko kewangan utama dan menstabilkan pasaran. Namun, kajian mengenai model teori yang membimbing campur tangan sebegini adalah sangat terhad. Kajian ini berusaha mengisi jurang tersebut dengan pembangunan model kerajaan heuristik sebagai panduan. Model ini berasaskan dua ciri utama: (1) Pelabur dan kerajaan menggunakan purata bergerak mudah untuk mengira nilai asas pasaran; dan (2) Kerajaan menggunakan model linear mudah untuk menentukan ambang dan pecahan intervensi. Kajian dimulakan dengan meneliti volatiliti berlebihan dalam pasaran saham China menggunakan model ejen heterogen (H-HAM), yang terdiri daripada pelabur berbalik purata dan pengikut tren. Seterusnya, model HG-HAM diperkenalkan dengan menambah ejen kerajaan sebagai panduan untuk intervensi. Parameter model dianggarkan menggunakan data harian dari 2006 hingga 2022, meliputi tiga tempoh penting: krisis kewangan 2008, kejatuhan pasaran saham China 2015, dan pandemik COVID-19. Simulasi dinamik sistem mengesahkan keberkesanan model, dan analisis senario dilakukan untuk menentukan strategi intervensi kerajaan yang optimum dalam senario kejatuhan pasaran. Kajian ini menemui empat hasil utama: (1) H-HAM berjaya menangkap peralihan antara rejim heterogen, yang menyebabkan turun naik besar dalam pasaran China; (2) Kerajaan memberikan maklum balas negatif kepada perubahan harga saham, bertindak sebagai

daya penstabil yang mengembalikan harga kepada nilai asasnya; (3) Selang penumpuan teras HG-HAM lebih besar berbanding H-HAM, menunjukkan campur tangan kerajaan mampu menstabilkan pasaran; dan (4) Dalam situasi kejatuhan pasaran, saiz campur tangan kerajaan lebih kritikal berbanding ambang intervensi itu sendiri. Kajian ini memberi pandangan penting tentang intervensi kerajaan dalam pasaran yang tidak berfungsi, yang relevan bukan sahaja untuk China tetapi juga untuk negara-negara lain di seluruh dunia.

DEVELOPING A HEURISTIC HETEROGENEOUS AGENT MODEL FOR GOVERNMENT INTERVENTION DURING STOCK MARKET CRASHES IN CHINA

ABSTRACT

The Chinese stock market, characterised by a predominance of inexperienced retail investors and high levels of speculation, is notably marked by active government intervention aimed at managing major financial risks and stabilising financial markets. However, there is a scarcity of research on theoretical models that guide such intervention. This study seeks to fill that gap by developing a heuristic government model that provides guidance. The heuristic characteristics of the model are reflected in two key aspects: (1) Both investors and the government utilize a simple moving average to calculate the fundamental value of the stock market; and (2) The government employs a simple linear model to determine the intervention threshold and intervention fraction. The study begins by examining excess volatility in China's stock market using a heuristic heterogeneous agent model (H-HAM) comprising mean-reverting and trend-following investors. It then develops a novel heuristic government HAM (HG-HAM) by introducing a government agent to provide guidance for government intervention. The model parameters are estimated using daily data from the Chinese Stock Index 300 (CSI 300) spanning 2006 to 2022, covering three significant periods of market fluctuation: the 2008 financial crisis, the 2015 Chinese stock market crash, and the COVID-19 epidemic. System dynamics simulations are employed to explore the dynamic characteristics of the HG-HAM, confirming its effectiveness, and scenario-response analysis is conducted to simulate optimal government intervention strategies in specific stock market crash scenarios.

This study yields four main findings: (1) The H-HAM effectively captures the endogenous switching between heterogeneous regimes, a key contributor to large fluctuations in China's stock market; (2) The government exerts a negative feedback effect on the dynamic changes in stock prices, acting as a "centripetal force" that drives prices back to their fundamental value; (3) The core convergence interval of the HG-HAM is larger than that of the H-HAM, indicating that government participation can effectively stabilize the stock market; and (4) In specific stock market crash scenarios, the government fraction at the intervention threshold is a more critical determinant of intervention success than the intervention threshold itself. This study offers valuable insights into effective government intervention in a dysfunctional market, with practical significance not only for China but also for other countries worldwide.

CHAPTER 1

INTRODUCTION

1.1 Overview

Stock market crashes have continuously occurred since the inception of the stock market, with recent examples including the Asian financial crisis in the 1990s, the global financial crisis of 2008-2009, and the crash during the COVID-19 pandemic. These crashes repeatedly exposed the flaw of the invisible hand of the market: market failure. In light of this flaw, can the visible hand of government rectify the situation? This study attempts to develop a government intervention model with the goal of reducing market excessive volatility and maintaining market stability in the Chinese stock market.

1.1.1 China's Stock Market

1.1.1(a) A Brief Introduction of China's Stock Market

Since the establishment of the Shanghai Stock Exchange (SSE) and the Shenzhen Stock Exchange (SZSE) in 1990, the Chinese stock market has witnessed remarkable growth. By the end of 2023, the number of listed companies had exceeded 5,300 across SSE, SZSE and the Beijing Stock Exchange, which was established in September 2021.[1] Today, the Chinese stock market stands as the world's

[1] See *https://www.capco.org.cn/sjfb/dytj/index.html*.

second-largest by total market capitalization, trailing only the U.S. stock market.

