The Emergence of Asset Price Bubbles and Debt Overhang

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To my parents,
Guanghua Tang and Mingjing Li

Abstract

This paper has an in-depth discussion on the correlation between asset price bubbles and monetary policy. In this paper we proposed a novel theory of asset bubbles; provided empirical evidence of our theory; provided a discussion on the correlation between debt overhang, which is a common problem for enterprises after the burst of asset bubbles, and the power structure of enterprises.

In the first chapter, we briefly introduced the historical background of asset price bubbles and the motivation of our paper. We believe that the current literature research is insufficient on how monetary policy affects asset bubbles. Since 2022 the inflation is leading to the tightening of monetary policy highlights the necessity to study the impact of monetary policy on asset price bubbles. Moreover, in the adverse scenario of asset price bubble bursts, we also need to explore how to alleviate debt overhang to promote economic recovery.

In the second chapter we provide a theory of the relation between asset price bubbles and monetary policy. With incomplete information, the uncertainty caused by stochastic technology shock leads to a bubble. Households adjust investment decisions through the case-based decision (CBD) process from the information generated by utility feedback that strengthens or weakens their beliefs. Without easing monetary policy, this information feedback process will exclude bubbles in the long-term equilibrium in which bubbles stochastically emerges. Easing monetary policy mitigates the problem of investment misallocation, and hence distorts the information feedback and enables bubbles to exist in the long-term equilibrium.

In the third chapter we analyze the effects of monetary policy on asset bubble in the US stock market over the period 1954-2019 based on ex post mispricing indicator at the firm level by using a fixed-effect panel model. The results suggest that easing (tight) monetary policy have a positive (negative) effect on the upward movement of asset mispricing.

In fourth chapter we use a structural vector autoregression (SVAR) model identified by directed acyclic graphs (DAGs) to conduct market-level analysis. In line with firm level analysis, our evidence in this chapter suggests that easing (tightening) monetary policy has a significantly positive (negative) effect on the upward movements of bubble components or asset overpricing.

In the fifth chapter we discussed the effect of centralized decision power on the debt overhang, to discuss if the adverse consequences of asset price bubble could be mitigated through diversified power structure of companies. Following the stakeholder theory, we assume that a more diversified decision structure tends to maximum the overall interest of the firm. We developed a theory to model how a centralized management would influence the decision process of investment over debt overhang. We show that a firm with higher CEO power react more sensitive to the effect of debt overhang, which support our hypothesis.

In the sixth chapter, we provide a summary and conclusions.

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Declaration

I declare that, except where explicit reference is made to the contribution of others, that this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution

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Abbreviations

- OLG - Overlapping Generation
- CBDT - Case-based Decision Theory
- CBD - Case-based Decision
- MPL - Marginal Productivity of Labour
- MPK - Marginal Productivity of Capital
- QE - Quantitative Easing
- GDP - Gross Domestic Product
- CPI - Consumer Price Index
- CSI - Consumer Sentiment Index
- lnVol - Natural Logarithm of Trading Volume
- lnSize - Natural Logarithm of Firm Size
- SP 500 - Standard and Poor's 500
- FFR - Federal Funds Rate
- M2 - Seasonally Adjusted Broad Money Supply
- M2G - Monthly Growth of Seasonally Adjusted Broad Money Supply
- SIC - Standard Industrial Classification
- amadMb - annual moving average of dMB
- SVAR - Structure Vector Autoregression
- DAG - Directed Acyclic Graph
- VAR - Vector Autogression
- AIC - Akaike Information criteria

- `BIC` - Ayesian Information Criteria
- `VAR` - Vector Autogression
- `CIG` - Conditional Independence Graph
- `PC` - Peter Spirtes and Clark Glymour algorithm
- `CCI` - OECD Consumer Confidence Index
- `YS10-2` - United States and 10 years to 2 years treasury yield spread
- `CEO` - Chief Executive Officer
- `CCI` - OECD Consumer Confidence Index
- `CSHO` - Common Shares Outstanding
- `(PCA` - Principal Components Analysis
- `(SIC` - Standard Industrial Classification system

Chapter 1

Introduction and Motivation

Asset price bubbles are deviations of asset prices from fundamentals over a longer period of time (Hott, 2009). In the economic history of the past four centuries, examples of asset price bubbles abound. From the Dutch Tulip Mania of 1634 (Garber, 1989), the England South Sea Bubble in 1720(Temin and Voth, 2004), the France Mississippi Bubble in 1719 (Garber, 1990), to the recent Japanese real estate bubble of the 1990s, the NASDAQ dot-com price bubble of 1998–2000(Ofek and Richardson 2003) and the 2008 US subprime mortgage crisis, among others. It is evident that significant deviations of asset prices from their intrinsic values are not isolated incidents.

Looking back at numerous bubble events throughout history, it can be observed that, while the specific details of asset bubbles vary in each cases, for example bubbles can emerge in different asset categories, ranging from commodities (such as tulips, sugar, or grains) to financial assets (especially stocks and bonds), real estate (land as well as residential and commercial properties), and even infrastructure projects. However, the emerge and collapse of asset price bubbles have repeatedly played out in the course of the world economy's development, covering almost every instance of financial crisis.

Substabtial literature have proved that asset price bubbles could cause damage to real economic activities. The expansion phase of asset price bubbles could lead to misallocation of resources, because the investment move to speculation assets rather than productive enterprises (Caballero and Krishnamurthy, 2006; Hirano et al., 2015). This transfer process increases the risk of mortgage foreclosure by lenders when the bubble bursts, as well as the risk of economic recession or even overall economic crisis(Case et al., 2000). The collapse of the asset price bubbles has increased the bad debts of the banking industry, and bank failure may cause a large-scale economic recession. Bezemer, D.J., 2011.Evgenidis, A. and Malliaris, A.G., 2020.

The phenomenon of asset price bubbles, characterized by the rapid and unsustainable increase in the prices of financial assets, has proven to be a source of financial instability. Shiller (1981), as well as LeRoy and Porter (1981), pointed out that the volatility of rational stock prices, based on the dividend discount model, is greater than the volatility of actual prices. They found that measures of stock price volatility over the past century appear to be five to thirteen times to high to be attributed to new information about future real dividends if uncertainty about future dividends is measured by the sample standard deviations of real dividends around their long-run exponential growth path. Subsequently, Blanchard and Watson (1982), and Tirole (1985), argued that the presence of bubbles in stock prices could lead to a violation of the variance-bound condition.

Given the significant impact of asset price bubbles on the economy, studying the causes and evolution of bubbles is a crucial topic in economics. Literature has provided substantial explainations for the emergence of asset price bubbles. important bubble theories include rational bubble theory (Diba and Grossman, 1988), dynamic inefficiency theory (Tirole, 1985), agency theory (Allen and Gale, 2000), noise trader theory (Harrison and Kreps, 1978; De Long et al., 1990), extrapolative expectation theory (Hirshleifer et al., 2015; Barberis et al., 2018), speculation theory (Shiller., 2014), credit constraint theory (Miao et al, 2014; Martin and Ventura, 2016; Miao and Wang, 2018), shorting (Nutz, and

Scheinkman, 2020), diagnostic expectation (Bordalo et al., 2021), imitation (Johansen et al., 2000), and herding (Devenow and Welch, 1996). These studies provide important interpretation on the emergence of asset bubbles, however they do not address the issue of monetary policy and asset bubbles.

Brunnermeier and Schnabel (2015) analysized 23 bubble episodes, find that most of the identified asset bubble emerged when the stance of monetary policy was expansive. For example the Japan real estate bubble in 1990s,US subprime housing bubble in 2007 and Spanish housing bubble in 2000s are accompanied by easing monetary policy. Even for earlier periods, when central banks either did not exist or were more similar to private banks, the issuance of bank notes by private banks often had an expansionary effect on money supply in the early phase of a bubble episode. For example Latin American Mania in England in 1824-25, and Germany Gründerkrise bubble in 1873, were denomination by issuing of banknotes.US panic in 1857 and Australia panic in 1893 are accompanied by gold discoveries.

Moreover, some bubbles seem to have been fueled by foreign capital inflows. For example, during the 1840s, the Railway Mania in England was driven by substantial foreign investments, the Panic of 1857 in the United State was driven by capital flow in from Europe. Foreign capital also played a substantial role in the Panic of 1893 and the German stock price bubble of 1927. Often, when bubbles burst, capital flows redirect, sparking new asset price booms in other regions. Examples of this include the Scandinavian and Asian asset price bubbles that followed the bursting of the Japanese real estate bubble, as well as the dot-com bubble and the U.S. subprime housing bubble after the Asian crisis. These events have underscored the intricate relationship between asset price bubbles and monetary policy, a connection that has captured the attention of economists, policymakers, and market participants alike. Consequently, understanding the dynamics of asset price bubbles, the cause of their formation, and mitigation of their negative impacts has emerged as a critical area of research and policy consideration.

Motivation for this paper can be categorized into four main aspects. First, Although the severity of the 2007 financial crisis push scholars to rethink the relation between monetary policy, and asset bubble, but the theoretical research about how monetary policy affect the condition of bubble emerges (or bursts) is insufficient. Monetary policy affect asset prices through many channels, and the most direct of which is through the discount rate channel. Taking the Gordon growth model as an example, for a company with a constant dividend distribution, the long-term interest rate increase from 2% to 5% will reduce its present value by five times. Belke, and Polleit (2006) suggest that the rise in central bank interest rates could lower the dividend distribution of companies, as reinvestment of corporate profits is considered more advantageous compared to income payments, thus lower the fundamental value. Moreover, monetary interventions on asset price could through inflation or financial accelerators channel (Bernanke et al, 1994, Laopodis 2010), but the fluctuation of asset price does not necessarily mean the deviation from its fundamental value. In fact, the effect of monetary policy on asset bubble is a lack of discussion in the literature. theoretical studies on the relation between monetary policy and asset price bubbles reach different conclusions. Closely related recent research on monetary policy and asset mispricing includes Gali (2014) who argues that monetary policy can not affect the conditions of rational bubble existence. Dong, Miao, and Wang (2020) demonstrate that, as entrepreneurs trade bubble assets to increase net worth, monetary policy affects the conditions of the existence of bubbles, and the steady-state bubble size. Asriyan et al., (2021) argue that bubbles can provide additional unbacked assets and that monetary policy complements unbacked assets, which reduces volatility and optimizes their scale. Jarrow, and Lamichhane (2022) suggest that accommodative monetary policy leads to larger bubbles and increases systemic risk, unless the policy keeps inflation under control. Bernanke, B. and Gertler, M., 2000 suggest that It is neither necessary nor desirable for monetary policy to respond to changes in asset prices, except to the extent that they help to forecast inflationary or deflationary pressures.

Second, while substantial of literature has identify the presence of asset price bubbles, there has been comparatively limited research devoted to the quantification of these bubbles. This scarcity of measurement tools has made it challenging to comprehensively analyze the impact of monetary policies on asset price bubbles. The measurement of asset price bubbles is a highly complex issue primarily due to the determination of fundamental value. In empirlcal research, Bordo and Landon-Lane (2014) shows that easing monetary policy has a positive impact on asset prices, especially in periods of asset price booms; Van Norden and Schaller (1993) proposed the use of the dividend multiplier method, assuming that the logarithm of dividends follows a first-order random walk process. Under this assumption, they derived the fundamental value of stocks for a specific period as a multiple of current dividends. Jordà et al (2015) find that the emergence of asset bubbles are closely related with easing monetary policy. Ioannidou, Ongena, and Peydró, (2015) show that a lower policy rate spurs the granting of riskier loans to borrowers with worse credit histories, lower ex-ante internal ratings, and weaker ex-post performance. Kindleberger and Aliber (2015) note that: ”not every expansion of money leads to a mania, but every mania has been associated with the expansion of credit”. On the other hand, Galí and Gambetti (2015) document that there is no evidence to support the view that interest rate increases can constrain asset bubbles. Blot et al. (2017) find that monetary policy does not affect bubble components, and that in the U.S. a restrictive monetary policy shock has positive effects on stock price bubbles.

Third, in 2023, major economic entities represented by the United States and Europe are experiencing persistent high inflation, leading to a forced tightening of monetary policy. The risk of asset price bubbles causing an economic downturn has also significantly increased, emphasizing the urgent need to study the impact of monetary policy on asset price bubbles.

After the 2008 economic crisis, incentive monetary policy has been simultaneously adopted by the world's major economies such as the United States, China, Japan, and Europe. Amid this boom by monetary easing, we see asset prices around the world hikes dramatically. Take the world's two largest economy the US and China for example. In term of the US, Nasdaq Composite hikes from around 2600 before subprime crisis to 9520 in FEB 2020, the Q ratio of US companies reaches 1.98 in 2019 Q3, in history only the peak of tech bubble (2.17) higher than that (Z.1 Financial Accounts of the United States, Federal Reserve). On the other hand, the China's real estate price appreciated tremendously as well. In 2017, housing sales totaled around 2 trillion USD, equivalent to 16.4% of China's GDP, and the national housing price index in 2017 is about 4 times of its 2008 level (Chang Liu and Wei Xiong, 2018). Two commonly used indicators for measuring the price of real estate are the ratio of house price to income and the ratio of house price to rent, in normal condition those are around 1:8 and 1:15 respectively, but in China tier one city those indicators reach 1:20 and 1:40 respectively (Jianglin, 2010; Zhang and Hung., 2018).

The Federal Reserve once tightened monetary policy in 2019, but the COVID-19 pandemic has reversed this trend. From 2020 to 2022, the major economies have adopted strong stimulative monetary and fiscal policies to cope with the impact of the pandemic. The Federal Reserve slashed the federal funds rate twice to 0.25%, and began an unprecedented $1.5 trillion repurchase program on March 12, 2020. A few days later, on March 15, 2020, the central bank restarted the QE process, buying $120 billion of new bonds per month, and continuing the policy until the end of 2021. Similar policies have been adopted by major economies such as the UK, European Union, and Japan. During this period, financial assets such as global stock indexes, real estate, and digital currencies continued to rise, defying the gloomy economic environment.

In 2022, the divergence between asset prices and fundamentals has led to widespread concerns about asset price bubbles. Fuelled by the Russian-Ukrainian war, high inflation, and a sudden tightening of monetary policy in the US and Europe greatly exacerbated financial risks. In this context, it is valuable to study the impact of monetary policy on the emergence of asset price bubbles, and obtain empirical evidence.

Fourth, the harm caused by the bursting of asset price bubbles is enormous, with debt overhang being one of the most prominent factors contributing to this harm. It holds great significance to introduce a fresh and valuable theory aimed at tackling this issue.

Debt overhang is the condition of an organization that has existing debt so great that it cannot easily borrow more money, even when that new borrowing is actually a good investment that would more than pay for itself (Myers, 1977) . The expansion and burst of asset bubbles will lead to the overhang of corporate debt, which is a major problem that has slowed the recovery. For example, in the 1990s, the bursting of the Japanese real estate bubble led to a significant decline in the total asset value of the Japanese corporate sector. This, in turn, substantially increased leverage ratios and gave rise to a severe debt overhang issue, ultimately resulting in insufficient investment and economic recession. Kalemli-Özcan, Laeven, and Moreno, (2022) find that the negative effect of firm leverage on investment is persistent for several years after the shock in the countries with sovereign stress. The corporate leverage channel can explain about 20% of the cumulative decline in aggregate private sector investment over the crisis period.

Giving the significant role of asset price bubbles in the functioning of the economy, further research into the mechanisms behind the monetary policy and the emergence of asset price bubbles is necessary.

The rest of the paper proceeds as follows. In the second chapter, we provided a brief overview of the theoretical literature on asset price bubbles, with a particular focus on the theoretical research about relationship between monetary policy and asset price bubbles. Building on this foundation, we introduced our own theoretical model, which, from the perspective of information asymmetry, elucidates the critical link between easing monetary policy and asset price bubbles.

In the third and fourth chapter, we provided a brief overview of empirical research related to asset price bubbles, with a particular focus on the empirical research about the relationship between monetary policy and asset price bubbles. We acknowledged that a key challenge in empirical research lies in quantifying bubbles. As a result, we employed an ex-post analysis approach to measure the fluctuations in asset price bubbles and, based on this analysis, discussed the empirical connection between monetary policy and asset price bubbles.

In the fifth chapter, we find that the burst of asset price bubbles can lead to a severe debt overhang problem, causing prolonged economic recession. We reviewed the research on the debt overhang and innovatively proposed theoretical and empirical possibilities for alleviating debt overhang from a corporate governance perspective.

In that last chapter we made summarize and conclusions.

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Chapter 2

Monetary Policy and Asset Price Bubbles with Incomplete Information

2.1 Introduction

In this Chapter, we shed further insight into the topic about monetary policy and asset price bubbles. The definition of asset price bubbles can be different. First, bubble is a sudden and sharp increase in the prices of one or more assets over a continuous period, initially driven by the rising prices that create expectations of further increases, thereby attracting new buyers. These speculators are not interested in the fundamental value of the assets but seek profits through buying and selling (Kindleberger, 2000). This definition emphasizes the significant role of investor expectations in asset price bubbles. Second, asset bubble is the price of an asset is higher and unrelated to the fundamental value (stigliz, 1990). This definition, while emphasizing the role of expectations, highlights the detachment of the actual asset price from its fundamental value. Third, asset bubble is irrational prosperity (Shiller, 2000). A speculative bubble is characterized by unsustainable price growth driven by investor buying behavior rather than by fundamental value. Fourth, asset bubble is the part of asset price exceeding the fundamental value due to risk transfer effect (Allen and Gale, 2000). For example the investors borrow to invest in both risk-free and risky assets. The portion of the returns on risky assets that exceeds the loan interest rate entirely belongs to the investors. If the returns on risky assets are lower than the loan interest rate, then all the risk is borne by the borrower. Regarding above literature, the definition of asset bubble can be divided into two categories depending on whether the fundamental value is considered. We believe that both category have their advantages and disadvantages. The first category of bubble can capture specific characteristics of the evolution of asset prices, which is why it is generally used for bubble identification. On the other hand, the second category better reflects the essence of asset price bubbles. Therefore, the second category generally used when it comes to measuring bubbles and understanding their formation mechanisms. In this paper, we define the asset price bubbles as the market price of an asset exceeds its price determined by fundamental factors by a significant amount for a prolonged period (Hott, 2009, Evanoff, Kaufman, and Malliaris, 2012). We consider a production economy based on the overlapping generation (OLG) model (Samuelson, 1958; Diamond, 1965; and Weil, 1987). In our framework, the economy is characterized by incomplete information due to stochastic technology shocks. New assets are generated by technology shocks with uncertainty about whether they are productive assets or simply bubbles. Economic agents do not have complete information for making such distinctions and hence, must acquire new information in the form of utility feedbacks from initial investment which allow agents to revise investment decisions. This decision-making mechanism follows the case-based decision theory (CBDT) (Gilboa and Schmeidler, 1995; Gilboa, Schmeidler, and Wakker 2002; Eichberger and Guerdjikova, 2013; Bleichrodt et al., 2017). In this process, when the information feedback meets prior judgements, the prior belief will be reinforced, otherwise the prior belief will be adjusted. Asset price bubbles distort the allocation of capital resources by turning investment into consumption (See, also, Diamond, 1965; Tirole, 1985; Gali, 2014, and 2021). Thus, a growing bubble will lead to a shortage of investment capital, resulting in decreases in total production. With the growth of bubbles, this allocation effect will become stronger and lead to economy welfare decreases. Crucially, we demonstrate that the money supply from easing monetary policy will mitigate the investment shortage and resource distortions in the economy, which will allow bubbles continue to exist.

There are two motivations for us to relax the rational expectation assumption in the traditional OLG model. First, in a benchmark OLG model, the dynamic inefficiency theory suggests that when steady interest rate is less than the economic growth rate, the emergence of asset bubbles helps interest rates to converge to the economic growth rate, and hence increases the economic efficiency. However, the relevant empirical evidence is skeptical of this view. For example, Abel et al. (1989) documnet that *"In the United States, profit has exceeded investment in every year since 1929. This finding leads us to conclude that the US economy is dynamically efficient."*. Similarly, some theoretical work explains the coexistence of rational expectation and asset bubbles by the positive effect of bubbles (Martin and Ventura, 2012; Miao and Wang, 2012; Miao et al, 2014). Empirical studies, however, document significantly negative effects of bubbles (Schularick and Taylor, 2012; Brunnermeier and Schnabel, 2016). Second, despite studies have highlighted the correlation between incomplete information and asset bubbles (Allen et al., 1993; Brunnermeier, 2001; Hong and Stein, 2003; Conlon, 2004; Li and Xue, 2009), investor belief and asset bubbles (Hong, Scheinkman, and Xiong, 2006; Scheinkman and Xiong, 2003) little has been researched on the role of monetary policy in the decision-making process when agents require utility feedback to assess investment. The ingredient of incomplete information in our framework allows us to take an approach close to reality, and enhances understandings in the effect of monetary policy on asset bubbles.

The contribution of this paper is twofold. First, we provide a new perspective on the relationship between bubbles and monetary policy, and demonstrate the coexistence of monetary expansion and the emergence of asset bubbles. Our results suggest that asset bubbles are one of the consequences of easing monetary policy because easing monetary policy can mitigate the negative effect of asset bubbles. Second, this paper introduces the possible information distortion effect of easing monetary policy. By incorporating the CBDT into a bubble model, we show that easing monetary policy distorts the information feedback and enables bubbles to exist in the long-term equilibrium. We point out that, without easing monetary policy, the information feedback process will exclude bubbles in the long-term equilibrium.

Our propositions are consistent with empirical evidence on the effect of monetary policy on asset bubbles. For example, Brunnermeier and Schnabel (2016) document anecdotal evidence which shows that the growth of asset price bubbles is accompanied by loose monetary conditions. Our results have important implications that monetary policy decisions should consider the policy effect on asset bubbles, and support the practices of central banks for factoring considerations of financial stability into monetary policy-making. For example, Oet, and Lyytinen (2017)) find that the Fed's monetary policy-making process systematically involves factors include financial stability, other than variables related to the standard Taylor rule.

The rest of the paper proceeds as follows. Section 2 presents the framework of the economy that we analyze. Section 3 derives the equilibrium and presents the propositions for the effects of easing monetary policy on asset price bubbles. Finally, Section 4 concludes.

2.2 The model

Our model builds on the OLG framework and includes critical ingredients that go beyond the classical assumptions in which households in our model face incomplete information and follow a case based decision process to update their judgement on assets. Each firm i in the firm sector is characterized by a technology coefficient a_i. New assets, which can be in the form of new firms in need of financing, are generated stochastically with efficiency uncertainty. A new asset can be a true technology innovation with technology coefficient a_i, or in fact represents a financial bubble b, which is an intrinsically worthless asset in our framework. In this model, prices are determined endogenously by the transaction of money and products. The interest rate is determined endogenously by the capital supply and demand. Monetary policy is represented by the target interest rate r^T, which is set by the central bank. By releasing or withdrawing money, the central bank keeps market interest rates at the target level. In this framework, we analyze the relation between information feedback, monetary policy, and asset price bubbles.

2.2.1 Households

2.2.1.1 Rational intertemporal behavior

Following the assumption of the OLG model, the economic system lives infinite individuals with each of them living for two periods. The individual born in period t seeks to maximize life-time utility U, and the utility function is given by:

$$U_{1,t}(C_{1,t}, C_{2,t+1}) = \max_{C_{1,t}, C_{2,t+1}} \log(C_{1,t}) + \beta E_t \left\{ \log(C_{2,t+1}) \right\} \tag{2.1}$$

where $C_{1,t} = \frac{C^M_{1,t}}{P_t}$ and $C_{2,t} = \frac{C^M_{2,t}}{P_t}$ are, respectively, the household's real consumption when young and old, $C^M_{1,t}$ and $C^M_{2,t}$ are, respectively, the household's nominal consumption when young and old, β is the subjective discount factor ($\beta \neq 0$ such that the young has motivation to invest), and P_t is the price level at time t. We define price $P_t = \frac{M_t}{Y_t}$, where Y_t is the total production in period t, M_t is the total amount of money supply at time t. We further define M_0 as the money supply in the initial state, and ΔM_t, calculated by $M_t - M_0$, is the change of money supply at time t after the emergence of a new asset. We assume that investors hold identical views on asset prices. Without perfect expectation, investors can overprice an intrinsically worthless asset Q (that is, a bubble asset), whose value is

Q_t ($Q_t \geq 0$) at time t, and expect such asset to generate a return by the increase of its market value to Q_{t+1} in the next period. In reality, the asset bubble is usually attached to valuable assets. For simplicity, in our model we separate the worthless part (bubble asset) and valuable part (productive asset) in the asset price [1].

The household sector is endowed with labor and inelastical supply. Aggregate labor supply, L is constantly equal to 1 (i.e., $L \equiv 1$) with no population growth. A young individual born in period t sells his labor to earn nominal wages W_t. He consumes C^M_{1t} and purchases two types of assets: (1) one-period nominal securities K_t yielding a nominal return r_t and (2) a bubble asset Q_t, in order to get capital revenue when he becomes old. Accordingly, the budget constrain for young people born in period t is given by:

$$C^M_{1,t} + K^M_t + Q_t = W_t \tag{2.2}$$

where K^M_t is the amount of money spent on capital assets, Q_t is the amount of money spent on bubble assets. When turning old, the individuals consume all their wealth from securities revenues and selling of bubble assets. Accordingly, the budget constrain is given by:

$$C^M_{2,t+1} = (1 + r_t)K^M_t + Q_{t+1} \tag{2.3}$$

where r_t is the nominal interest rate at time t, and E_t is the expectation operator at time t. To maximize life time utility, by considering equations (**??**), (2.2) and (2.3), the optimal allocation of capital across periods will follow:

$$\frac{\beta C_{1,t}}{C_{2,t+1}} \frac{P_t}{P_{t+1}} (1 + r_t) = 1 \tag{2.4}$$

1. First, intrinsic worthless asset commonly exist in our world, like fiat money (Diamond, 1965). Second, compared with separate the worthless part (bubble asset) and valuable part, assume bubble attached with valuable assets only make the bubble assets and valuable assets have a fixed proportion, but this limit do not bring meaningful impact on our conclusion. Third, separate the pure bubble and valuable asset is a widely used approach to simplify the bubble model(See, e.g., Gali, 2014, Miao and Wang, 2018.

and

$$\frac{\beta C_{1,t}}{C_{2,t+1}} \frac{P_t}{P_{t+1}} Q_{t+1} = Q_t \tag{2.5}$$

From utility function (??) we can derive that households' capital supply is determined by the cross term coefficient and young people's income. Accordingly, we obtain:

$$\frac{\beta}{1+\beta} W_t = K_t^M + Q_t. \tag{2.6}$$

2.2.1.2 Incomplete information and CBDT

In the previous subsection, equations (2.4) and (2.5) show that, at the aggregate level, a bubble asset will grow at the rate of r_t from Q_t to Q_{t+1}, and that households' allocation of capital is optimal. Crucially however, the intrinsic value of a bubble asset is zero, which distinguishes a bubble from a productive asset. Such bubbles do not generate the same level of production as dose a productive asset, and therefore could cause utility losses in the future. Importantly, we point out in our framework that economic agents are lack of information on whether the newly emerged technology shock represents a productive asset or simply a bubble. As a consequence, households must follow the CBD process when making decisions on the investment in a new asset.

We incorporate CBDT to model the process of receiving information through practice and adjusting practice by the arrival of new information. We combine the CBDT with the OLG model to analyze the impact of incomplete information on investors' utility maximization behavior.

We assume that, a new asset emerge at time t_0, it could be a productive asset a, or a bubble asset Q with initial size Q_0. We denote there is a corresponding decision coefficient λ_t, and the value of λ_t can be either 0 or 1, representing the individual's subjective judgment as to whether this technology is a real innovation ($\lambda = 1$) or a bubble ($\lambda = 0$). Following the CBDT model of Gilboa, and Schmeidler (1995), we assume that there exists a similarity function $H\{\lambda_t, \lambda_l\} = 1 - (\lambda_t - \lambda_l)^2$ to measure the similarity of decisions between time period t and time period l.

The subjective perception of the previous decision is measured by the change in utility ΔU_l, which is calculated by the utility at time l minus the initial utility U_0, capturing the individual's subjective perception of how correct their previous decision was. We introduce this concept because if the household makes a right decision on assets, and exogenous conditions (target interest rate) are the same, more production choices can not reduce households' utility. Households have a memory set Ω_{t-1} to record all previous scenarios after new asset emerged, including the target interest rate r^T, the decision set λ and the outcomes ΔU, all accumulated up to the time of decision at $t-1$.

Following our assumptions, households' decision set follows a CBD function which maximizes the expected utility:

$$E_t(\lambda_t) = \max_{\Omega_{t-1}(\lambda_l, r_l^T, \Delta U_l)} E_0(\lambda_t = 1) + \sum_{l=0}^{t-1} H\{\lambda_t, \lambda_l\} \cdot \Delta U_l \tag{2.7}$$

Where E_0 is the initial belief of newly emerged asset is productive asset. Following the CBD process, when the new asset a_i emerges at time 0 and the initial decision $\lambda_{i,0} = 1$, if $\Delta U_t(\lambda_t = 1) < 0$, then the CBD process will weaken the investor's belief on new asset λ_i, and lead to an adjustment for λ_i. On the other hand if $\Delta U_t(\lambda_t = 1) \geqslant 0$, the CBD process will keep or strengthen the investors' belief on new asset a_i. It is worth to note that the CBD maximize function do not conflict with the utility maximize equation 2.1, the decision process can be separate to two step. The first step households decide the total investment amount by utility maximize equation (equation 2.1), and in the second step the households decide whether to invest in newly emerged assets.

In order to better understand the CBD process in our model, imagine a new asset emerge at time t_0, it could be a productive asset a, or a bubble asset Q with initial size Q_0. The households have an initial utility U_0 , and a belief E_0 that the asset is a productive asset a, which means the decision coefficient $\lambda_{i,0} = 1$ otherwise they will not invest in this asset from the very beginning. Once investor invest in this asset, the total production will be affected at time t_1, and the household utility U_1 could be different with the initial utility U_0, the difference of utility are denoted as ΔU_0. Households' decision coefficient $\lambda_{i,0}$, and utility changes ΔU_0 at time 0 is the "case" at time 0, and added to the memory set $\Omega_0 = (\lambda_{i,0}, r^T, \Delta U_0)$. At the time t_1, household compare the utility changes ΔU_0 by equation (2.7), and choose a new decision coefficient $\lambda_{i,1}$ to maximize their utility.

By introducing the CBDT model, we establish the relationship between households' information and investment decisions. Through the combination of the CBDT and the OLG model, we enable investors' judgment on the technical efficiency to affect the total output, thereby providing a fresh perspective for analyzing the existence of bubbles in the OLG framework.

2.2.2 Firm sector

We assume that the firm sector follows the Cobb-Douglas production function, with the output elasticity of capital α $(0 < \alpha < 1)$, the output elasticity of labor $1 - \alpha$, and a technology coefficient $a_t = a^* > 0$. The firm sector faces stochastic emergence of asset bubbles (i.e., the introduction of the bubble asset Q).

The production function of the firm sector is given by:

$$Y_t = a_t K_t^{\alpha} L_t^{1-\alpha} \tag{2.8}$$

where Y_t is the total production at time t, K_t is the total capital input, and L_t is the total labor input.

In a competitive market, the market wages W_t and interest rate i_{t-1} are determined, respectively, by the equations of the marginal productivity of labour and capital, $MPL_t = (1-\alpha)a^* K_t^{\alpha} L_t^{1-\alpha} = \frac{W_t}{P^t}$, and $MPK_t = \alpha a^* K_t^{\alpha-1} L_t^{\alpha-1} = (1+r_{t-1})\frac{P_{t-1}}{P_t}$. From the MPL and MPK equations, the capital demand should follow:

$$(1+r_{t-1}) I_{t-1}^{D} = \alpha (M_0 + \Delta M_{t-1}) \tag{2.9}$$

and,

$$(1+r_{t-1}) = \frac{Y_{t-1}}{Y_t} \alpha K_t^{\alpha-1} \tag{2.10}$$

where M_0 is the stock of money supply before the new asset emerges, ΔM_{t-1} is the new money supply released by the central bank at time $t-1$, and I^D is nominal capital demand, and $I_t^D = K_{t+1} P_t$.

2.2.3 The central bank system

The central bank or monetary authority is an institution that manages the currency and monetary policy for a country or monetary union, the functions of the central bank have become increasingly important with the modern credit currency system. Central banks in developed countries usually have a long term monetary policy objectives that clearly specified by law (Friedman, 2008), such as the US congress established two key objectives for US federal reserve monetary policy–maximum employment and stable prices–in the Federal Reserve Reform Act of 1977. Furthermore, in order to prevent monetary policy conflicts, the monetary policy of modern central bank, include the Federal Reserve, the European Central Bank, and the Bank of Japan, is primarily aimed at a 2% stable inflation, because "is most consistent with achievement of both parts of the dual mandate". Under this policy structure, asset prices or asset bubble are not a primary consideration for the central bank monetary policy, therefore the monetary policy is measured as an exogenous factor in our model. For example, when the economy is subject to exogenous shocks resulting in price fluctuations, such as geopolitics conflicts, international trade, supply chain restructuring or COVID-19 epidemic, the central bank in our model could targeting a lower or higher interest rate to achieving their inflation target. In our model, the total production and inflation will rise when central bank targeting a lower interest rate and vise versa, fit well with the evidence.