China's stock market comprises two types of shares in mainland China: A-shares and B-shares. A-shares refer to the shares listed on the two primary stock exchanges and Beijing Stock Exchange, denominated in Renminbi (RMB). Research on the Chinese stock market mainly focus on A-shares, which account for approximately 96% of all traded shares.

B-shares were introduced in 1992 on both the SSE and SZSE. On the SSE, B-share prices are quoted in U.S. dollars, while on the SZSE, they are quoted in Hong Kong dollars. By the end of 2023, there are only 85 companies listed with B-shares on these exchanges, representing a tiny fraction of the overall market.

In terms of investor numbers, as of August 2023, there are 220 million individual A-share account holders and 515,000 institutional investors. Individual investors constitute 99.76% of the total.[2] In terms of trading volume, individual investors have consistently accounted for over 80% over the years. Since the introduction of the registration-based IPO regime, from 2019 to 2021, this proportion has gradually declined to 78%, 72.6%, and 65.1%, respectively.[3] In contrast, the trading proportion of domestic professional institutions such as public funds and private equity funds has been on the rise. Despite a recent decline in the trading volume of individual investors in the past two years, they remain the most crucial factor influencing the price dynamics and market performances. Especially, retail investors with larger account demonstrated strong predictive ability for returns (Jones et al., 2023).

[2]See *http://m.chinaclear.cn/zdjs/tjyb2/center_scsj_tjyb.shtml*.
[3]See *https://finance.caixin.com/2022-11-24/101969955.html*.

With the development of China's economy, China's stock market is also receiving increasing attention from the industry and academia. In just over three decades, China's stock market has undergone remarkable growth and transformation, benefiting not only from Western financial and economic theories and their approaches to managing capital markets — particularly their experience in the stock market — but also from government policies and regulatory measures tailored to the country's unique economic and institutional context. As of December 31, 2024, the cumulative market value of China's stocks had risen to an impressive 86.01 trillion RMB, consolidating its position as the world's second largest stock market. However, this rapid development has also revealed some shortcomings that urgently need attention and improvement. Overall, China's stock market exhibits the following distinctive characteristics.

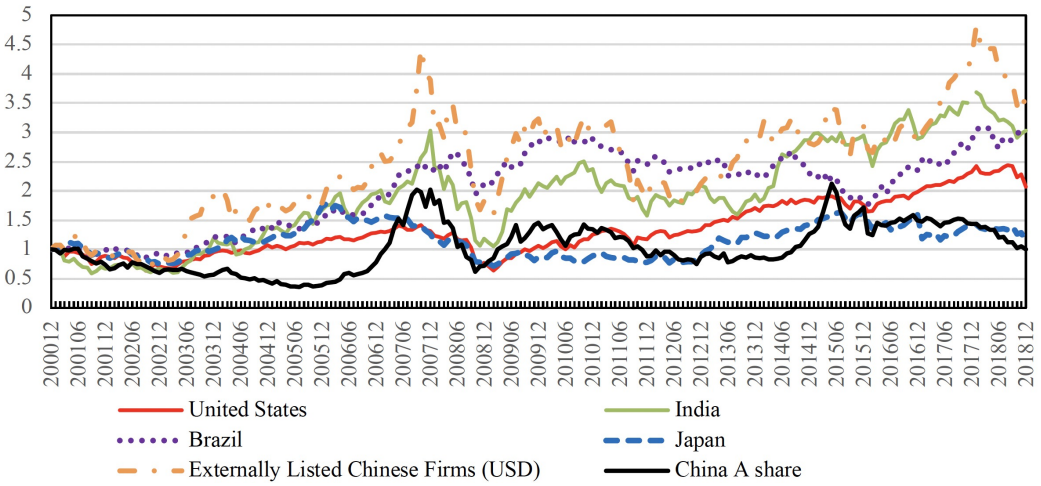
Firstly, a substantial portion of investors in China's stock market are inexperienced small and medium-sized investors. According to the *2023 Shenzhen Stock Exchange Annual Report* released by the SZSE, individual investors account for 99.73% of all investors. This percentage was 99.84%, 99.7%, and 99.73% in 2020, 2021, and 2022, respectively. These numerous retail investors often lack experience and knowledge in finance and investment, frequently exhibiting behaviours such as overconfidence, excessive pessimism, and other irrational tendencies.

Secondly, compared to the stock markets of developed Western countries, the Chinese stock market boasts a higher turnover rate and greater price volatility. Data spanning from 2014 to 2023 revealed that the average daily turnover rate of A-shares in China's was 1.07%, 1.5 times that of the United States during the same period.