Specifically in our model, the interest rate r is determined by the endogenous total supply and total demand of capital, the economy has no foreign investment. The total demand of capital is determined by nominal capital demand I^D of the firm sector as in equation (2.9) and the price of the bubble Q. In an economy where there exists a central bank, the total supply of capital is determined by the total investment I^S as in equation (2.6) and the money supply ΔM released by the central bank through direct asset purchases. When the central bank sets a target interest rate r^T, any enterprise willing to borrow at an interest rate higher than this level will get a loan. And if $I^D + QB > I^S$, the excess capital demand will be supplied by the central bank. In our model, money flows between the household and firm sectors. In the first step, young households receive money from wages at time t. In the second step, money transfers to the firm sector through investment and consumption. In the third step, the firm sector transfers money to young and elderly households through wages and capital gains at time $t+1$, which completes a cycle. Thus, in our model, economic agents do not hold cash across periods (see, also, Galí, 2021).

Accordingly, the capital market equilibrium is:

$$I_t^S(r) + \Delta M_t\left(r \mid r^T\right) = I_t^D(r) + Q_t(r)B \tag{2.11}$$

The central bank can participate in the money flow cycle by directly investing in the second step. The frictions that cause monetary non-neutrality come from delayed price adjustments, which allow monetary policy to affect the real interest rate, as shown in equation (2.26).

2.3 Equilibrium

2.3.1 Assumptions

We have two assumptions for our derivation.

Assumption 1*:* We define a competitive equilibrium for this economy as an allocation of $\left\{C_{1,t}, C_{2,t}, K_{t+1}\right\}$ together with a sequence of $\left\{P_t, \Delta M_t, Q_t, r_t\right\}$, such that households maximize utility described by equation (**??**) subject to constrains (2.2) and (2.3). The equilibrium must satisfy the market-clearing conditions for the goods market $\left\{C_{1,t} + C_{2,t} + K_{t+1} = Y_t\right\}$, the money market $\left\{W_t + (1+r_t)\left(I_{t-1}^S + \Delta M_{t-1}\right) \equiv M_0 + \Delta M_{t-1}\right\}$, and the capital market $\left\{I_t^S + \Delta M_t = I_t^D + Q_t\right\}$.

Assumption 2*:* We define a steady state of the economy as the environment where the total output maintains at a long term stability level of $\widetilde{Y}$ at time t_s:

$$Y_{t_s} = Y_{t_s+\varepsilon} = \widetilde{Y}, \varepsilon \in N^+ \tag{2.12}$$

Assumption 3*:* We assume the target of central bank when it adopts easing monetary policy is to keep the long-term interest rate at the level of r^T by releasing or withdrawing money supply ΔM_t at time t.

2.3.2 Equilibrium and propositions in natural monetary policy condition

We first outline the initial equilibrium without uncertain technology shocks and easing monetary policy. We define an easing monetary policy as the decision of the central bank to control the long-term interest rate via directly hold assets (See also, e.g., Joyce et al., 2012). We assume in natural monetary policy condition, the central bank does not adopt easing monetary policy so that $\Delta M_t \equiv 0$.

In steady state $P_t = P_{t+1}$ because $\Delta M_t \equiv 0$. From the MPK equation we see that, in a steady state, the interest rate r_{t-1} is determined by the firm's technology coefficient a_i and goods input K_t as:

$$\alpha a^* K_t^{\alpha-1} = (1+r_{t-1})\frac{P_{t-1}}{P_t} = (1+r_{t-1}) \tag{2.13}$$

The nominal capital demand I^D equals the goods input K times the goods price P. Thus, from equation $K_t \cdot P_{t-1} = I_{t-1}^D$, we obtain the nominal capital demand I_{t-1}^D as:

$$I_{t-1}^D = \left(\frac{\alpha a^*}{1+r_{t-1}}\right)^{\frac{1}{1-\alpha}} \cdot P_{t-1} \tag{2.14}$$

Considering the MPL equation, the sum of young people's income is:

$$W_t = (1-\alpha)M_0 \tag{2.15}$$

As a result of the households' maximization of life-time utility, from equations (2.4) and (2.5) we obtain the nominal capital supply:

$$I_t^S = (1-\alpha)M_0\frac{\beta}{1+\beta} \tag{2.16}$$

In the last step, because $\Delta M_t \equiv 0$ and $Q_t = 0$ (a bubbleless equilibrium), the financial market clearing condition is:

$$I_t^S = I_t^D \tag{2.17}$$

From the simultaneous equations (2.14), (2.16) and (2.17), we can derive an equilibrium condition in a steady state as:

$$\widetilde{K}_t = (1-\alpha)\cdot\frac{\beta}{1+\beta}\cdot\widetilde{Y}_t \tag{2.18}$$

where $\widetilde{K}$ is the capital goods input in a steady state, and $\widetilde{Y}_t = a^* K_i^\alpha L_i^{1-\alpha}$ from equation (2.13). Equation (2.18) shows that, in a steady equilibrium without bubbles and easing monetary policy, the capital goods input is a certain portion of total output, depending on α and the cross term coefficient β. Moreover, $\widetilde{K} = \left[(1-\alpha)\frac{\beta}{1+\beta}a^*\right]^{\frac{1}{1-\alpha}}$, and $\widetilde{Y} = a^*\left[(1-\alpha)\frac{\beta}{1+\beta}a^*\right]^{\frac{\alpha}{1-\alpha}}$. We can also derive the natural interest rate r^N in this condition as:

$$(1+r^N) = \frac{\alpha}{1-\alpha}\cdot\frac{1+\beta}{\beta} \tag{2.19}$$

Note that following our assumptions of $\beta \neq 0$ and $0 < \alpha < 1$, the natural interest rate is zero or positive $r^N \geq 0$ when $\alpha \geq \frac{\beta}{2\beta+1}$, and the natural interest rate is negative $r^N < 0$ when $\alpha < \frac{\beta}{2\beta+1}$. In the latter scenario the investment will be inefficient, as described by the dynamic inefficiency theory of Tirole (1985). From the goods market clearing condition, the allocation of real consumption in a steady state should follow:

$$\widetilde{C}_{1,t} = (1-\alpha)\cdot\frac{1}{1+\beta}\cdot\widetilde{Y}_t \tag{2.20}$$

and

$$\widetilde{C}_{2,t+1} = \alpha\cdot\widetilde{Y}_t \tag{2.21}$$

From above we know that in the initial equilibrium when total output reaches a steady state, the real consumption will remain in a steady state. Consider equation (5.5), the utility shock ΔU in the CBD process is constantly equal to zero and hence, dose not impact the decision set $\overrightarrow{\Lambda}_t$.

2.3.2.1 The emergence of a productive asset s

Proposition 1*:*

When $\Delta M_t \equiv 0$, and the natural interest rate $r^N \geq 0$, the emergence of a productive asset can stably exist in the long-term equilibrium.

Proof for proposition 1*:*

Suppose that a new firm s with a technology coefficient $a_s = a^*$ and $E(\lambda_{s,0}) = 1$ emerges at time 0. The emergence of such a new asset does not change the production function $Y_t = a^* K_i^{\alpha} L_i^{1-\alpha}$. With the emergence of this new asset, in a new steady state the total production $\widetilde{Y}_s$ is equal to the initial total production $\widetilde{Y}_0$. Following the utility equation (5.5), the utility shock after the emergence of this new asset is zero, i.e., $\Delta U_t = 0$. And from considering equation (2.3), the investment decision $\overrightarrow{\Lambda}_t$ remains unchanged in the equilibrium.

2.3.2.2 The emergence of a bubble asset Q

Proposition 2*:*

When $\Delta M_t \equiv 0$, and the natural interest rate $r^N \geq 0$, the asset bubble cannot stably exist in the long-term equilibrium. Investors will follow the CBD process and exclude the bubble asset.

Proof for proposition 2*:*

Suppose that a new bubble asset Q with an expected technology coefficient a_Q and an initial size Q_0, where $M_0 \gg Q_0 > 0$, emerges at time 0. Also suppose that households hold a wrong belief that $a_Q = a^*$ and therefore will finance this new asset when in fact it is not a productive asset. From equations (2.4) and (2.5), the household will only invest in a bubble asset when it at least generates the same return as productive assets. Thus, the market value of a rational bubble at time t is:

$$Q_t = Q_0 \prod_{l=0}^{t} (1 + r_l) \tag{2.22}$$

And the capital market clearing condition becomes:

$$I_t^S = I_t^D + Q_t \tag{2.23}$$

and:

$$K_{t+1} = \left[(1-\alpha)\cdot\frac{\beta}{1+\beta} - \frac{Q_t}{M_0}\right]\cdot Y_t \tag{2.24}$$

Because bubble assets do not introduce any new real technology to the initial technology coefficient set $\overrightarrow{A^*}$, therefore the total production remains the same as $Y^* = a^* K_i^{\alpha} L_i^{1-\alpha}$. Consider the scenario in which the natural interest rate is zero or positive $r^N \geq 0$ when $\alpha \geq \frac{\beta}{2\beta+1}$. With the expansion of bubble $Q(Q_0, t)$, we could derive $K_t < K_{t-1} < K_0$, and . Consider $r_t > 0$, $MPK = Y_t'(K) > 1$, the total consumption $C_{1,t} + C_{2,t} = Y_t(K_{t+1}) - K_{t+1}$, and the equation (2.5), we could derive that the utility will decrease with the expansion of bubbles. In this scenario the utility shock is negative $\Delta U_t < 0$ in every period. Moreover, consider $P_t = \frac{M_0}{Y_t(K)} > P_{t-1}$, the decrease of total production with the expansion of asset bubble will lead to inflation. Following the CBD process, the declining utility after the emergence of the bubble asset will weaken households' belief in the bubble asset, which will finally make households to adjust the investment decision λ from 1 to 0, and hence, stop financing bubble assets.

Proposition 3*:*

When $\Delta M_t \equiv 0$, and the natural interest rate $r^N < 0$, the asset bubble can stably exist in the long-term equilibrium because the emergence of asset bubbles increases investment efficiency.

Proof for proposition 3*:*

Now consider another scenario in which the natural interest rate is negative $r^N < 0$ when $\alpha < \frac{\beta}{2\beta+1}$. Following equation (2.24), the emergence of a new bubble asset Q will decrease investment. And because the initial size $M_0 \gg Q_0 > 0$, the emergence of bubble assets can not change the interest rate from negative to positive. We see that because interest rate is negative, the size of bubble will reduce over time, i.e., $Q_{t+1} < Q_t$, and $Y_t'(K) < 1$. Given the total consumption $(C_{1,t} + C_{2,t} = Y_t(K_{t+1}) - K_{t+1})$, the emergence of asset bubbles in a negative interest rate environment will increase the households' utility. Following the CBD process, the utility increase after the emergence of the bubble asset will strengthen households' belief in the bubble asset, hence enabling it to exist in the long term equilibrium. This conclusion is in line with the dynamic inefficiency theory.

2.3.3 Equilibrium with easing monetary policy

Following our assumptions, the target of central bank when it adopts easing monetary policy is to keep the long-term interest rate at the level of r^T by releasing or withdrawing money supply ΔM_t at time t. With the implementation of easing monetary policy, the target interest rate will be lower than the natural interest rate, i.e. $r^T \leq r^N$.

From the marginal capital production function MPK, the steady state capital input $\widetilde{K}$ is determined by the target long term interest rate r^T, which we denote as $\widetilde{K}(r^T)$. Considering the capital input, in a steady state the total production $\widetilde{Y}$ is determined by the target interest rate r^T, which we define as $\widetilde{Y}(r^T)$. Because $r^T \leq r^N$, it is easy to see that $\widetilde{K}(r^T) \geq \widetilde{K}(r^N)$. Accordingly:

$$\left(1 + r^T\right) \frac{P_{t-1}}{P_t} = \alpha a_i \widetilde{K}^{\alpha-1} \tag{2.25}$$

Considering capital market clearing condition and money market clearing condition, we obtain:

$$\frac{\widetilde{K}(r^T)}{\widetilde{Y}(r^T)} = \frac{(1-\alpha)(M_0+\Delta M_{t-1})\frac{\beta}{1+\beta}+\Delta M_t}{M_0+\Delta M_t} = \alpha\frac{1}{(1+r^T)}\frac{P_{t-1}}{P_t} \tag{2.26}$$

Simplify the equation we get:

$$\alpha\frac{1}{(1+r^T)} - (1-\alpha)\frac{\beta}{1+\beta} = \frac{\Delta M_t}{M_0+\Delta M_{t-1}} \tag{2.27}$$

Define $\theta = \alpha\frac{1}{(1+r^T)} - (1-\alpha)\frac{\beta}{1+\beta}$, and $0 < \theta < 1$ because of easing monetary policy. from above equation we could derive:

$$\Delta M_t = \frac{\theta M_0(1-\theta^t)}{1-\theta} \tag{2.28}$$

and,

$$\lim_{t\to\infty}\Delta M_t = \frac{\theta M_0}{1-\theta} \tag{2.29}$$

The above function describe that monetary policy causes inflation in the early stages of easing, but gradually convergence to 0. From the market clearing condition $\widetilde{C}_{1,t}+\widetilde{C}_{2,t}+\widetilde{K}_{t+1} = \widetilde{Y} = \widetilde{Y}(r^T)$, the real total consumption will be constant $\widetilde{C}_{1,t}+\widetilde{C}_{2,t} = \widetilde{Y}(r^T)-\widetilde{K}(r^T)$. Because $r^T \leq r^N$ and $\widetilde{K}(r^T) \geq \widetilde{K}(r^N)$, the amount of household investment cannot reach the required investment level. The central bank will therefore need to increase money supply to lower the interest rate to the target level r^T. The greater this investment gap is, the more money the central bank will need to release. From previous analysis we know the total output remains constant at $\widetilde{Y}$ level. Following the equation (**??**), and constant total consumption $C_{1,t}+C_{2,t}$, the CBD process will have no impact on the household's decision set $\overrightarrow{\Lambda}_t$ because $\Delta U_t = 0$.

2.3.3.1 The emergence of a productive asset s

Proposition 4*:*

When the central bank targets a long term interest rate that is lower than or equal to the natural interest rate, $r^T \leq r^N$, the emergence of a productive asset can stably exist in the long-term equilibrium.

Proof for proposition 4*:*

Suppose a new firm s with a technology coefficient $a_s = a^*$ emerges at time 0. The same as in section 3.1, the emergence of the new asset has no impact on the production equation $Y_t = a^* K_i^{\alpha} L_i^{1-\alpha}$. With the emergence of such a new asset, in the new steady state the total production $\widetilde{Y}_s$ is equal to the initial total production $\widetilde{Y}_0$. From the utility equation (??), the utility shock after this new asset emerges is zero, i.e., $\Delta U_t = 0$. Based on the assumption of the CBD process, households' belief on the new asset remains the same, and thus the investment behavior remains unchanged in the long term equilibrium.

2.3.3.2 The emergence of a bubble asset Q

Proposition 5*:*

When the central bank targets a long term interest rate that is lower than or equal to the natural interest rate, $r^T \leq r^N$, an easing monetary policy will enable the rational bubble to exist in the long-term equilibrium.

Proof for proposition 5*:*

Suppose a new bubble asset Q with a market value $Q_0 > 0$, and $E(\lambda_{b,0}) = 1$ emerges at time 0. Also suppose that ouseholds hold wrong belief that $a_b = a^*$ when in fact it is not true. Because the emergence of a bubble asset will not introduce any real technology, therefore the production function $Y(r)$ remains the same after the bubble asset emerges. Considering the capital market clearing condition, in order to keep the long-term interest rate at the level of r^T after the emergence of the asset bubble Q, the change of central banks' monetary supply ΔM_t at time t will follow:

$$\frac{\widetilde{K}(r^T)}{\widetilde{Y}(r^T)} = \frac{(1-\alpha)(M_0+\Delta M_{t-1})\frac{\beta}{1+\beta}+\Delta M_t - Q_t}{M_0+\Delta M_t} = \alpha\frac{1}{(1+r^T)}\frac{P_{t-1}}{P_t} \tag{2.30}$$

from above equation we could derive:

$$\Delta M_t = \frac{\theta M_0(1-\theta^t)}{1-\theta} + Q_0\frac{\theta^{t-1}(1-(\frac{1+r^T}{\theta})^t)}{1-\frac{1+r^T}{\theta}} \tag{2.31}$$

and,

$$\lim_{t\to\infty}\Delta M_t = \frac{\theta M_0}{1-\theta} + \frac{Q_t}{(1+r^T)-\theta} \tag{2.32}$$

The function above suggest that the existence of bubble will cause inflation in easing monetary policy condition. To hold the targeted interest rate, the central bank need to release more money with the expansion of asset bubble. From goods market clearing condition we get the equations below:

$$\widetilde{Y}_t = a^*\widetilde{K}_t^{\alpha}L_t^{1-\alpha} \tag{2.33}$$

$$C_{1,t} + E\left(C_{2,t+1}\right) = \widetilde{Y} - \widetilde{K} \tag{2.34}$$

From equation(2.5), (2.30) , and (2.34), we could derive the emergence of bubbles in an easing monetary condition will have no impact on capital input K, total production Y and the aggregate consumption $C_{1,t}$, and $C_{2,t}$. The households utility will be constant because of constant total consumption. Based on the CBD process, and considering the utility equation (??), households' wrong belief on the bubble asset will remain unchanged because the utility shock after new asset emerges is zero. Thus, in this scenario the asset bubble can exist in the long term equilibrium.