Additionally, among the world's major stock markets, China Securities Index 300 (CSI 300) exhibits relatively high price volatility. For instance, the standard deviation of monthly returns for the CSI 300 Index over the past decade was 7.3%, whereas the corresponding figure for the S&P 500 Index was 3.9%.[4]

1.1.1(b) Return and Risk Characteristics

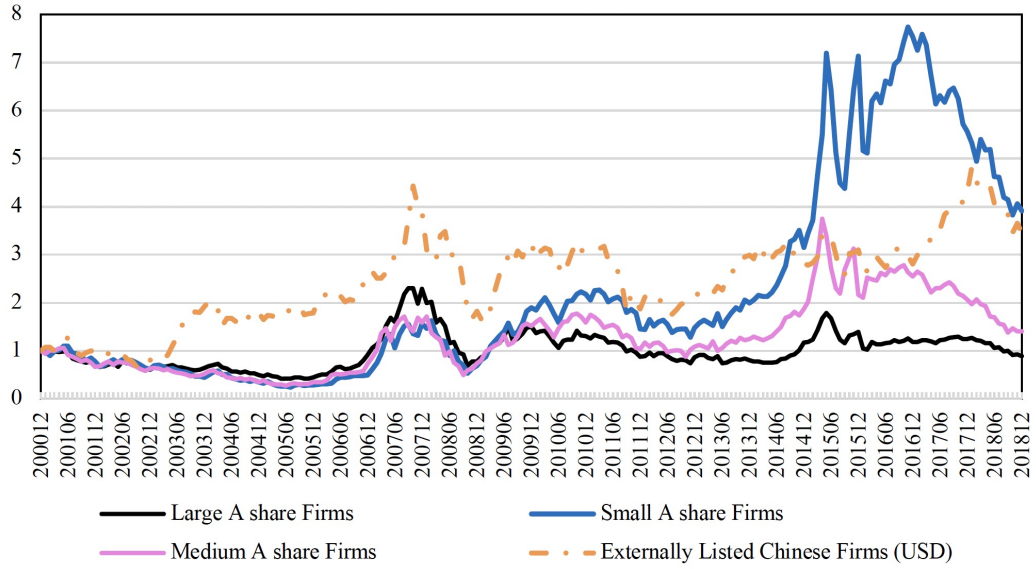
1) **Returns of Chinese A-share market**. According to Allen et al. (2024), from 2000 to 2018, China's stock market performed the worst among several major stock markets. If an investment portfolio in the Chinese A-share market, valued at 1 RMB at the beginning of 2000, was held until the end of 2018, the portfolio would have only increased to 1.01 RMB after adjusting for inflation. This return performance was even worse than that of the Japanese stock market, which suffered from prolonged economic and financial problems during the same period. Figure 1.1 shows the the buy-and



Source: Allen et al. (2024). Dissecting the long-term performance of the Chinese stock market. *The Journal of Finance*, 79(2), 993-1054.

Figure 1.1: Buy-and-Hold Returns of Stocks Listed in Large Countries

[4]The data is sourced from the Wind Database.

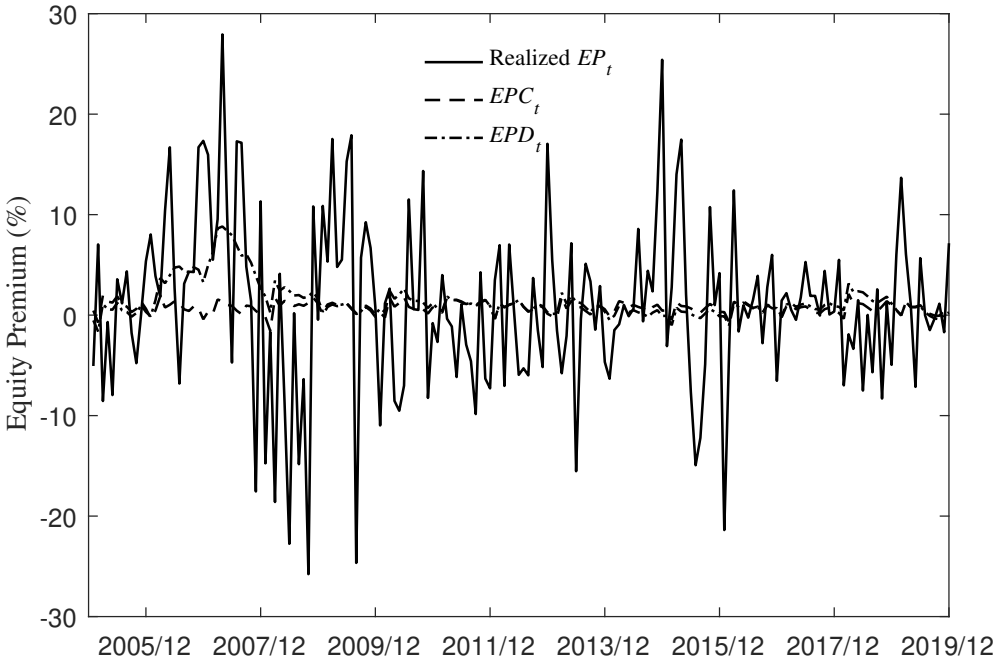


Source: Allen et al. (2024). Dissecting the long-term performance of the Chinese stock market. *The Journal of Finance*, 79(2), 993-1054.