2.4 Conclusions

This chapter provides a new perspective of easing monetary policy with respect to the development of asset price bubbles. We define asset price bubbles as deviations of asset prices from fundamentals over a longer period of time, compared with other definition such as rapid increase of asset prices (Brunnermeier, 2016), our definition generally used when it comes to measuring bubbles and understanding their formation mechanisms (Dong, Miao, Wang, 2020; Galí, 2021).

We consider asset bubbles in which households behave rationally to maximize expected utility. Our model suggests that, without easing monetary policy, the emergence of bubbles will cause utility losses. Thus, households who follow the rational expectation would exclude bubbles in the long-term equilibrium. On the other hand, unconventional easing monetary policy will mitigate the problem of investment distortion caused by asset bubbles. Investors' investment in bubble assets will no longer crowd out investment in productive assets because firms can always obtain financing at a fixed real cost of capital. In this condition, the emergence of bubbles will no longer cause a negative utility shock, and therefore households could invest in bubble assets.

Our theory links asset price bubbles with easing monetary policy in a persuasive way, provide theoretical explanations for the evidences that easing monetary policy lead to asset price bubbles (Bordo and Landon-Lane, 2014, Jordà et al, 2015, Kindlebeger and Aliber, 2015). We further enriched the research between asset price bubbles and monetary policy, fills the gap in the literature (Tiole, 1985; Gali, 2014) that there is no direct relationship between asset bubbles and total output, and therefore get different conclusions with Galí, and Gambetti (2015), and Blot (2017). Our research combined the CBDT and OLG model, enabling the OLG model to discuss the investment process of households under incomplete information, developed the application of CBDT in asset pricing research (Eichberger and Guerdjikova, 2013; Bleichrodt et al., 2017)

Our model enhances the understanding in the relation between, asset bubbles and unconventional monetary policy. Our theory points out the potential risks of unconventional easing monetary policy as it disappears the negative impact of asset bubble on production, and therefore enable it to exist in long term equilibrium.

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Chapter 3

A Firm Level Empirical Analysis of Monetary Policy's Effect on Stock Mispricing

3.1 Introduction

Unconventional easing monetary policy with surging asset price is a significant feature of the global economy in last decades. After a short reverse of monetary policy in 2019, major economies have entered a new round of quantitative easing (QE) to cope with coronavirus pandemic, during which we see significant decoupling of asset price and economic growth. This phenomenon has generated a renewed interest in the link between monetary policy and asset mispricing. Discuss the possible impact of monetary policy on asset mispricing help us understand the impact of monetary policy on financial stability, especially when monetary policy shifts sharply in response to inflation in 2022.

Monetary policy is a key determination of asset price, but the relation between monetary policy and asset msipricing did not rise widely interest until 1990s (Bernanke and Gertler 2000; Goodhart, Hofmann et al. 2000) after a series of bubbles crash in Japan, United States and Latin America being found closely related with monetary policy (Borio et al. 1994). This topic received further attention after the 2008-09 financial crisis, as many claims that easing monetary policy played an important role in financing real estate bubbles (Ahrend et al. 2008;Taylor 2009).

Asset mispricing or asset bubble is the perceived deviation of asset prices from fundamentals (Hott, 2009, Evanoff, Kaufman, and Malliaris, 2012). In most asset mispricing theories, monetary policy could lead to asset price bubbles but not included as a direct factor. For example, noise trader model (Harrison and Kreps 1978; De Long et al. 1990)assumes that a portion of investors are irrational and driven by sentiment, they will amplify the fluctuation of fundamental value and resulting in asset price bubbles. Extrapolative expectation (Hirshleifer et al. 2015) is investors base their expectations for future asset prices on past price movements rather than on fundamental economic or financial data. Extrapolative expectation bubble is driven by the belief that an asset's recent price trend will continue indefinitely. Imitation (Johansen, Sornette et al. 2010) or herding (Devenow and Welch 1996) model believe the group irrational behavior could amplify the fluctuation of fundamental value. Consider lowering interest rates could lower the discount rate and increase fundamental value, the change of monetary policy could be interpret as simultaneous change of market expectation on asset price, and therefore lead irrational investors to overvalue or undervalue it, but the effect of monetary policy on asset mispricing is not clear established.

In recent years more research try to directly link monetary policy with asset mispricing, Asriyan et al. 2021 argue the growth of bubbles absorbs credit and diverts it away from investment, creating a debt overhang effect, but monetary policy could influence debt overhang effect through inflation channel. Dong et al. 2020 assumes entrepreneurs are hetero-geneous in investment efficiency and face credit constraints, they can trade bubble assets to raise their net worth. These theories shed light on the relation between monetary policy and asset bubbles, but did not form a consensus view yet.

On the other hand, the empirical research on this topic did not provide sufficient evidence. By the methods literature applied to observe asset mispricing, we could roughly divided them into three. First, using the asset price's unusual fluctuation to represent mispricing. Dokko et al (2011) using VAR model analysing US housing price and federal funds rate, found that easing monetary policy significant related with house price surge. Bordo and Landon-Lane 2013 using a panel of up to 18 OECD countries from 1920 to 2011 found that easing monetary policy – that is having an interest rate below the target rate or having a growth rate of money above the target growth rate – does positively impact asset prices and this correspondence is heightened during periods when asset prices grew quickly and then subsequently suffered a significant correction. Second, estimate the range of rational price by specific indicators such as Tobin's Q, Price-earnings ratio, or house price to income/rent ratio, and compare it with the market price (Glaeser et al. 2017). Lv, (2010) using house price to rent ratio measure Chinese real estate bubbles, believe that easing monetary policy is not an explanation for asset price bubbles. Third, observe asset mispricing by historical case studies (Kindleberger and Aliber 2011). Brunnermeier and Schnabel 2015 has carefully analysed the background and process of asset price bubble over the past four hundred years, and found that the emergence of asset price bubbles are always accompanied by a easing monetary condition. Despite different conclusions carried by them, we find there are two main shortcomings.

First, most research rely on indirect methods which incapable to distinguish the swing of bubble component from the swing of fundamental prices. Besides, research observe asset mispricing by direct methods indicate different conclusions compared with the common view. For example, Galí and Gambetti 2015 using TVC-SVAR model analysed the effect of federal funds rate on US stock price, found there has no evidence to support an increase of interest rate could constrain rational bubbles. Blot et al. 2017 using ex post fundamental value to observe US stock market bubbles, suggest that monetary policy dose not affect bubble components, and in US where a restrictive monetary policy shock even has positive effect on bubbles.

Second, studies focus on periods of significant volatility in asset prices, rather than the entire period. Different from the bubble's intense crushing part that can be clearly observed, the emerge of bubble is slow, subtle, and could last several years to decade (Borio et al. 1994), therefore the conclusions could be biased.

To further investigate the relation between monetary policy and asset bubble, we build an indicator to obtain the move of mispricing by the ex post fundamental value. Ex-post measurement methods calculate historical fundamental value by historical accounting data. Houmes, and Skantz (2010) calculate the fundamental value of US equity by ex-post deividend. Blot (2017) measuring US stock market bubble with ex-post stock price and ex-post dividend. Ohlson (1995), Frankel and Lee (1998), and Badertscher, (2011) using ex-post book value to calculate the fundamental value. Smith et al, 2006 , and Hatzvi et al (2008) calculate the fundamental value of US house market by ex-post rental revenue. Ex-ante measurement methods predict the future trajectory of an asset's fundamental value based on certain underlying assumptions. For example, Van Norden and Schaller (1993) proposed dividend multiplier method , which assumes that the logarithm of dividends follows a first-order random walk process, under which the fundamental value of stocks at time 't' is derived as a multiple of the current period's dividends.

Compared with ex-ante methods, fundamental value observed by ex-post methods excludes projections and probabilities, it represents what investors earn rather than estimated values. But in our article, it is very reasonable to measure asset price bubble by ex post fundamental prices. First, we assume that investors are rational, and second, we assume investors are risk neutral, thus the average expected income should be the same as ex post fundamental value. Oulton (2007) test the ex-post and ex-ante method, found that based on a simple model of temporary equilibrium, ex post is better in theory

This study implements empirical analysis based on this indicator from both firm-level and market level. The main contribution of this study is build a direct indicator of asset mispricing, and empirical analyzed the impact of monetary policy on asset mispricing, provides more evidence on this topic.

The remainder of the chapter is organized as follows, section 3.2 introduce the mispricing indicator; Section 3.3 present the results of empirical analysis at firm level.

3.2 Observe the movement of bubble component.

3.2.1 Define the bubble component

Begin with the discount equation for asset prices, we assume that the security price P for company i at time t consists of two parts, the fundamental component F, and the bubble component B (note that the bubble component can be negative when assets are undervalued):

$$P_{i,t} = F_{i,t} + B_{i,t} \tag{3.1}$$

—

The fundamental value of a security is given by the dividend discount model (Subramanyam and Venkatachalam 2007; Fung et al 2010; Blot et al 2018), in which the present value equals to the rationally expected discounted future cash flow (dividend):

$$F_{i,t} = E_t\left[\sum_{\tau=1}^{\infty} \cdot \left(\prod_{\upsilon=1}^{\tau} \frac{1}{1+r_{i,t+\upsilon}}\right) D_{i,t+\tau}\right] \tag{3.2}$$

where $D_{i,t}$ is the dividend of company i at time t, $F_{i,t}$ is the expected fundamental value of company i at time t, τ and υ are the term number, and $r_{i,t}$ is the firm-specific discount rate for stock i at time t.

Since ex ante fundamental value $F_{i,t}$ is unobservable, therefore we define ex post fundamental value $\overline{F}_{i,t}$ as the present value of realized future cash flow.

$$\overline{F}_{i,t} = \sum_{\tau=1}^{\infty} \cdot \left(\prod_{\upsilon=1}^{\tau} \frac{1}{1+r_{i,t+\upsilon}}\right) \overline{D}_{i,t+\tau} \tag{3.3}$$

Note that the fundamental value is the rational expectation of future cash flow, but ex post fundamental value is the realized cash flow, therefore the fundamental value and ex post fundamental value are not always equal. We further define the fundamental value $F_{i,t}$ equals to the $\overline{F}_{i,t}$ plus an error term ε, shown as $F_{i,t} = \overline{F}_{i,t} + \varepsilon_{i,t}$. We could derive where $E(\varepsilon) = 0$, and $COV(F,\varepsilon) = 0$, otherwise the investors' expectation are not rational because they can improve their investment revenue by historical investment records (shiller 1980).

Assume the realized dividend streams are $\overline{D}_{i,t}$ for company i at time t, and t equals to $1,2,\cdots,T$ is observable. We define T is the terminal date. For stock that have been delisted, T represents its delisting date, for stocks that were not delisted, T represents the latest date in the sample. We We transform the equation 3.3 as the discounted realized dividends plus the terminal ex post fundamental value:

$$\overline{F}_{i,t} = \sum_{\tau=1}^{T-t-1}\left(\prod_{\upsilon=1}^{\tau}\frac{1}{1+r_{i,t+\upsilon}}\right)\cdot\overline{D}_{i,t+\tau} + \left(\prod_{\upsilon=1}^{T-t-1}\frac{1}{1+r_{i,t+\upsilon}}\right)\overline{F}_{i,T} \tag{3.4}$$

In above equation the only term we cannot directly observe is the terminal ex post fundamental value. In a bubbleless market condition, this term can be approximated by the terminal stock price $P_{i,T}$, but this study assumes the existence of bubbles as in equation 3.1. If we want to observe terminal ex post fundamental value by $P_{i,T}$, we need to calculate the fist order difference of fundamental value to eliminate the terminal bubble term. Define $\widetilde{F}_{i,t}$ as observed ex post fundamental value by using terminal stock price to replace terminal fundamental value, where $\widetilde{F}_{i,t} = \sum_{\tau=1}^{T-t-1}\left(\prod_{\upsilon=1}^{\tau}\frac{1}{1+r_{i,t+\upsilon}}\right)\cdot\overline{D}_{i,t} + \left(\prod_{\upsilon=1}^{T-t-1}\frac{1}{1+r_{i,t+\upsilon}}\right)P_{i,T}$ and substitute the equation 3.1 into the equation 3.4, we got:

$$\widetilde{F}_{i,t} = \overline{F}_{i,t} + \left(\prod_{\upsilon=1}^{T-t-1}\frac{1}{1+r_{i,t+\upsilon}}\right)B_{i,T} \tag{3.5}$$

The first order difference of $\widetilde{F}_{i,t}$ equals to the first order difference of ex post fundamental value plus a bubble term:

$$\widetilde{F}_{i,t+1} - \widetilde{F}_{i,t} = \left(\overline{F}_{i,t+1} - \overline{F}_{i,t}\right) + \left(\prod_{\upsilon=1}^{T-t-2}\frac{1}{1+r_{i,t+\upsilon}}\right)\left(1-\frac{1}{1+r_{i,t+1}}\right)B_{i,T} \tag{3.6}$$

In which the last term $\left(\prod_{\upsilon=0}^{T-t-2}\frac{1}{1+r_{f,t+\upsilon}}\right)\left(1-\frac{1}{1+r_{i,t+1}}\right)B_{i,T}$ is an adjustment term bring by future uncertainty, and $\left(\prod_{\upsilon=1}^{T-t-2}\frac{1}{1+r_{f,t+\upsilon}}\right)\left(1-\frac{1}{1+r_{i,t+1}}\right)B_{i,T}\to 0$ when the discount factor $\frac{1}{1+r_{i,t+1}}\to 1$. Calculate the first order difference of equation 3.1, and substitute the equation 3.4 and 3.6, we could derive:

$$\Delta P_{i,t}=\Delta\widetilde{F}_{i,t}+\Delta B_{i,t}+\eta_{i,t} \tag{3.7}$$

where $\Delta P_{i,t}=P_{i.t}-P_{i,t-1}$, $\Delta\widetilde{F}_{i,t}=\widetilde{F}_{i,t}-\widetilde{F}_{i,t-1}$, $\Delta B_{i,t}=B_{i.t}-B_{i,t-1}$ and η is an error term equals to $(\varepsilon_{i,t}-\varepsilon_{i,t-1})$, we can derive $E(\eta_{i,t})=E(\varepsilon_{i,t}-\varepsilon_{i,t-1})=0$. Therefore, based on assumptions that investors behave rationally, and the sample frequency is high enough so that the discount factor close to one ($\frac{1}{1+r_{i,t}}\to 1$), we can derive equation 3.7, which provide a reliable method for observing the fluctuation of asset price bubbles. When the sample frequency is high enough, the change of bubble can be observed by the change of approximated ex post fundamental value and the change of stock price.

3.2.2 Observe the change of bubble component

Based on the equation 3.5 and 3.7, we calculate the change of bubble component in three steps, first we calculate the observed ex post fundamental value $\widetilde{F}_{i,t}$. To eliminate the impact of market operation such as secondary offering, repurchase or suspension, this study apply cumulative factor $CFA_{i,t}$ to adjust the stock price[1], so that a comparison can be made on an equivalent basis between prices over time, accordingly:

$$\widetilde{F}_{i,t}=\sum_{\tau=0}^{T-t-1}\left[\left(\prod_{\upsilon=1}^{\tau}\frac{1}{1+r_{i,t+\upsilon}}\right)\cdot\overline{D}_{i,t}\cdot CFA_{i,t}\right]+\left(\prod_{\upsilon=1}^{T-t-1}\frac{1}{1+r_{i,t+\upsilon}}\right)\cdot P_{i,T}\cdot CFA_{i,T} \tag{3.8}$$

1. Cumulative factor is used to adjust stock prices after a distribution so that a comparison can be made on an equivalent basis between prices before and after the distribution. Define C_0 is the adjustment base date, and f is the split factor, the CFA (cumulative adjustment factor) is: if $t=C_0$, then $C(t)=1$; if $t>C_0$, and no split events since t-1,$C(t)=C(t-1)$; if $t>C_0$and a split event with factor f since t-1,$C(t)=C(t-1)*f$; if $t>C_0$and split event change $C(t)=C(t-1)/f$;if $t<C_0$and a split event change $C(t)=C(t+1)*f$. The value of CFA from Wharton database

where $\overline{D}_{i,t}$ is historical dividend. We further assume that investors are risk neutral, therefore the discount rate $r_{i,t}$ for stock i at time t equals to the risk free rate $r_{f,t}$, therefore $\cdot \prod_0^\tau \frac{1}{1+r_{i,t+\tau}} = \prod_0^\tau \frac{1}{1+r_{f,t+\tau}}$. In second step, after we got the observed ex post fundamental value $\widetilde{F}_{i,t}$, the change of bubble component for stock i $\Delta B_{i,t}$ is observed by:

$$\Delta B_{i,t} = (P_{i.t} \cdot CFA_{i,t} - P_{i,t-1} \cdot CFA_{i,t-1}) - \left(\widetilde{F}_{i,t} - \widetilde{F}_{i,t-1}\right) \tag{3.9}$$

where the $P_{i.t} \cdot CFA_{i,t}$ represent the adjusted stock price.

In third step, to make the change of bubble component for stock i in time t, $\Delta B_{i,t}$, comparable between different companies, we set $\Delta b_{i,t}$ as the change of bubble component relative to stock price, shown as:

$$\Delta b_{i,t} = \frac{(P_{i.t} - P_{i,t-1}) - \left(\widetilde{F}_{i,t} - \widetilde{F}_{i,t-1}\right)}{P_{i,t-1}} \tag{3.10}$$

The $\Delta b_{i,t}$ represent the change of bubble component relative to the investment for stock i at time t. The economic implication of Δb is the change of bubble component per dollar investment in stock i. From equation we know that a positive$\Delta b_{i,t}$ means the bubble component is increasing over time, and a negative $\Delta b_{i,t}$ means the bubble component is decreasing over time. Note that the Δb could be greater than 1 or less than -1, which means the change of bubble component greater than its price, and it is because the stock could be under-valued compare with its fundamental value. For example, at time $t-1$ the price of a stock is 5 dollars, and its fundamental value is 500 dollars, in next period, the stock price remain the same but the fundamental value decreased 10 dollars, in this case, the change of bubble component $\Delta b_{i,t}$ equals to 2, means the bubble component (mispricing component) increased two dollars for per dollar investment.

In our model the change in bubble component are primarily driven by changes in stock prices, just like described by shiller (1981) extraordinary volatility. To test if The correlation coefficient between the monthly change of stock price and bubble component is 0.8243. The correlation coefficient between bubble component and the stock return is -0.1729, between bubble component and the monthly change of stock return is -0.2323.

Table 3.1: **Correlation matrix**

This table reports the source and factor of variables.
[See Appendix Table 3.2]

3.3 Firm level bubble analysis

3.3.1 Methodology

We build a panel model include bubble variable and monetary variables to solve this question. Following the results of Hausman test, we run panel regression with fixed effect. The model details are shown below:

$$\Delta b_{i,t} = \beta_0 + \beta_1 FFR_{i,t} + \beta_2 M2G_{i,t} + \beta_k Control_k + \rho_i + \delta_t + \varepsilon_{i,t} \tag{3.11}$$

where ρ_i represent for individual fixed effect, δ_t is time fixed effect and $\varepsilon_{i,t}$ is the error term. The control variables include consumer sentiment index (CSI), inflation (CPIg), GDP growth rate (GDPg), natural logarithm of trading volume (lnVol), and the natural logarithm of firm size (lnSize). There are two main advantages measuring asset bubble by firm level data. First, monetary policy is impervious to the change of bubbles of a single firm, thus the endogenous problem can be avoided in firm level analysis. Second, firm level data help us minimize the terminal value problem. The average listing time for an US stocks is just 139 months. There are 7650 stocks listed at the end of 2019 and only account for 22.8% of total stocks have been listed in history. Compared with research using composite indicator, such as SP 500 or NASDAQ index to measuring asset bubbles, in our model terminal value have less impact on the results.

3.3.2 Data

This study focuses on the US stock market, and the stock data is collected from The Center for Research in Security Prices (CRSP) database. We collected monthly updated US stock data from JAN 1925 to DEC 2019. Total of 33556 different stocks have been listed during the 94 years period we have covered. We apply the federal funds rate (FFR) and Seasonally adjusted broad money supply (M2) to measure the US monetary policy. The monthly FFR data covered from JAN 1954 to DEC 2019 (Federal Reserve Bank of St. Louis), the monthly M2 stock data covered from January 1959 to December 2019 (Federal Reserve Bank of St. Louis).

Following previous literatures, we will consider the market sentiment, inflation, economic growth, trading volume (Scheinkman and Xiong., 2003; Yang and Zhang., 2013; Berger and Turtle, 2015), company size (Fama and French, 1992) as control variables. The variables and its source can be found in appendix.

To control the scale effect, the trading volume is calculated by monthly trading volume/ shares outstanding, the size was calculated by size/market size. This paper through the industry dummy variables to control the industry effects, and the division is based on Standard Industrial Classification (SIC) system. Definition of variables can be find in the following table:

Table 3.2: **The characteristics and measurement of variables**

This table reports the source and factor of variables.
[See Appendix Table 3.1]

3.3.3 Description of bubble in firm level

We calculated the Δb for 33556 companies that have been listed in U.S stock market from DEC 1925 to DEC 2019, Δb (range from 1%-99%) is shown below:

Table 3.3: **Panel data description of Δb**

Δb	*Mean*	*Std.Dev*	*Min*	*Max*	*Observations*
overall	-0.00231	0.207	-26.00198	19.883	N = 4490940
between stocks		0.0456	-2.259	2.324	n = 33554
within stocks		0.199	-27.157	19.838	T = 133.842

The mean of $\Delta b_{i,t}$ is -0.00231, with standard deviation 0.207, and the average duration T of a company is 133.842 months. The minimum value of $\Delta b_{i,t}$ observed in stock Kansas City Southern (KSU) in the MAY 1974. The companies' price at that time is too small compared with its rational value, make the company's dB relatively sensitive, and during 1974 its fundamental value fluctuate wildly. The highest $\Delta b_{i,t}$ value observed from (PHUN) in DEC 2018. Our data shows the adjusted stock price rose from 14.26 dollars to 297.79 dollars in few days but in the mean while its fundamental value almost remain the same. Its share price soon dropped back in the next month, and reached 5.75 dollors in APR 2019.

In this distribution we found that 2% of observations located beyond the range of -0.422 and 0.533. That means in history from 1925 to 2019, 2% of monthly bubble component fluctuation over -42.2% and 53.3% of stock price. Also from the 10% and 90% $\Delta b_{i,t}$ value we know that 20% of monthly bubble component fluctuation over -15.7% and 14.6% of stock price.

3.3.4 Evidence

3.3.4.1 Data Description

Table 3 reports the statistical analysis of the main variables in our panel regression. The value of $\Delta b_{i,t}$ are slightly different from previous discussion, it is because regression sample only cover from JAN 1954 to DEC 2019 to match with other variables. The mean of $\Delta b_{i,t}$ is -0.0023 and the standard deviation of $\Delta b_{i,t}$ is 0.1997, a $t-test$ cannot reject the mean of $\Delta b_{i,t}$ different with 0 at a 90% confidence level, suggest that in long term perspective the asset price bubble have no significant upward or downward trend. The mean of FFR is 0.048, suggest that the monthly average level of federal funds rate is 4.8%, with a standard deviation of 0.0365. The mean of $M2G$ is 1.0023, suggest that the monthly average growth rate of M2 money stocks (US Federal Reserve measurement) is 0.23%, with a standard deviation of 0.0047. For other control variables, the mean and standard deviation for consumer sentiment index is 0.8717 and 0.1228 respectively; the mean and standard deviation for US GDP growth rate is 0.0048 and 0.0029 respectively; the mean and standard deviation for US CPI growth rate is 0.0029 and 0.0031 respectively; the mean and standard deviation for logarithm trading volume is -0.0077 and 0.0146 respectively; the mean and standard deviation for logarithm firm size is -0.1087 and 0.2101 respectively. Moreover, the data for trading volume has the most missing values, therefore it only have 3,907,020 observations.

Table 3.4: **Panel data description**

Note: This table reports the statistical description of variables covered from 1954-2019.

	Mean	*Std. Dev*	*Min*	*Max*	*Observations*
Δb	-0.0023	0.1997	-26.0020	19.883	4,219,284
FFR	0.0480	0.0365	0.0007	0.1910	4,248,441
M2G	1.0023	0.0047	0.9849	1.0305	4,190,929
CSI	0.8717	0.1228	0.5170	1.1200	4,254,730
GDPg	0.0048	0.0029	-0.0062	0.0195	4,247,390
CPIg	0.0029	0.0031	-0.0180	0.0178	4,247,390
lnVol	-0.0077	0.0146	-0.1288	0.1029	3,907,020
lnSize	-0.1087	0.2101	-0.2256	-0.0248	4,251,852

3.3.4.2 Multicollinearity test

Usually panel data do not need multicollinearity test, but in our paper the confidential level of almost every indicator is very high. To ensure the robustness of regression, we implement variance inflation factor (VIF) test on our model, find that all variables' VIF value are less than 1.2, which suggest our model do not have multicollinearity problems.

Table 3.5: **VIF test**

This table reports the multicollinearity testt of our regression by VIF (Variance Inflation Factor Test) tests.

[See Appendix Table 3.5]

3.3.4.3 Stationary test

To avoid the spurious regression problem in our analysis, we also test the stationary of data. We apply Fisher-type (Choi 2001) unit root tests because our data sample is unbalanced. The results shown that the P value of inverse chi-squared, P value of inverse normal, P value of inverse logit t and P value of modified inv. chi-squared Pm for all variables are less than 0.0001. This result strongly suggest that our variables are stationary.

Table 3.6: **VIF test**

This table reports the stationary test of our regression by Fisher-type unit root tests

[See Appendix Table 3.6]

3.3.4.4 Empirical results

We apply equation 3.11 to examine the association between monetary policy and the swing of asset bubbles. Table 4 and 5 present the main regression results, the only difference is in table 8 we using FFR to represent monetary policy, but in table 9 we using M2 growth rate to represent it.

Table 3.7: **The table of panel regression, monetary policy is represented by FFR**

This table reports the coefficient estimates from the firm-level regression with FFR over the period 1954-2019 with the standard deviation in parentheses. Model 1 to 4 control firm effects, Model 5 and 6 using CSI, LnSize and LnVol as control variables, control time effects and industry effects respectively except firm effects. Model 7 further take GDPg and CPIg as control variables, control firm effects. Definitions of variables are provided in Table 1. The symbols ***, ** and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
FFR	-0.597***	-0.553***	-0.557***	-0.553***	-0.947***	-0.555***	-0.490***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)
CSI	-0.014***	-0.014***	-0.013***	-0.013***	0.853***	-0.013***	-0.030***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.069)	(0.000)	(0.000)
GDPg							1.803***
							(0.042)
CPIg							-2.245***
							(0.041)
lnVol			0.348***	0.382***	0.083***	0.381***	0.390***
			(0.010)	(0.011)	(0.011)	(0.011)	(0.011)
lnSize		0.089***		-0.305***	-0.091***	-0.307***	-0.338
		(0.012)		(0.012)	(0.012)	(0.012)	(0.012)
Constant	0.039***	0.048***	0.038***	0.005***	-0.763***	0.028***	0.011
	(0.001)	(0.001)	(0.001)	(0.002)	(0.057)	(0.003)	(0.002)
Ind effect	No	No	No	No	No	Yes	No
Time effect	No	No	No	No	Yes	No	No
Obs	4,212,999	4,210,184	3,868,945	3,868,945	3,868,945	3,868,945	3,867,895
R2	0.0041	0.0039	0.0034	0.0038	0.0697	0.0038	0.0049

Table 3.8: **The table of panel regression, monetary policy is represented by M2G**

This table reports the coefficient estimates from the firm-level regression with FFR over the period 1954-2019 with the standard deviation in parentheses. Model 1 to 4 control firm effects, Model 5 and 6 using CSI, LnSize and LnVol as control variables, control time effects and industry effects respectively except firm effects. Model 7 further take GDPg and CPIg as control variables, control firm effects. Definitions of variables are provided in Table 1. The symbols ***, ** and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
M2G	1.347***	1.347***	1.117***	1.104***	1.103***	1.882*	0.511***
	(0.021)	(0.021)	(0.022)	(0.022)	(0.022)	(1.065)	(0.030)
CSI	-0.009***	-0.009***	-0.021***	-0.021***	-0.021***	1.294***	-0.041***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.139)	(0.001)
GDPg							1.551***
							(0.043)
CPIg							-4.419***
							(0.052)
lnVol			0.493***	0.538***	0.538***	0.088***	0.516***
			(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
lnSize		0.089***		-0.305***	-0.091***	-0.307***	-0.338
		(0.012)		(0.012)	(0.012)	(0.012)	(0.012)
Constant	-1.344***	-1.343***	-1.099***	-1.128***	-1.121	-0.025***	0.001
	(0.021)	(0.021)	(0.022)	(0.022)	(0.022)	(0.002)	(0.002)
Ind effect	No	No	No	No	No	Yes	No
Time effect	No	No	No	No	Yes	No	No
Obs	4,155,595	4,152,780	3,811,770	3,811,770	3,811,770	3,811,770	3,811,770
R2	0.0009	0.0009	0.0010	0.0017	0.0015	0.0695	0.0017

The models in both table are similar, in model 1 only CSI was added as control variable, in model 2 CSI and LnSize were added as control variables, in model 3 CSI and LnVol were added as control variables, in model 4 CSI, LnSize and LnVol were all added as control variables. Model 1 to 4 only control firm specific effects, Model 5 and 6 using CSI, LnSize and LnVol as control variables, control firm fixed effect but also control time effect and industry effect respectively. Model 7 further add GDPg and CPIg as control variables. As is evident from the table, the effect of monetary policy on asset bubble is significant in any tests, and the conclusions are consistent. The coefficient of FFR are all negative, suggests easing monetary policy has a significant positive effect on the positive swing of bubble components. The regression in model 7 which include all control variables suggest that

1% increase of federal funds rate will decrease 0.49% stock price of bubble component, 1 point increase of consumer sentiment index will decrease 0.03% stock price of bubble component, 1% increase of monthly GDP growth rate will increase 1.803% stock price of bubble component, 1% increase of monthly CPI growth rate will decrease 2.245% stock price of bubble component, 1% increase of trading volume will increase 0.0039% stock price of bubble component, and 1% increase of firm size will decrease 0.0034% stock price of bubble component.

The coefficient of M2G are all positive, also suggests easing monetary policy has a significant positive effect on the expansion of bubble components. For example, model 7 suggest that 1% increase of monthly M2 growth rate will increase 0.511% stock price of bubble component. The coefficient of CSI, GDPg, and CPIg is negative, positive, and negative respectively. Suggests the increase of market sentiment and inflation have negative effects on the change of bubble component, the increase of GDP gwoth rate have positive effects on the change of bubble component. The sign of GDPg and CPIg are in line with literature, the negative effect of market sentiment could because of during high sentiment period the fundamental value rise faster and squeeze out bubble components. The results also shows that trading volume have a significant positive impact on expansion of asset bubbles, and company size has significant negative impact on expansion of asset bubbles.

3.4 Conclusions

In this chapter we provide a model and empirical evidence that the movement of asset mispricing is significantly affected by monetary policy. As a result, we proved that easing (tight) monetary policy have a positive (negative) effect on the upward movement of asset mispricing. This conclusion is supported by firm-level US stock market empirical analysis covered from 1954 to 2019. Our conclusion in line with Bordo and Landon-Lane (2014), and Kindlebeger and Aliber (2015).

We developed the methods of observe asset bubble by ex post rational price, filling the gap in empirical research that literature rarely use firm level data to observe asset price bubbles (Hatzvi et al 2008, Houmes and Skantz 2010, Badertscher, 2011). Our indicator cope well with historical events, by using firm-level data and SVAR method, we discussed and avoid the endogenous bias caused by contemporaneous correlation between monetary policy and bubbles. Our findings are robust in different models (fixed effect panel regression and SVAR), different calculation of bubble indicator (one month or three month US treasury return), and different representative of monetary policy (FFR or M2G). In comparison, Gali and Gambetti (2015) based on an estimated vector-autoregression with time-varying coefficients, applied to quarterly US data, concludes that stock prices increase persistently in response to an exogenous tightening of monetary policy. Rigobon and Sack (2003), uses an identification technique based on the heteroskedasticity of stock market returns to measure the reaction of monetary policy to the stock market, find a significant policy response, with a 5 percent rise (fall) in the SP 500 index increasing the likelihood of a 25 basis point tightening (easing) by about a half. Blot et al, (2017) use a Principal Component Analysis to estimate new bubble indicators for the stock and housing markets in the United States based on structural, econometric and statistical approaches. The research find that the effects of monetary policy are asymmetric so the responses to restrictive and expansionary shocks must be differentiated, expansionary interest rate policies would inflate stock price bubbles whereas expansionary balance-sheet measures would not.

This chapter has developed the method of using ex post rational price to study the movements of bubble components (mispricing). Our conclusions are not consistent with the results of previous empirical research (Galí and Gambetti 2015; Blot et al, 2017), providing a different view for the research on the relation between monetary policy and asset mispricing. The findings in this study provides valuable evidence for the development of the theory about asset bubble and monetary policy.

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Chapter 4

A Market Level Analysis of Monetary Policy's Effect on Stock Mispricing

4.1 Methodology

This paper studies the market level effects of monetary policy shocks on stock bubble (mispricing) by means of structure vector autoregression (SVAR) identified through directed acyclic graph (DAG).