Figure 1.2: Returns of Large, Medium, and Small Firms Stocks Listed in the A-share Market

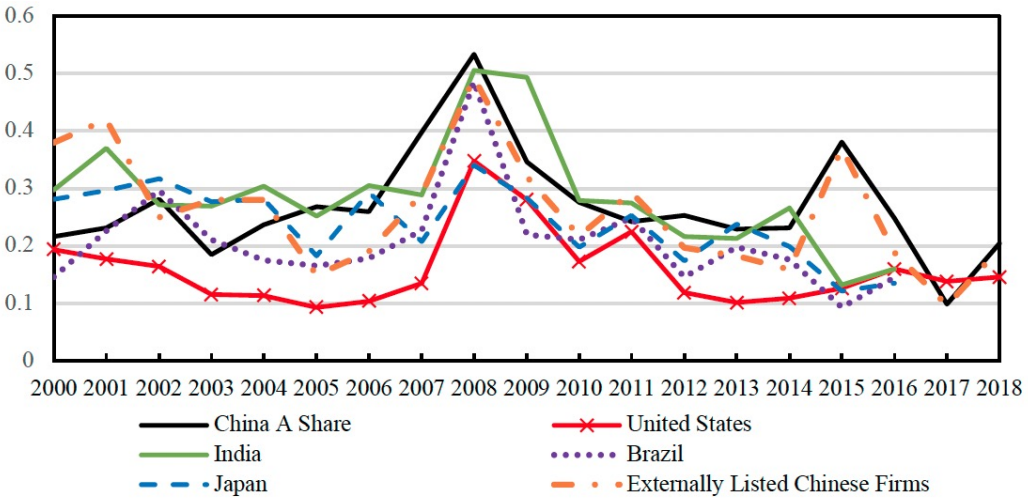
hold returns of stocks listed in the markets of China, India, Brazil, the US and Japan. Besides the cumulative returns, Hu et al. (2021) and Huang et al. (2020) calculated the average returns of the Chinese A-share market. According to Hu et al. (2021), from 1993 to 2016, the annualized return on large-company stocks in the Chinese A-share market, adjusted for inflation, was 1.64% (the geometric mean), while the corresponding return for small-company stocks was 16.60% (adjusting for inflation). This is consistent with the results of Allen et al. (2024). Figure 1.2 shows the average returns of small, medium, and large A-share companies. In addition, Huang et al. (2020) calculated the average returns of the CSI 300 index (2005–2017) and found that the realized yearly equity premium was 8.11% (the geometric mean).

2) **Risks of Chinese A-share market**. Volatility of returns is commonly used to measure risk in the stock market. Zhou, Huang, et al. (2022) calculated the monthly equity premium on the CSI 300 index (2015–2019) and found it fluctuated in the



Source: Zhou et al. (2022). Behavioural heterogeneity and equity premium volatility in China. *Applied Economics Letters*, 29(15), 1399–1404. *EP* (Equity Premium), *EPC* (EP based on the consumption growth model), *EPD* (EP based on the dividend growth model).

Figure 1.3: The Realized Equity Premium on the CSI 300 Index



Source: Allen et al. (2024). Dissecting the long-term performance of the Chinese stock market. *The Journal of Finance*, 79(2), 993-1054.

Figure 1.4: Comparing Annualized Stock Return Volatilities among Large Markets

interval of $[-25.8\%, 27.9\%]$. Figure 1.3 shows the volatility of the realized equity premium on CSI 300 index. Allen et al. (2024) compared the volatilities of annualized stock return for A-share firms and firms listed in other large markets, and found that A-share firms exhibited significant volatility (Figure 1.4). Hu et al. (2021) investigated the volatility of annual returns for all A-share listed firms, finding that from 1993 to 2016, small-cap stocks exhibited the highest risk, with a standard deviation of 66.44%, and delivered the highest total return, with a geometric mean of 21.4% (unadjusted for inflation). In contrast, over the same period, large-company stocks also exhibited impressive risk, with a standard deviation of 59.12%, yet yielded the lowest total return, with a geometric mean of 5.8%. Overall, the Chinese A-share market exhibits higher risk but provides the lowest return among major stock markets. This trend was particularly evident during the sharp fluctuations observed in September and October 2024.

1.1.1(c) China's Model of Managing the Stock Market

Since the economic reforms in 1978, China's economy has achieved remarkable success, with the most notable accomplishment being the lifting of the largest number of impoverished people out of poverty. Therefore, it is unsurprising that its approach has drawn substantial attention from the global world. In recent years, there has been a growing body of literature investigating China's mode of managing the economic and financial system, such as Hu et al. (2009), Ji (2010), Naughton (2010), Zhao (2017), Song and Xiong (2018), Brunnermeier et al. (2022) and He and Wei (2023).

Compared to stock markets in Western countries, the Chinese stock market

exhibits distinctive Chinese characteristics. Firstly, state-owned enterprises have the largest market capitalization share.[5] Naughton (2010) argued that the intertwining of state and market is a distinctive feature that sets China apart from other markets. The prompt rebound of the Chinese stock market after the 2008 financial crisis was, to a significant extent, driven by state-owned enterprises, which played a key role in economic activity (Ji, 2010). Correspondingly, one of the primary reasons for the overall under-performance of the Chinese stock market among large markets is also attributed to the poor performance of large state-owned enterprises (Allen et al., 2024).

Secondly, intensive government intervention is another distinctive characteristic of China's model for managing the stock market. The study titled *China's Model of Managing the Financial System* (Brunnermeier et al., 2022), published in the journal of *Review of Economic Studies*, is regarded as one of the most profound pieces of literature investigating Chinese government intervention in the stock market. This paper developed a equilibrium model comprising government and found that while the government can reduce excess volatility, it can also introduce policy noise to the market and impact price efficiency. After conducting a welfare analysis, Brunnermeier et al. (2022) concludes that financial stability is prioritized over other policy objectives in the Chinese stock market. To maintain market stability, the Chinese government has implemented a series of intervention measures, including reducing stamp taxes on stock trading, temporarily halting initial public offerings, lowering bank reserve requirements and deposit rates, and directly entering the

[5] According to a inner report of Cinda Securities, as of February 3, 2023, state-owned enterprises accounted for 46.9% of the total market capitalization of Chinese A-share market, while private enterprises held 39.9%, ranking second.

market to purchase targeted stocks (Huang et al., 2019; Li & Jin, 2019).

Government intervention in the Chinese stock market is characterized by its paternalistic management, which is deeply rooted in China's culture and history. China's stock market development time is short, whether from the construction of relevant laws and regulations, or the education and protection of investors, there are many deficiencies. The Chinese government's direct and indirect intervention in the stock market is essential to ensure its healthy development and to protect the interests of small and medium-sized investors. As a result, the Chinese government's involvement in the stock market is more active and frequent compared to Western countries. After the 2015 Chines stock market crash, to maintain market stability and public confidence, the Chinese government has established the "national team" fund for direct market intervention.[6]

1.1.2 Frequent Stock Market Crashes

Over the last three decades, global stock markets have experienced frequent episodes of stock market crashes. Each past stock market crash has triggered a sharp decline in stock prices, causing significant losses for investors. It may even lead to a severe economic crisis, resulting in economic decline and recession. Taking the example of the Asian financial crisis, from July 1, 1997 to January 31, 1998, the major stock indices in Asia experienced significant declines: the SET (Stock Exchange of Thailand) Index plummeted by 50%,[7] the KLC (Kuala Lumpur

[6]This fund, featuring entities such as China Securities Finance Corporation Limited, Central Huijin Investment Limited Liability Company and China Financial Stability Development Fund, plays key roles in direct market intervention.

[7]Here, the maximum daily closing price decline during the sample period is calculated, with data sourced from *https://finance.yahoo.com/*, and the same applies to the subsequent figures in this section.

Composite) Index of Malaysia dropped by 56%, the JKSE (Jakarta Composite) Index of Indonesian plunged by 54%, the KOSPI (Korea Composite Stock Price Index) saw a 55% decline, the PSEi (Philippine Stock Exchange Index) experienced a 46% drop, the Japanese N225 (Nikkei 225) Index fell by 28%, the Hong Kong Hang Seng Index plummeted by 51%, and the Singapore STI Index (Strait Times Index) witnessed a 46% decline, as shown in Table 1.1. This financial crisis marked the end of decades of economic prosperity in Asia, resulting in the bankruptcy and closure of tens of thousands of businesses. It triggered a severe economic recession and even led to political instability in Thailand, Indonesia and Korea.

Table 1.1: Decline of Major Stock Markets during Asian Financial Crisis

Country/Region	Stock Index	Decline
Thailand	SET	50%
Malaysia	KLC	56%
Indonesia	JKSE	54%
Korea	KOSPI	55%
Philippines	PSEi	46%
Japan	N225	28%
Hong Kong	Hang Seng	51%
Singapore	STI	46%

Ten years later, the 2008 global financial crisis originating in the United States once again plunged stock markets worldwide into panic. The global financial crisis was the most severe since the Great Depression of the 1930s. During the period from September 1, 2008 to March, 31 2009, with the bankruptcy of Lehman Brothers, the

S&P 500 (Standers&Poor's 500) Index in the United States plummeted by 46%, the FTSE 100 (Financial Times Stock Exchange 100) Index in the United Kingdom dropped by 46%, the DAX (Deutscher Aktienindex) in Germany saw a 44% drop, the CAC 40 (Cotation Assistée en Continu 40) Index in France registered a 44% decrease. In Asia, the drops were impressed, with CSI 300 (China Securities Index 300) plunging by 71% and Japan's N225 Index witnessing a decline of 48%.[8] Additionally, some other emerging markets also suffered significant losses, with the Brazil IBOV (Índice Bovespa) Index falling by 52% and the India Nifty 50 (National Stock Exchange Fifty) Index dropping by 45%, as shown in Table 1.2. These figures vividly reflect the far-reaching impact of the 2008 financial crisis on global stock markets, exposing the vulnerability of financial systems during times of crisis. In this global financial crisis, not only did stock markets drop sharply, causing substantial losses for investors, but also many businesses and individuals went bankrupt. Countless people lost their jobs, and the global economy took a hard hit, leading to a negative growth in the global GDP the subsequent year.[9]

Following the 2008 financial crisis, a fresh set of challenges emerged in stock markets, triggered by the widespread impact of the global COVID-19 pandemic. From January 1, 2020 to March 30, 2020, the S&P 500 Index plummeted by 34%, the N225 Index experienced a 31% decline, the FTSE 100 Index decreased by 35%, the DAX Index saw a 38% drop, the CAC 40 Index registered a 38% decrease, the MIB (Milano Indice di Borsa) Index in Italy underwent a 41% decline, and the CSI 300 Index witnessed a dip of 14%, as shown in Table 1.3. During this sharp decline, the

[8] At that time, the Chinese stock market was undergoing a surge, with the index at a relatively high level, resulting in a more substantial decline.

[9] According to World Bank, the global GDP growth rate was 2.1% in 2008 and -1.3% in 2009. The data is sourced from *https://datatopics.worldbank.org/world-development-indicators/*.