In Chapter 3 the $\Delta b_{i,t}$ describes the swing of bubble component in company level. To have a concept of market level asset bubble fluctuations, we define the change of market bubble component as ΔMb_t. The ΔMb_t is the weighted average of bubble fluctuation $\Delta b_{i,t}$ over time, calculated by following equations:

$$\Delta Mb_t = \sum_{i=0}^{\infty} \left(\frac{dB_{i,t} * MV_{i,t}}{TMV_t} \right) \tag{4.1}$$

where $MV_{i,t}$ is the market value of company i at time t, TMV_t is the total market value at time t. The ΔMb_t represent the change of market bubble component in per dollar investment at time t.

The vector autogression (VAR) models is an alternative to multivariate simultaneous equation models, all dependent or independent variables in this approach are treated as endogenous. In a regular unrestricted VAR model, all the explanatory variables regress the lagged items of other explanatory variables, so as to estimate the dynamic relationship between endogenous variables. Compared with VAR model, the SVAR model imposes key restrictions that set conditions as to how certain variables would behave, and it also allows for contemporaneous relations among variables.

Following the previous research on similar topic (Galí and Gambetti 2015), let $GDPg_t$, FFR_t , $CPIg_t$, and CSI_t, denote, respectively, the growth rate of output, the federal funds rate, the growth rate of consumer price index and the consumer sentiment index. We define $x_t = [\Delta Mb_t, FFR_t, CSI_t, CPIg_t, GDPg_t]\prime$. The relation between those variables and the structure shocks are assumed to take the form of a VAR model as:

$$x_t = A_1 x_{t-1} + A_2 x_{t-2} + \cdots + A_k x_{t-k} + e_t \tag{4.2}$$

where A_k is the 5×5 coefficient matrix to be estimated, k is the order of lags, and e_t is a 5-dimensional vector of reduced-form disturbances. The equation can also written as:

$$A(L) x_t = e_t \tag{4.3}$$

where $A(L)$ is a polynomial in the lag operator L, and $A(L) = I - A_1 L - A_2 L^2 - \cdots - A_k L^k$. To identify the contemporaneous relations between variables, we transform the VAR models into SVAR models, the SVAR model are written as:

$$B_0 x_t = B_1 x_{t-1} + B_2 x_{t-2} + \cdots + B_k x_{t-k} + u_t \tag{4.4}$$

where B_k is the 5×5 coefficient matrix to be estimated, k is the order of lags, The equation can also be written as the lag operator form as:

$$B(L) x_t = u_t \tag{4.5}$$

where $B(L)$ is a polynomial in the lag operator L, and $B(L) = B_0 - B_1 L - B_2 L^2 - \cdots - B_k L^k$. If $A(L)$ and $B(L)$ are invertible matrix, from $x_t = A^{-1}(L) e_t$ and $x_t = B^{-1}(L) u_t$ we can derive the relationship between the structure disturbance u_t and the reduced form disturbance e_t by the following:

$$A^{-1}(L) e_t = B^{-1}(L) u_t \tag{4.6}$$

More generally, If A and B are invertible matrix, and satisfy $A \cdot A(L) x_t = A e_t$, $A e_t = B u_t$, $E(u_t) = 0$, $E(u_t u_t') = I_n$, then it is an AB form SVAR model (Bernanke, 1986; Sims, 1986), the other model of SVAR include K form and C form, but both K and C are a reduced from of AB form. To identify SVAR model we need impose restrictions on matrix A and B. Following the results of Akaike information criteria (AIC) and ayesian information criteria (BIC), we set $k = 1$. The difference between VAR and SVAR is the latter need to be restricted to make the model identifiable. The restrictions usually based on economic theories and parameter calibration, but in this study, the economic theory about the relation between bubbles and other variables are uncertain. Therefore we have to find a method to identify the SVAR model based on statistical characteristics. Following the research made by (Fragetta and Melina 2011;Wu and Xu 2021), we apply graphic modeling theory and trace DAGs of the residuals in VAR model. Inferring causal relation is a challenging task, and the DAG provide a method to determine causal structure among variables based on observational data. First, in the structural model, disturbances are assumed to be uncorrelated with each other. Therefore we restrict matrix $\boldsymbol{B}$ to be a (5×5) diagonal matrix, and the diagonal elements of $\boldsymbol{B}$ will represent estimated standard deviations of the structural shocks. Second, we construct a conditional independence graph (CIG), a graphical representation of all statistically significant interconnections among all variables. From the CIG, we can derive DAG by PC (Peter Spirtes and Clark Glymour) algorithm (Spirtes et al. 1999; Uhler et al. 2013). The link and direction in DAG indicate the direction of a statistical causality between variables, and it can be used to restrict SVAR model. Following these steps, we could establish an identified SVAR model by DAGs.

4.2 Description of bubble in market level

The description of ΔMb_t is present in table 5 and figure 1.

Table 4.1: **Description of ΔMb_t**

dMB	*Mean*	*Std.Dev*	*Min*	*Max*	*Observations*
overall	-0.004	0.0543	-0.299	0.372	1128

Figure 4.1: **The value of ΔMb_t**

This figure presents the value of dMB over time. The red bar is the value of monthly dMB, the blue shadow is the period that the annual moving average of dMB below one standard deviation, and the purple shadow is the period that the annual moving average of dMB is above one standard deviation.

[See appendix figure 4.1]

The mean of dMB is -0.00448, and it close to zero compared with its standard deviation 0.0543. In figure 1, We add a blue shadow to that month If the annual moving average below one standard deviation, represent in this period bubble shrinking fast (or speed up undervalue mispricing). Similar, If the annual moving average is above one standard deviation then we will add a purple shadow showing this month bubble expansion fast (or speed up back to normal from undervalue mispricing).

The data started from 1927-33 great depression, and at the same time ΔMb_t shows the asset mispricing experiencing downward adjustment from OCT 1929 to SEP 1932. Other major downward adjustment occurs during OCT 1937 to APR 1938 before world war 2; 1979 to 1982 during financial crisis; FEB 2001 to SEP 2001 during the crash of tech bubble, and 2008 during the subprime crisis. The description of dMB in figure 1 shows this indicator matches historical events.

Before performing a SVAR analysis, we make a preliminary analysis of the relation between ΔMb_t and monetary policy, so as to get an intuitive impression of the correlation between the two variables. We first calculate the 12 month moving average of ΔMb_t (*amadMb*) to eliminate the noise. Figure 3 presents the relation between the federal funds rate (FFR) and the *amadMb*, figure 4 presents the scatter plot of monetary policy and *amadMb*.

Figure 4.2: **The relation between the federal funds rate (FFR) and the annual moving average of ΔMb_t.**

[See appendix for Figure 4.2]

Figure 4.3: **Scatter plot of FFR and amadMB**

[See appendix for Figure 4.3]

As can be seen from those figures, the monetary policy has significant negative effects on $amadMb$. A simple univariate OLS regression between monetary policy (FFR and M2G) and $\Delta Mb/amadMb$ also significantly support this view. Moveover, in fighre 3 there have few exceptions such as the period of dot com bubble and subprime crisis. During this period the bubble component is increasing with the FFR decreasing simultaneously. We believe these exceptions could because of the great swing of asset bubble make the central bank to change monetary policy to keep economy stable, but the decreasing of FFR cannot immediately change the moving trend of mispiricng. This endogenous problem is also the reason we believe those research only focus on financial crisis period are not robust.

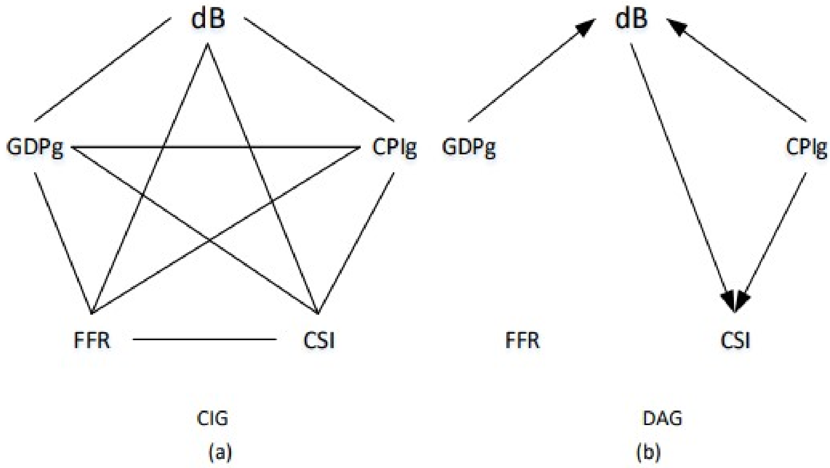
4.3 Evidence

4.3.1 DAG and SVAR identification.

we first build a VAR model following equation 4.2 and the order of lag $k = 1$, include variables ΔMb_t, FFR_t, CSI_t, $CPIg_t$ and $GDPg_t$. We have tested the multicollinearity problem by residual correlation matrix, and the results suggest that there have no significant multicollinearity problem. Following the previous research, we build a CIG which assumes these five variables are interconnected, and derive a DAG from residual correlation matrix by PC algorithm, the results are as following:

Figure 4.4: **The DAG**

Note: This figure (a) reports the CIG, figure (b) reports the DAG derived by PC algorithm through Tetrad v6.8. The arrows represent the direction of causality, each link represent the causality significant at 95% level.



The DAG results depicted as fighre 5, represent for the contemporaneous causality between variables. As suggest by DAG, at 5% significance level (same results at 10% significance level), the change of bubble component and the growth of CPI have a contemporaneous impact on the market sentiment, growth of GDP and growth of CPI have a contemporaneous impact on the change of bubble component. The interest rate do not have contemporaneous relation with other four variables.

This study use the results of DAG depicted in figure 5 to impose restrictions on SVAR matrix $\boldsymbol{A}$, we impose identifying restrictions on the SVAR matrix. For variables have no significant contemporaneous causalities, we set the coefficient at 0. For illustrative purposes we show what the relationship between the structural disturbances $\boldsymbol{u}$ and the VAR disturbances $\boldsymbol{e}$ looks like:

$$
\begin{bmatrix} 1 & 0 & 0 & a_{1,4} & a_{1,5} \\ 0 & 1 & 0 & 0 & 0 \\ a_{3,1} & 0 & 1 & a_{3,4} & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}
\begin{bmatrix} e_{\Delta Mb} \\ e_{FFR} \\ e_{CSI} \\ e_{CPIg} \\ e_{GDPg} \end{bmatrix}
=
\begin{bmatrix} b_{1,1} & 0 & 0 & 0 & 0 \\ 0 & b_{2,2} & 0 & 0 & 0 \\ 0 & 0 & b_{3,3} & 0 & 0 \\ 0 & 0 & 0 & b_{4,4} & 0 \\ 0 & 0 & 0 & 0 & b_{5,5} \end{bmatrix}
\begin{bmatrix} u_{\Delta Mb} \\ u_{FFR} \\ u_{CSI} \\ u_{CPIg} \\ u_{GDPg} \end{bmatrix}
$$

4.3.2 Empirical results

In this section, we present empirical results by analysing the impulse response obtained from above matrix. The regression results of SVAR model present as following table 11:

Table 4.2: **Coefficient of SVAR model**

Note: This table reports the coefficient estimates from the SVAR model over the period 1954-2019 with the standard deviation in parentheses. The symbols ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.
[See appendix for table 4.2]

We found all variables are significant at 1% level except $a_{3,4}$, and the impulse response are depicted as figure 4.5:

Figure 4.5: **Impulse response**

Note: These figures report the impulse responses for the market-level SVAR model. gray area represents 95% confidence intervals, and responses are shown for an 18-month horizon. The title present as a form of (impact variable, response variable).
[See appendix for figure 4.5]

Figure 5 shows the results of the impulse responses from the SVAR estimation. Column 5 in Figure 5 displays the impact of macroeconomic variables on the change of the bubble component (Δbm). The central interest of our empirical analysis is presented in the second row of column 5, which shows that, controlling for other economic factors such as CSI, CPI and GDP growth rates, a one standard deviation increase in the FFR in a month lowers the change of the bubble component Δbm by 1.4% in the next month, and reaches its peak of 1.8% in the month after. The impacts then slowly decline over time, but continue to exhibit negative effects of greater than 1% on Δbm up to 18 months. The impacts in all the 18 months are significantly different from 0 at the 95% confidence interval. Our findings show that the negative impact of the federal funds rate on the change of the bubble component Δbm is significant, both statistically and economically, and long lasting. Our evidence suggests that lifting the federal funds rate helps to constrain asset price bubbles, which supports our theoretical predictions. Our evidence is consistent with the findings of Bordo and Landon-Lane (2014), Jord'a et al (2015), and Caraiani and Călin (2020).

For other control variables, the first row in column 5 shows that a on standard deviation increase in CPI growth rate in a month lowers Δbm by 3% in the next month, and 5% in the month after. The impact of CPI growth rate on Δbm then gradually reduces to 0 within 5 months. The third row in column 5 shows that a on standard deviation increase in monthly GDP growth rate increases Δbm by 5% in the next month, and then reduces to 0 within 10 months. The second row in column 1 shows that a on standard deviation increase in FFR have persistent and negative effect on the CPI, and the second row in column 3 shows FFR have insignificant effect on GDP growth rate. These results are consistent with our model implications. The fourth row of in column 5 shows that the impact of CSI on Δbm is statistically insignificant, as indicated by the inclusion of 0 inside the 95% confidence interval. The fifth row in column 5 shows that a one standard deviation increase in Δbm has a positive impact of 45% on itself in next month, and then reduces to 0 within 3 months. This finding indicates that the change of the bubble component is positively autocorrelated.

The impacts of the bubble component on other variables are in the bottom row in Figure 5. The growth of the bubble component in a month has a negative, albeit statistically insignificant, impact on the federal funds rate in the next month, with such an impact later turns positive. On the other hand, positive movements of the bubble component have a positive impact on inflation (CPIg) and consumer sentiment. The effect of the bubble component on the GDP growth rate is statistically insignificant.

4.4 Robust test

4.4.1 Risk free rate

In previous research we use one month treasury rate as risk free rate to calculate the $\Delta \boldsymbol{b}$. Consider the liquidity of stock asset, literature usually use one month or three month treasury rate as risk free discount rate. To test if regression result still robust when we change the selection of risk free rate, we use three month treasure rate as discount rate, calculate $\Delta \boldsymbol{b}$ (three-month) and analysis it by same regression. The result present as table 8.

Table 4.3: **The regression results of Δb (calculated by 3 month treasury rate)**

Note: This table reports the coefficient estimates from the firm-level regression with FFR and M2G over the period 1954-2019 with the standard deviation in parentheses. The risk-free rate used to calculate dB is three-month treasury return. The symbols ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively. Model 1 to 3 use FFR as independent variable, control firm effects; firm effects and time effects; firm effects and industry effects, respectively. Model 4 to 6 use M2G as independent variable, control firm effects; firm effects and time effects; firm effects and industry effects, respectively. Definitions of variables are provided in Table 1.

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
FFR	-0.550***	-2.791***	-0.553***			
	(0.004)	(1.005)	(0.004)			
M2G				1.122***	1.800	1.121***
				(0.024)	(1.179)	(0.024)
CSI	-0.014***	0.444***	-0.014***	-0.022***	1.271***	-0.022***
	(0.000)	(0.064)	(0.000)	(0.000)	(0.154)	(0.000)
lnVol	0.373***	0.088***	0.372***	0.528***	0.093***	0.528***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
lnSize	-0.307***	-0.102***	-0.401***	-0.113***	-0.113	-0.402***
	(0.013)	(0.013)	(0.013)	(0.014)	(0.014)	(0.014)
Constant	0.005***	-0.340***	0.029***	-1.147***	-2.993***	-1.138***
	(0.169)	(0.552)	(0.003)	(0.024)	(1.132)	(0.024)
Ind effect	No	No	Yes	No	No	Yes
Time effect	No	Yes	No	No	Yes	No
Obs	3,867,895	3,867,895	3,867,895	3,811,770	3,811,770	3,811,770
R2	0.0032	0.0589	0.0032	0.0014	0.0588	0.0013

Compared with regression use Δb (one-month) data, the coefficient and significance in table 7 changed very less.

4.4.2 Market sentiment

In previous section, especially in firm level analysis we find that market sentiment is negatively related with bubble component, this finding runs counter to the intuitive perception of the relationship between stock prices and market sentiment.

To test if this finding is robust, we apply OECD Consumer Confidence Index (CCI) for the United States and 10 years to 2 years treasury yield spread (YS10-2) as alternative measures of market sentiment. The results are shown below:

Table 4.4: **The regression results of Δb with alternative measures of market sentiment**

Note: This table reports the coefficient estimates from the firm-level data with the standard deviation in parentheses. The risk-free rate used to calculate dB is three-month treasury return. The symbols ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively. Model 1 and 2 use CCI as the measure of market sentiment, covered from 1960 to 2019; Model 3 and 4 use 10 years to 2 years treausry yield spread as the measure of market sentiment, covered from 1976 to 2019. Definitions of variables are provided in Table 1.

	(1)	**(2)**	**(3)**	**(4)**
FFR	-0.499***		-0.580***	
	(0.004)		(0.007)	
M2G		0.471***		0.577***
		(0.030)		(0.031)
CCI	-0.132***	-0.228***		
	(0.008)	(0.008)		
YS10-2			-0.292***	-0.851***
			(0.019)	(0.013)
GDPg	1.638***	1.420***	1.773***	1.345***
	(0.044)	(0.044)	(0.047)	(0.046)
CPIg	-2.122***	-4.268***	-2.005***	-3.418***
	(0.041)	(0.052)	(0.043)	(0.055)
lnVol	0.386***	0.517***	0.222***	0.403***
	(0.011)	(0.011)	(0.012)	(0.011)
lnSize	-0.344***	-.420***	-.474***	-.617***
	(0.012)	(0.012)	(0.013)	(0.013)
Constant	0.117***	0.191***	-0.025***	-0.070***
	(0.791)	(0.795)	(0.002)	(0.001)
Obs	3,798,877	3,798,877	3,372,261	3,372,261
R2	0.0047	0.0031	0.0039	0.0031

The regression results suggest that market sentiment negatively related with the bubble component, the coefficient of all other variables are consistent with our results presented in section 4. This results indicate that our conclusion is robust. We further regressed the stock price and the change of fundamental value with market sentiment, the results shows that market sentiment positively related with the stock price and fundamental value. These results indicate that when the market has positive sentiment, the fundamental price of the stock rises faster than the price, which squeezes out the bubble component.

4.5 Conclusions

In this chapter we proved that easing (tight) monetary policy have a positive (negative) effect on the upward movement of asset mispricing at market level empirical analysis covered from 1954 to 2019. In this chapter we build an indicator of market level bubble component, and by using SVAR method, we discussed the endogenous bias caused by contemporaneous correlation between monetary policy and bubbles. The results of our empirical analysis shows that a one standard deviation increase in the FFR in a month lowers the change of the bubble component Δbm by 1.4% in the next month, and reaches its peak of 1.8% in the month after. The impacts then slowly decline over time, but continue to exhibit negative effects of greater than 1% on Δbm up to 18 months. The impacts in all the 18 months are significantly different from 0 at the 95% confidence interval. Our findings show that the negative impact of the federal funds rate on the change of the bubble component Δbm is significant, both statistically and economically, and long lasting. Our evidence suggests that lifting the federal funds rate helps to constrain asset price bubbles, which supports our theoretical predictions.

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Chapter 5

CEO power and debt overhang

5.1 Introduction

A prominent consequence of the emergence and collapse of asset price bubbles is debt overhang (Illing, Ono,and Schlegl, 2018). Debt overhang suggests that the equity-holders of a firm with great debt burden will tend to under-invest because a fraction of the profit of their investment will accrue to debt-holders upon default (Myers, 1977), the theory of debt overhang supported by substantial evidence (Manso, 2008; Cai, and Zhang, 2011;Vanlaer, Picarelli, and Marneffe, 2021; Donaldson, Piacentino, and Thakor, 2019). Debt overhang causes systemic low investment rates seen in the post-crisis period (Lamont, 1995;). The indebtedness of the private sector is considered a major impediment to economic recovery. Jordà, Schularick, and Taylor (2015) analysed bubbles in housing and equity markets in 17 countries over the past 140 years, found that credit make bubbles more dangerous for economy. When fueled by credit booms, asset price bubbles increase financial crisis risks; upon collapse they tend to be followed by deeper recessions and slower recoveries.

Asset price bubbles is an important causes of debt overhang, enterprises and individuals tend to raise debt during the period of asset price rising, while the bursting of asset price bubble will rapidly deteriorate the balance sheet of private sectors. . Gjerstad and Smith (2009) found The Crash of 2008 was caused by the bursting of a housing bubble of unusual size that was fed by a massive expansion of mortgage credit. when the bubble burst and housing prices declined, household losses quickly exceeded their equity, the problem of debt overhang emerge. Liquidity loss and solvency fears created a feedback cycle of diminished financing, reduced housing demand, falling housing prices, more borrower losses, and further damage to the financial system and eventually the stock market and the real economy. Eggertsson and Krugman (2012) and Korinek and Simsek (2016) illustrate the reduction in private demand due to debt overhang during balance sheet recessions. Koo (2014) found the debt overhang and balance sheet recession caused by Japanese real estate bubble in the 1990s are the reasons for Japanese ”lost decades”.

Consider the widespread economic losses caused by debt overhang, literature have provided possible instruments to mitigate the negative effect of it, such as issuing short term debt (Myers 1977; Diamond, and He, 2014), special bank regulation (Andrabi, and Di Meana, 1994), or using contingent convertible capital instruments, but so far the the influence channels from the perspective of corporate governance have not been mentioned.

Board consensus reached in literature is that debt overhang cause inefficiency investment because the equity value-maximizing investment level is lower than the organizational value-maximizing investment level. In general circumstance, the manager of a company is the agent of shareholders' interests, therefore the decision-making power of the company's operation is owned by shareholders. But this precondition of debt overhang will differ with the power structure of senior managers. For example, the agency cost hypothesis predicts that managers, when less monitored by shareholders, tend to make self-maximizing decisions that may not necessarily meet the interest of shareholders. The stakeholder theory believe that a diversified decision structure have positive impact on the stakeholder management (Harjoto, Laksmana, and Lee, 2015; Fernandez, and Thams, 2019; Padilla-Angulo, 2020). Therefore, the decision power structure possibly have significant influence on the firm's investment policy.

Corporate strategy must serve the purpose of organizations, which is shaped by vision, leadership and ethics (Lynch 2006), and the power structure in management teams have great influence on all of these determinants. Although large firms have many officers, but typically only a small subset of them is responsible for setting policy (Thompson et al 2017). This decision-making group usually consist by the CEO and several top managers, therefore CEO power can be a good proxy for decision power concentration. Finkelstein (1992) first empirically discuss the dimensions and measurement of power in management teams, and build a proxy of CEO power. In most scenario, CEO is the most powerful member in this group, but this power structure is also determined by many other factors other than the position, such as shareholding, or board support. Making corporate strategy is a shared effort in which a dominant coalition collectively shapes organization outcomes. (Daily and Johnson 1997; Baldenius et al 2014, Abernethy et al 2015).

The empirical measurement of CEO power in previous literature is different, but they are basically made up of one or more of four basic factors, which is CEO duality, CEO remuneration, CEO expertise, and CEO stockholding (Pathan 2009; Liu and Jiraporn 2010; Korkeamäki, Liljeblom, and Pasternack 2017; Li et, al. 2018; Muttakin, Khan and Mihret 2018).The research about CEO power covers the topic of corporate financing strategy (Mehran, Taggart and Yermac 1999; Jiraporn, Chintrakarn, and Liu 2012; Korkeamäki, Liljeblom, and Pasternack 2017); risk taking (Pathan, S., 2009; Lewellyn, and Muller 2012; Mollah, and Liljeblom 2016); merge and acquisitions (Chikh, and Filbien 2011), and compensation (Henderson, Masli, Richardson, and Sanchez 2010; Abernethy, Kuang, and Qin, 2015), but no previous literature discussed the possible effect of CEO power on debt overhang.

Previous literature shows that higher CEO power affect the corporate investment policy through various channels. The most mentioned channel is the agency problem. The monitoring from the board and other executives can no longer provides sufficient constrain on CEO with higher power. Following the empire building hypothesis (Jensen and Meckling 1976, Chhaochharia et al., 2012; Levi et al., 2014), the CEO with higher power have motivation to invest more than shareholder's interest. Higher CEO power could also amplify the effect of CEO's personal characters, such as overconfidence (Malmendier. and Tate, 2005) or personal leverage preference (Korkeamäki, Liljeblom, and Pasternack, 2017). Moreover, the CEO power could change the firm's risk preference (Pathan, 2009, Lewellyn, and Muller, 2010; Kahle, 2012) and further change the firm's investment policy, although the conclusion on this topic is not consensus. CEO with higher power could either promoting excessive risky investment or adopting risk aversion strategies. With many evidence, we believe the CEO power could be an important determinant of corporate investment policy, and in this paper we are going to provide further discussion on this topic.

Different with the relation between investment and CEO power, the phenomenon of insufficient investment caused by the effect of debt overhang provide us another perspective of the relation between corporate decision structure and corporate behavior. It is because the CEO has less interest conflict with shareholders when facing the impact of debt overhang. Compared with personal decision, literature suggest that groups have more experience, increased processing capabilities, the ability to monitor each other for mistake, and shared information (Stahlberget al., 1995; Gilovich, Griffin, and Kahneman, 2002; Kugler, Kausel, and Kocher, 2012). We believe diversified decision structure could influence the stakeholder management by setting policies that prioritizes the interest of non-financial stakeholders or providing the firm with valuable knowledge for better manage the overall interest (Fernandez, and Thams, 2019). In this paper we proposed a novel and important debate on whether corporate with centralized decision power will tend to maximize the interests of shareholders or the organizations when there has no conflict with CEO's own interests.

In our theory, we model companies' investment decision as a result of maximum management utility, which is a combination of equity holders' utility and organization's utility. We model the effect of debt overhang as a transformation of investment return from equity holder to debt owner upon default, which is proposed by Myers 1977; Leland, and Toft 1996. We assume a management team with lower CEO power tend to maximum the organization's utility, but firm with higher CEO power have an increased tendency to catering equity holder's interest.

We measure the CEO power from four dimensions, which is CEO tenure, CEO stock holding, CEO duality (combining the roles of the CEO and the chair of the board of directors), and CEO remuneration. We build our proxy of CEO power by principal component analysis, and unweighted average respectively. Following the research of), and Alanis,Chava,and Kumar (2018), we build our proxy of debt overhang by the leverage, recovery ratio, and the value of the hitting claim. Following the research of), we take average Tobin's Q ratio as a control variable. We use fixed effect panel model empirically analysis the relation between investment, CEO power and debt overhang. The results indicate that CEO power significantly increase the corporate investment, which is in line with the empire building hypothesis. CEO power could amplify the negative effect of debt overhang on investment, suggest that with centralized decision power, the corporate management tend to maximum the shareholder's interest. Instead, corporate with lower CEO power tend to mitigate the negative effect of debt overhang, suggest that with diversified decision power, the corporate management tend to maximum the organization's interest.

We conduct extensive robustness checks, and all our evidence support our hypothesis. First, we construct a proxy for CEO overconfidence, following Malmendier and Tate (2005), and Campbell, et al. (2011). We include this proxy for CEO overconfidence to explain the tendency to initiate, increase, decrease, and omit dividends. Our findings show that CEO power have distinct effects on dividends, and stand out as the most consistent variable explaining dividend decisions. In fact, the proxies for CEO overconfidence by themselves exhibit contradicting and non-intuitive effects on various dividend decisions. This is consistent with Alti and Tetlock (2014), who show that an overconfidence bias predicts future asset returns in the opposite direction of those predicted by overextrapolation.

Second, we control for the effect of corporate events, such as seasoned equity offerings or share repurchases, on earnings per share. Our findings remain unchanged. Third, Bliss, Cheng, and Denis (2015) document significant reductions in corporate payouts during the 2008–2009 financial crisis. We control for periods of financial crises, and the pattern of results remains unchanged. Fourth, we take share repurchases into account to analyze the effect of dividend initiations, and our findings remain unchanged.

The rest of the paper is organized as follows. Section 2 develops our hypotheses. Section 3 describes the sample and variable constructions. Section 4 tests firms' dividend decisions following CEO power, examines firm-level relations between patterns of changes in past earnings and dividend decisions, and investigates the effects of managerial overreactions deriving from the rarity of success or failure on dividend payments. Section 5 conducts a series of robustness tests. Finally, Section 6 concludes the paper.

5.2 A Theory of management power and debt overhang

We model a levered firm with endogenous investment and default possibility. Following the stakeholder theory, we assume a diversified decision structure tend to maximum the overall interests of the company, instead, management with a centralized decision structure will tend to maximum the shareholder's interest.

5.2.1 Model

Debt overhang suggests that the equity-holders of a firm with great debt burden will tend to under-invest because a fraction of the profit of their investment will accrue to debt-holders upon default. Myers (1977) break the current value of a firm V into the present value of assets already in place and the present value of future growth opportunities, as $V = V_A + V_G$, where V_G determined by the future cash flow of investments. However the equity owner and debt owner have different utility maximization functions. Myers (1977) claim there is a transfer of value from stockholders, who make the investment, to bondholders, who contribute nothing, and he predict that appropriate investment incentives exist only when this transfer of value equals to 0. Leland, and Toft 1996 examines the optimal capital structure of a firm that can choose both the amount and maturity of its debt. In his model bankruptcy is determined endogenously rather than by the imposition of a positive net worth condition or by a cash flow constraint. The model predicts leverage, credit spreads, default rates, while short term debt does not exploit tax benefits as completely as long term debt, it is more likely to provide incentive compatibility between debt holders and equity holders. Short term debt reduces or eliminates "asset substitution" agency costs. The tax advantage of debt must be balanced against bankruptcy and agency costs in determining the optimal maturity of the capital structure. Following the research made by (Myers 1977; Leland, and Toft 1996), we simplify the model of debt overhang as following:

The firm: let V define the asset value and we got:

$$V_t = V_t^E + V_t^D \tag{5.1}$$

Where V_t is the market value of asset, V_t^E is the market value of equity and V_t^D is the market value of debt. The effect of an incremental discretionary investment on the discounted present market value of equity is:

$$\frac{dV_t^E}{dI_t} = \frac{dV_t}{dI_t} - \frac{dV_t^D}{dI_t} \tag{5.2}$$

We define the investment function $V(I)$ is an increasing and concave function, that is, $V_t'(I_t) > 0$, and $V_t''(I_t) < 0$.

The investment policy which maximizes the value of the firm is to keep invest until $\frac{dV}{dI} < 1$. This means the optimal decisions for firm to maximum the firm value is to invest all project with positive net present value, project have positive present value may not necessarily attractive to the firm's owners. Due to the existence of default risk, at any point in time the value of bond is related to the value of the firm and the uncertainty about the firm's future value (Jaffee and Russell 1976), as following:

$$V_t^D = f_t(V_t, \sigma^2) \tag{5.3}$$

—

Where V_t is the market value, and σ^2 is the variance rate of overall market value. Consider the default risk decrease with the firm value therefore $\frac{\partial f_t}{\partial V_t} > 0$, and we could derive:

$$\frac{dV_t^E}{dI_t} = \frac{dV_t}{dI_t} \cdot (1 - \frac{\partial f_t}{\partial V_t}) - \frac{\partial f_t}{\partial \sigma^2}(\left(\frac{\partial \sigma_t^2}{\partial I_t}\right)) \tag{5.4}$$

Equation 4.4 is obtained by substituting Equation 4.3 into 4.2 and taking the derivative. Represent that increase in enterprise equity value brought by one unit of investment is equal to the total enterprise value increase brought by one unit of investment minus the value transferred to the debt owner due to the decrease in default probability. This value is manifested as the increase of market value of corporate bonds when the enterprise equity value increases. Assume that the firm's risk level is unaffected by the investment decision where $\frac{\partial \sigma_t^2}{\partial I_t} = 0$, the equation suggest that there is a transfer of value $\frac{dV_t}{dI_t} \cdot \frac{\partial f_t}{\partial V_t} > 0$ from shareholder to debt owner due to the decrease of default risk.

The manager:

let ρ define the CEO power, and we assume with the decrease of ρ, the decision made by a diversified decision group will more in line with the overall interests of the company, as following:

$$\max_{I_t}^{m} U(I_t) = V_t(I_t) - \rho V_t^D(I_t) - I_t \tag{5.5}$$

We propose that when CEO have higher power, i.e. $\rho = 1$, firms investment strategy tend to maximum the shareholder's utility, and when CEO have less power, i.e. $\rho = 0$, firms investment strategy tend to maximum the overall utility. Note that when $\rho = 1$, the equation 5.5 is the same as standard debt overhang equation (Myers 1977), where the management only take shareholder's preference into consideration.

Proposition: The negative effects of debtoverhang will increase with CEO power.

Proof of proposition: for any $0 \leqslant \rho \leqslant 1$, the first order condition of equation 5.5 that solves for the optimal investment level is:

$$\partial_I E^m U(I) = \frac{dV_t}{dI_t} - \rho \cdot .... \frac{dV_t}{dI_t} \cdot \frac{\partial f_t}{\partial V_t} = 1 \tag{5.6}$$

We define $U^*(I,\rho)$ is the optimal investment level, and I^* is the optimal investment level, and we could derive that:

$$\frac{dV_t}{dI_t^*} = \frac{1}{1-\rho\frac{\partial f}{\partial V}} \tag{5.7}$$

we could derive that with the increase of CEO power ρ, the left side $\frac{1}{1-\rho\frac{\partial f}{\partial V}}$ will also increase, and consider $V'(I) > 0$, and $V''(I) < 0$, we could derive the investment equation $I^*(\rho)$ is an decrease equation where $\frac{dI^*(\rho)}{d\rho} < 0$. This conclusion represent that the negative effects of debtoverhang will increase with CEO power.