Table 1.2: Decline of Major Stock Markets during 2008 Global Financial Crisis

Country	Stock Index	Decline
United States	S&P 500	46%
United Kingdom	FTSE 100	46%
Germany	DAX	44%
France	CAC 40	44%
Japan	N225	46%
China	CSI 300	71%
Brazil	IBOV	52%
India	Nifty 50	45%

S&P 500 Index triggered the circuit breaker mechanism four times in the span of eight consecutive trading days.[10] Since the establishment of the circuit breaker mechanism in 1987, including the four during the COVID-19 pandemic, there have been a total of five circuit breakers. Although this stock market crisis was triggered by the COVID-19 pandemic, it has indeed exposed the vulnerability of the stock market.

In recent years, in addition to the three stock market crashes mentioned above that have affected the world, there have been a number of stock market crashes that have affected local regions, such as the 2015 China's stock market crash.

[10]The first circuit breaker occurred on March 9, 2020, at 9:34 a.m. when the S&P 500 Index fell by 7%, triggering the circuit breaker mechanism. Trading was halted for 15 minutes, resuming at 9:49 a.m. The S&P 500 closed the day with a 7.6% decline. The second occurred on March 12, at 9:35 a.m. when the S&P 500 Index fell by 7%. The index closed the day with a 9.5% decline. The third occurred on Mach 16, at 9:42 a.m. when the S&P 500 Index fell by 7%. The index closed the day with a 11.98% decline. The fourth occurred on Mach 18, at 9:34 a.m. when the S&P 500 Index fell by 7%. The index closed the day with a 5.89% decline. The data is sourced from *https://finance.eastmoney.com/a/202003211426884343.html*.

Table 1.3: Decline of Major Stock Markets during COVID-19 Pandemic

Country	Stock Index	Decline
United States	S&P 500	34%
United Kingdom	FTSE 100	35%
Germany	DAX	38%
France	CAC 40	38%
Japan	N225	31%
Italy	MIB	41%
China	CSI 300	14%

1.1.3 Global Government Intervention

It is indisputable that a stock market crash poses a significant threat to the robust and stable development of financial markets, disrupting the normal functioning of economic activities and potentially triggering a systemic financial crisis. Consequently, many countries and regions worldwide implement a range of measures to intervene in the capital market during such crises. These interventions include administrative measures such as short-selling bans, fiscal policies involving subsidies and tax cuts, monetary policies encompassing changes in interest rates and deposit reserves, and direct participation in the asset market through the purchase of underlying stocks. In a word, governments employ various methods, including direct buying and selling of securities, dissemination of market information to influence market sentiment and trader expectations, and restrictions on trading types or scales to uphold market sentiment.

Among these intervention strategies, direct trading in the stock market stands out

as a crucial method employed by governments because the intervention effect by the direct trading is more directive and quicker. For instance, to do direct intervention during stock market crashes, Japan took steps to stabilize its stock markets by establishing the Mutual Securities Fund in 1951 and 1964, as well as the Stock Market Stabilization Fund in 1995. Similarly, Korea established the Security Fund in 1990, Hong Kong initiated the Yingfu Fund for the Asian financial crisis in 1998, Taiwan implemented the National Security Fund in 2000, and China introduced the "national team" Fund for the stock crash in 2015. These government intervention funds are dedicated to stabilizing the stock market by executing counteractive operations that mitigate excessive volatility, with the overarching goal of preserving market stability.

Besides the interventions by Asian counties and regions, the United States government also intervened in the stock market, such as, the Federal Reserve's decisive intervention during the 1987 stock market crash, the market calming behaviour after the 9/11 terrorist attacks in 2001, and a series of market support measures implemented by the United States Treasury and the Federal Reserve during the 2008 financial crisis. Although the United States has not established a specialized government intervention fund, the motivation and purpose of its intervention is the same as that of a government intervention fund. In fact, since the 2008 global financial crisis, even governments in the OECD (Organization for Economic Co-operation and Development) countries have intervened in the market after episodes of large fluctuations or severe market dysfunction. Government direct intervention in the stock market is becoming increasingly common.

1.2 Problem Statement

As China's capital market becomes more open to the outside world, the risks of external impact are also increasing. The maintenance of stability in the capital market and the safeguarding of the bottom line against systemic financial risks have been repeatedly emphasized in major economic and financial conferences of the Chinese government in recent years. The stock market plays a crucial role in the financial system, and its stable and healthy development is of paramount importance to the entire financial system.

To maintain stability in the stock market, the Chinese government established the "national team" fund during the stock market crash in 2015. Currently, research on the "national team" fund primarily focuses on empirical studies of its stock-holding preferences and intervention effects, with relatively less attention given to theoretical and model-based research on its interventions. Based on recent research on the "national team" fund, it is observed that its intervention actions lack scientific guidance, intervention decisions and timing are somewhat arbitrary, and the intervention effects are not satisfactory. During the process of "national team" fund intervention, investors (both individual and institutional) are tend to trading stocks traded by the fund while ignoring the fundamental information about the underlying stocks, which introduces policy noise into the market and decreases market efficiency.

Therefore, **the key and urgent issue in the government intervention process is how to resolve the dilemma of balancing the need to keep market stability while also maintaining market efficiency**. If the government intervention is guided by a scientific theory or model, and if the government's trading behaviour can promote the

price reversion of the underlying stocks to their fundamental values, the process of price reversion will undoubtedly be accelerated by the tracking trading of individual and institutional investors in the market. In this situation, government intervention can reduce the volatility of the market, thereby helping to maintain the market efficiency. That is why it is especially important to develop a scientific model to provide appropriate guidance to government intervention.

1.3 Research Gap

Over the past decades, research on stock market crashes and government intervention has has focused on several key areas. First, the debate on government intervention during market failures. After the 1929 Wall Street crash, a belief in market self-correction led to widespread economic devastation. This spurred Keynes' 1936 theory advocating government intervention to stabilize economies. The debate has since evolved, with neoliberalism in the 1970s opposing excessive intervention, but failures in the 1990s Asian financial crisis revived support for moderate government action, as seen in New Keynesianism (Zhang et al., 2018). During the 2008 global financial crisis, governments took direct action, such as bailouts and short-selling restrictions, to prevent systemic risks (Boulton & Braga-alves, 2010; Cheng et al., 2012; Jin & Liu, 2009). While intervention mitigated short-term crises, findings on its long-term impact remain mixed. Some studies suggest that such actions raised risk-taking behaviour in financial institutions (Duchin & Sosyura, 2014) and impaired price discovery efficiency when market participants overly focused on government signals (Brunnermeier et al., 2022).

Second, the causes of stock market crashes and the necessity of government intervention. Crashes are often triggered by liquidity shortages, as identified by various studies, see for example Brunnermeier and Pedersen (2009) and Cai and Song (2010). Strategic government intervention can relieve liquidity pressures and mitigate crash risks in the short term (Huang et al., 2019; Li & Jin, 2019). Behavioural factors, such as investor overreaction and bounded rationality, further intensify volatility (Hommes & in't Veld, 2017; Shiller, 1990). Since Zeeman (1974) introduced the first heterogeneous agent model (HAM) in asset price dynamics, HAMs have proven effective in explaining bubbles, crashes, and excess volatility (Chiarella et al., 2014; Lof, 2015; Zhang et al., 2019). However, research on how to develop a HAM with government intervention remains scarce.

Third, empirical studies on government intervention in stock markets. Case studies from the Asian financial crisis, the 2008 global crisis, and the 2015 Chinese stock market crash highlight mixed outcomes. Hong Kong's 1998 intervention stabilized prices but disrupted normal market dynamics (Bhanot & Kadapakkam, 2006; Su et al., 2002). Similarly, U.S. interventions in the 2008 global financial crisis mitigated risks but also increased systemic risk in some financial institutions (Grace et al., 2017; Pennathur et al., 2014). In China's 2015 market intervention, government actions effectively calmed volatility, yet concerns arose over reduced market efficiency as investor focus shifted from fundamentals to government signals (Li & Jin, 2019; Zheng & Xu, 2019).

In light of the existing research, this study identified several key gaps:

(1) Mixed Findings on the Necessity of Government Intervention: The literature reveals conflicting results regarding the necessity of government intervention during a stock market crash.

(2) Limited Theoretical Models for Direct Intervention: Although many studies demonstrate that HAMs offer strong explanatory power for stock market crashes, there is a relative scarcity of literature focused on developing a heuristic HAM that provides guidance on direct government intervention during a stock market crash.

(3) Varied Results on Intervention Effects: Existing studies present diverse outcomes concerning the effects of government intervention during financial crises.

(4) Insufficient Guidance on Optimal Intervention Strategies: There is little literature providing a method for determining an optimal strategy for government intervention in a given crash scenario.

1.4 Research Questions

The study aims to address these gaps through the investigation of the following research questions:

(1) Why is the government intervention necessary during the stock market crashes in China?

(2) How can government intervention be modelled in the heuristic HAM to alleviate the dilemma of government intervention?

(3) Does the heuristic HAM offer effective guidance for government intervention during stock market crashes in China?

(4) Which intervention level produces more favourable outcomes in a specific crash scenario?

1.5 Research Objectives

The study systematically explores the following research objectives:

(1) To investigate the necessity of government intervention during stock market crashes in China by employing a heuristic benchmark HAM with two traditional agents.

(2) To extend the benchmark HAM without government intervention into a heuristic HAM that incorporates government intervention.

(3) To estimate model parameters and evaluate the effectiveness of the heuristic HAM with government intervention.

(4) To simulate optimal government intervention strategies under specific stock market crash scenarios.

1.6 Research Significance

According to fundamental theories of financial economics, individual investor behaviour serves as a key driver of macroeconomic phenomena in capital markets. This study begins its exploration from the perspective of investors' belief

transformations during stock market crashes. It aims to develop a mathematical model to provide guidance for government intervention during stock market crashes, which holds both theoretical and practical significance.

1.6.1 Theoretical Significance

This study has several contributions to the literature on government intervention and behavioural heterogeneity. Firstly, it provides insights into addressing a common dilemma encountered during government intervention processes. Such interventions often face the challenge of balancing market stability with market efficiency. The intervention model developed in this research provides a theoretical solution to this dilemma.

Secondly, this study enriches the variety of behavioural HAMs and expands their applicability. Traditionally, behavioural HAMs are mainly employed to explain market anomalies, such as excessive volatility and market bubbles. In this research, a heuristic decision-making approach is introduced into a HAM, along with the integration of an additional government agent. Consequently, the new HAM can provide theoretical guidance for government intervention.

Furthermore, this study represents a significant endeavour to incorporate a heuristic decision-making approach into a behavioural HAM. Previous HAMs often relied on conventional asset pricing models, such as the dynamic Gordon growth model and the Campbell-Cochrane consumption-habit model, to determine the fundamental values of capital assets, which formed the basis for calculating price deviations. For instances, see Boswijk et al. (2007), Lof (2015), Hommes and in't

Veld (2017), Zhang et al. (2019) and Zhou, Li, et al. (2022). In contrast, this study estimates fundamental values using a heuristic decision-making approach rather than relying on standard asset pricing models. This heuristic approach is not only faster and more cost-effective but also demonstrates greater accuracy compared to traditional asset pricing models (Gigerenzer & Gaissmaier, 2011).

1.6.2 Practical Significance

In practical terms, this study holds the following significance. Firstly, it offers valuable guidance for effective government intervention. HAMs can capture the positive and negative feedback forces that drive asset price fluctuations. The involvement of the government enhances the strength of negative feedback on prices, thereby contributing to market stability. The insights generated can offer suggestion for decision-making related to the management and operation of government intervention funds and other practical activities.

Secondly, establishing a scientifically grounded government intervention model strengthens the institutional foundations of the Chinese stock market. This enhancement increases the market's resilience against both systemic and non-systemic risks, thereby elevating the overall level of financial risk management.

Moreover, the proposed model holds global practical significance. Its insights offer valuable perspectives on how governments can effectively intervene in dysfunctional markets. While particularly relevant to China, the model's applicability extends beyond borders, providing insights that can benefit other countries worldwide. Therefore, this study not only contributes to strengthening the

foundational infrastructure of China's financial system but also provides valuable suggestions for the development of capital markets in other developing countries.

1.7 Definition of Key Terms

The definitions of the key terms addressed in this study are as follows:

Excess Volatility: Excess volatility refers to the phenomenon in which the degree of asset price fluctuations in financial markets exceeds what can be reasonably explained by fundamental economic factors. It is frequently used to describe the volatility of asset prices relative to their fundamental value or intrinsic factors (Shiller, 1981).

Stock Market Crash: Stock Market Crash or Stock Market Crisis is a sudden and sustained decline that exceeds the reasonable range explainable by fundamental economic factors, resulting in investor panic and a severe loss of market confidence (Akerlof & Shiller, 2009).

Government Intervention: Government intervention refers to actions taken by the government in economic or social activities to achieve specific goals or solve problems (Keynes, 1936).

Animal Spirits: In economics, Animal Spirits refers to factors related to emotions, confidence, and expectations in human behaviour. The term describes people's attitudes and emotions toward uncertainty about the future and economic activities (Keynes, 1936).

Heuristic Decision-making: Heuristic Decision-making is a strategy that ignores part of the information, with the goal of make decisions more quickly, frugally, and/or accurately than more complex methods (Gigerenzer & Gaissmaier, 2011).

Behavioural Heterogeneity: Behavioural Heterogeneity refers to the behavioural differences exhibited among individuals in specific situations. In the fields of economics and finance, this concept typically involves the decision-making and behavioural disparities among individual investors or market participants. These differences may be influenced not only by rationality and information but also by emotions, psychological biases, and other irrational factors. Therefore, the concept of behavioural heterogeneity emphasizes the diversity among market participants and the existence of irrational behaviour (Boswijk et al., 2007; Brock & Hommes, 1998; Zeeman, 1974).

Heterogeneous Agent Model: Heterogeneous Agent Model refers to a model used in economic and financial research that takes into account the diverse characteristics, behaviours, and decision rules among market participants. In this model, the modelled agents are endowed with heterogeneity, meaning they differ from each other and may have distinct information, risk preferences, expectations, and other individual traits. Heterogeneous agent models are commonly employed to more realistically depict the diversity of market participants, particularly in terms of investment decisions, risk tolerance, and information acquisition. The use of such models aids in capturing the interactions among different types of participants in the market and their responses to various factors, providing a more comprehensive understanding of market behaviour and dynamics (Dieci & He, 2018).

Mean-reverting Investors: Mean-reverting investors tend to believe that asset prices are determined solely by their fundamental value, as defined by the present discounted value of future dividends. They expect asset prices to revert to their fundamental value over time (Brock & Hommes, 1998).

Trend-following Investors: The investment beliefs held by trend-following investors contrast with those of mean-reverting investors. Trend-followers contend that asset prices are not entirely determined by fundamentals and can instead be predicted using simple technical trading rules, extrapolation of trends, and other patterns observed in historical prices (Brock & Hommes, 1998).

System Dynamics Simulation: System Dynamics Simulation refers to the process of using system dynamics, a method in the field of systems thinking and modelling, to simulate and analyse the dynamic behaviour of complex systems over time. In this approach, a system is represented as a set of interconnected components or variables, and the relationships between these components are modelled using mathematical equations. System dynamics simulations are valuable for understanding the feedback loops, delays, and nonlinear interactions within a system. This method allows researchers and analysts to explore how changes in one part of the system can influence the entire system over time. It is commonly employed in various fields, including economics, engineering, ecology, and management, to gain insights into the behaviour of complex systems and to inform decision-making processes.

Scenario-response Analysis: Scenario-response analysis refers to a method used to examine the potential outcomes or responses of a system or situation under