5.2.2 Hypothesis development

Empire building hypothesis believes that CEO or executives have personal interest to increase the size and scope of their power and influence. To achieve this goal, they have motivations to expend the corporate business units or staffing levels instead of maximum shareholder's interest. This phenomenon cause firms with high free cash flows have motivations to over-invest on inefficient projects (Jensen and Meckling 1976, Jensen 1986). the CEO with higher power are less constrained by other executives and broad, therefore they are motivated by their personal interests to invest more than shareholder's will (Chhaochharia et al., 2012; Levi et al., 2014).

Hypothesis 1: corporate with higher CEO power tend to have higher investment level.

The stakeholder theory is a view of organization management or business ethics that accounts for multiple entities impacted by corporate strategies (Donaldson, and Preston, 1995). Research suggest that board diversity increase corporate social responsibility (Harjoto, Laksmana, and Lee, 2015), and stakeholder management. Following previous research, we assume centralized decision power will make corporate strategies less concern about other entities and overall interest when CEO have less interest conflict with shareholders. As presented in our model in section 2.1, we believe a centralized decision power will amplify the negative effect of debt overhang on investment.

Hypothesis 2: higher CEO power could amplify the negative effect of debt overhang on investment.

5.3 Measure CEO Power and debt overhang

Since the main variables in this article cannot be obtained directly, we first empirically estimate the CEO power and debt overhang.

5.3.1 CEO power

Consider the theory of the power in management teams (Finkelstein 1992), and the research made by Pathan (2009), Liu and Jiraporn (2010), Korkeamäk et al (2017), and Li et al (2018). We construct the composite index for CEO power by four dimensions: (1)Tenure. Korkeamäki et al (2017) note that longer tenure allows the CEO to increase his power within the organization. The CEO's tenure is equal to one plus the fiscal year minus the year he became CEO (plus one means if CEO became CEO less than one year will be approximate to one). Then we build a dummy variable $\boldsymbol{DT}$ equals to 1 if a CEO's tenure above the average, and 0 if otherwise. (2) Stock holding. The stock holding is used to measure the ownership of the company (Veprauskaite and Adams 2013). The stock holding equals to the CEO owned shares excluded options ($\boldsymbol{SHROWN\_EXCL\_OPTS}$) divided by common shares outstanding ($\boldsymbol{CSHO}$). Then we build a dummy variable $\boldsymbol{DSH}$

equals to 1 if a CEO's stock holding above average and 0 if otherwise.(3) CEO duality. We build a dummy variable DD equals to 1 if a CEO is also a chairman, and 0 if otherwise. (4) CEO remuneration. The executive's revenue is measured by the salary plus bonus ($EXECRANKANN$). We build a dummy variable DR equals to 1 if the CEO has the highest revenue among the executive team, and 0 otherwise.

We use the principal components analysis (PCA) and unweighted average method to build the proxy of CEO power. Principal component analysis is a versatile statistical method for reducing a cases-by-variables data table to its essential features, called principal components. Principal components are a few linear combinations of the original variables that maximally explain the variance of all the variables. In the process, the method provides an approximation of the original data table using only these few major components (Greenacre et al, 2022). The PCA method provides us with a more statistically significant index construction method. Compared to scoring or aggregation, the PCA method avoids the process of weighting index components based on subjective judgment. To calculate the $CEOP\_PCA$, we first standardization the four variables DT, DSH, DD, and DR. Then we compute the covariance matrix of variables and calculate the eigenvectors and eigenvalues. Last we identify the principal component and calculate the composite factor $CEOP\_PCA$ which is the average of principle components weighted by the contribution of total variance. The unweighted average of CEO power ($CEOP\_AVE$) equals to the average score of above four dimensions ($DT + DSH + DD + DR/4$).

Table 5.1: **Data description of CEO power variables**

The first four columns of Table 1 report the numbers of firms with unweighted average CEO power (CEOP_AVE) equals to 0, 0.25, 0.5, 0.75, 1 (N0, N0.25, N0.5, N0.75, N1), the last four column report the mean of CEOP_AVE, the mean of CEOP_PCA, the standard error of the mean of CEOP_PCA, and total number of firms by year.

YEAR	*N0*	*N0.25*	*N0.5*	*N0.75*	*N1*	*Mean AVE*	*Mean PCA*	*Std PCA*	*all firms*
1992	12	78	174	142	27	0.5543	0.2785	0.7297	433
1993	41	186	441	366	122	0.5740	0.3172	0.7645	1156
1994	52	289	543	494	172	0.5718	0.2953	0.7795	1550
1995	56	347	552	461	183	0.5575	0.2510	0.7967	1599
1996	69	340	597	455	189	0.5538	0.2428	0.8068	1650
1997	68	355	627	450	173	0.5456	0.2144	0.7942	1673
1998	71	388	639	454	177	0.5402	0.1954	0.7993	1729
1999	81	400	663	502	162	0.5365	0.1747	0.7937	1808
2000	91	412	681	449	156	0.5233	0.1354	0.8008	1789
2001	82	455	621	388	123	0.5022	0.0744	0.7874	1669
2002	66	454	646	366	141	0.5093	0.1072	0.7799	1673
2003	94	467	649	373	158	0.5049	0.0930	0.8103	1741
2004	89	487	625	398	151	0.5050	0.0991	0.8094	1750
2005	103	534	597	388	131	0.4872	0.0406	0.8172	1753
2006	100	608	625	407	132	0.4817	0.0160	0.8095	1872
2007	140	793	738	460	137	0.4626	-0.0694	0.8012	2268
2008	149	782	712	433	123	0.4544	-0.0893	0.8017	2199
2009	139	778	725	424	106	0.4517	-0.0984	0.7825	2172
2010	143	763	730	411	98	0.4485	-0.1084	0.7783	2145
2011	155	724	709	425	98	0.4511	-0.1008	0.7927	2111
2012	135	736	702	420	93	0.4521	-0.1010	0.7821	2086
2013	132	730	734	408	80	0.4489	-0.1056	0.7687	2084
2014	145	693	745	406	81	0.4499	-0.1028	0.7746	2070
2015	138	715	678	388	77	0.4438	-0.1210	0.7737	1996
2016	149	706	627	365	71	0.4352	-0.1456	0.7838	1918
2017	134	743	571	352	62	0.4282	-0.1677	0.7722	1862
2018	146	763	515	308	60	0.4125	-0.2166	0.7736	1792
2019	161	778	436	288	58	0.3989	-0.2636	0.7852	1721
2020	142	692	453	245	48	0.3995	-0.2597	0.7695	1580

Table 1 presents a detailed description of CEO power, include ***CEOP_AVE*** and ***CEOP_PCA***. We find that the CEO power keep decreasing from 1992 to 2020, with the mean of ***CEOP_AVE*** dropped from 0.55 to 0.40, and the mean of ***CEOP_PCA*** dropped from 0.28 to -0.25. The number of observations is based on the listing companies, exclude the companies have missing CEO data.

5.3.2 Debt overhang

Myers (1977) showed that default risk undermines the incentives to invest for indebted firms, thus measuring debt overhang entails evaluating how a company's high levels of debt may be impeding its capacity to engage in profitable investments, ultimately resulting in suboptimal performance. In empirical research, leverage ratios or debt ratios could be used to measure debt overhang (Brunnermeier and Krishnamurthy, 2020, Cevik and Miryugin, 2022, Jordà et al, 2022), but these measurement could be biased for not strictly adhere to the definition of debt overhang. Hennessy (2004) estimates the debt overhang using Moody's hazard rates by bond ratings, Alanis, Chava, and Kumar (2018) observe debt overhang by the expected value of hitting claim. Following their research, we define the normalized corporate debt overhang by $\boldsymbol{Overhang} = \frac{R}{K}$, which is the imputed market value of lenders' recovery claim $\boldsymbol{R}$ in default normalized by the capital stock $\boldsymbol{K}$. Following this definition, we measure the effect of debt overhang by the leverage, recovery ratio, and the value of the hitting claim. Based on the different measurement of recovery ratio, we construct three proxies of debt overhang $\boldsymbol{Overhang}^{APR}$, $\boldsymbol{Overhang}^{AVE}$, and $\boldsymbol{Overhang}^{WEI}$.

We measure the effect of debt overhang ($\boldsymbol{Overhang}^{APR}$) when no violation on the absolute priority rule (In the event of corporate liquidation, debts to creditors will be paid off first, then shareholders divide the remaining assets) as following:

$$Overhang_i^{APR} = (1-\varphi)\cdot\left(\frac{LTD}{K}\right)\cdot\left(\sum_{t=1}^{20}\phi_{i,t}d_t\right) \tag{5.8}$$

where φ is the the proportional cost of financial distress, LTD denote the value of long-term debt, $\phi_{i,t}$ is the default probabilities for corporate i in time t measured by bond rating, and d_t is the discount factors in time t. This equation suggest that when absolute priority rule is completely satisfied, the debt owner only suffer lost from financial distress cost in default.

Consider the uniform φ ignores the industry variation of default loss, we build the other two measurements of debt overhang $Overhang^{AVE}$, and $Overhang^{WEI}$ by the observed recovery ratio from Altman, and Kishore (1996) as following:

$$Overhang_i^{AVE} = rr_i^{AVE} \cdot \left(\frac{LTD}{K}\right) \cdot \left(\sum_{t=1}^{20} \phi_{i,t} d_t\right) \tag{5.9}$$

where $Overhang^{AVE}$ is the debt overhang measurement by the average recovery ratio, rr^{AVE} denotes the average recovery ratio by SIC three digital industry code upon default.

and:

$$Overhang_i^{WEI} = rr_i^{WEI} \cdot \left(\frac{LTD}{K}\right) \cdot \left(\sum_{t=1}^{20} \phi_{i,t} d_t\right) \tag{5.10}$$

where $Overhang^{WEI}$ is the debt overhang measurement by the weighted recovery ratio, rr^{WEI} denotes the weighted recovery ratio by SIC three digital industry code upon default.

In detail of empirical implementation, we set the financial distress cost $\varphi = 10\%$ based on previous research (Weiss, L. A. 1990, Andrade and Kaplan 1998, Alanis, Chava,and Kumar, 2018). The default risk $\phi_{i,t}$ is estimated from discrete-time hazard model (Shumway, 2001; Cheng, Chu, and Hwang, 2010, and Alanis,Chava,and Kumar, 2018), which has been shown outperform other extant bankruptcy prediction models or bond rating (Chava, Stefanescu, and Turnbull 2011). We estimate the bankruptcy model with Altman's variables, which includes working capital to total assets, retained earnings to total assets, earnings before interest and taxes to total assets, market equity to total liabilities, sales to total assets, and logarithm of corporate age. The data for coefficient estimation covers the period from 1962-1992. We then forecasting the risk of bankruptcy with the data from 1992 to 2020. The discount factors (d_t) are calculated from long-term Treasuries. Detailed descriptions are presented as table 4.2:

Table 5.2: **Data Description of Investment and Debt Overhang**

The table reports the mean of investment, debt overhang_ave (D_ave), dent overhang_wei (D_wei), and debt overhang_apr (D_apr) by year.

YEAR	*investment*	*D_ave*	*D_wei*	*D_apr*
	0.1138	0.0083	0.0086	0.0158
1993	0.1299	0.0109	0.0140	0.0210
1994	0.1428	0.0165	0.0201	0.0322
1995	0.1403	0.0180	0.0217	0.0365
1996	0.1410	0.0200	0.0250	0.0416
1997	0.1486	0.0186	0.0220	0.0387
1998	0.1525	0.0378	0.0449	0.0752
1999	0.1569	0.0353	0.0446	0.0704
2000	0.1643	0.0423	0.0514	0.0863
2001	0.1333	0.0555	0.0676	0.1042
2002	0.1034	0.0633	0.0753	0.1185
2003	0.1028	0.0387	0.0478	0.0719
2004	0.1073	0.0467	0.0562	0.0847
2005	0.1145	0.0424	0.0535	0.0790
2006	0.1260	0.0357	0.0469	0.0673
2007	0.1643	0.0518	0.0628	0.1000
2008	0.1564	0.0944	0.1144	0.1829
2009	0.1269	0.0591	0.0721	0.1130
2010	0.0966	0.0386	0.0483	0.0725
2011	0.1109	0.0514	0.0620	0.0961
2012	0.1140	0.0488	0.0566	0.0937
2013	0.1123	0.0346	0.0413	0.0653
2014	0.1172	0.0472	0.0571	0.0919
2015	0.1096	0.0710	0.0817	0.1421
2016	0.1032	0.0607	0.0705	0.1159
2017	0.1021	0.0656	0.0802	0.1251
2018	0.1045	0.0656	0.0769	0.1240
2019	0.0901	0.0688	0.0817	0.1342
2020	0.0739	0.0929	0.1063	0.1802

We find that the mean of $Overhang^{APR}$ lager than the $Overhang^{AVE}$ and $Overhang^{WEI}$, indicate that debt owner usually suffer extra loss other than financial distress costs upon default. The market level overhang fluctuated over time, but reaches the peak in 2002, 2008, 2015 and 2020, indicate that the time-series evolutions of debt overhang closely related with financial crisis, which we will have furture discussion in section 5. Consider debt overhang is an important independent variable of investment, we also include the data of investment (*inv*) in table 2. We found the investment reaches its low at 2003, 2010, 2017, and 2020, shows a possible negative correlation with debt overhang.

5.3.3 The average Tobin's Q

Tobin's Q ratio is assumed to represent a firm's investment or growth opportunities (Tobin, 1969). Mussa (1977) and Abel (1983) proved that the marginal Q, which represents the shadow price of capital, is a sufficient statistic for investment opportunities. Since marginal Q is unobservable, Tobin's average Q is commonly used as an empirical proxy of marginal Q, which defined as the ratio of equity value plus debt value to replacement cost of the capital stock, and assumed to represent a firm's investment or growth opportunities (Tobin, 1969). Hayashi (1982), and Abel and Eberly (1994) provide formal justifications for this replacemants, suggest that Tobin's Q and marginal Q are equal under when investment is irreversible. Therefore Tobin's Q is a sufficient proxy of corporate investment opportunities (Lang, Ofek, and Stulz 1996, Hennessy 2004).

For the measurment of Tobin's Q, Lindenberg and Ross (1981), and Lang and Litzenberger (1989) developed the L-R algorithm, which based on the accounting data to observe Tobin's Q ratio. L-R method considered the term structure, and liquidating of corporate asset. Daines, (2001) and, Chung and Pruitt 1994 simplified the L-R method, measure the approximate Q ratio by the market value and total assets. Lewellen, and Badrinath 1997 measure the Q ratio as a firm's market value divided by the replacement cost of the firm's assets. Hennessy (2004, 2007) suggest that the average Tobin's Q is an important control variable of corporate investment, which represent the shadow price of capital. Following the research made by Alanis, Chava, and Kumar (2018), we use the ratio of the market value of assets to total assets as a proxy for Tobin's Q, given as following:

$$TobinQ_t^I = \frac{at_t + csho_t * prcc_t - ceq_t - txdb_t}{at_t} \tag{5.11}$$

Where $TobinQ_t^I$ is the indirectly measured average Tobin's Q at time t, at_t is the total asset value at time t, $csho_t$ is the common shares outstanding at time t, $prcc_t$ is the closing price at time t, ceq_t is the total common/ordinary equity at time t, and $txdb_t$ is the deferred tax.

5.3.4 Data and Sample statistics

Our measures of CEO power are derived from EXECUCOMP database, include $BECAMECEO$ (the data become CEO), CEO owned shares excluded options ($SHROWN\_EXCL\_OPTS$), CEO salary $SALARY$ and CEO bonus $BONUS$, and the CEO's current rank by salary and bonus $EXECRANK$. CEO's most recent title $TITLE$ used to observe if CEO is also chairman. Our meausre of corporate accounting data are from COMPUSTAT data base. We based on corporate accounting data from 1962 to 1992 to build our forecasting model of corporate default risk ϕ. The data of long term treasure rate d_t are from Board of Governors of the Federal Reserve System (US). The stock price data is from CRSP database. We using the NYSE size breakpoints to calculate the market capitalization percentile $NYP_{i,t}$ of firm i in fiscal year t. Normalized corporate free cash flow (FCF) is calculated by $FCF = \frac{dvc+oibdp-dp-xint-txt+dvp}{ppegt}$, where dvc is common and ordinary dividends, $oibdp$ is the operating income before depreciation, dp is depreciation and amortization, $xint$ is total interest and related expense, txt is the total income taxes, dvp is the preferred dividends, and corporate free cash flow is normalized by the value of gross property, plant and equipment ($ppegt$). To mitigate the influence from extreme value, in this paper the 1% fraction of the normalized corporate free cash flow (FCF) is winsorized in each tail. Consider the EXECUCOMP database start from 1992,Our sample covers all firms listed on the NYSE, AMEX, and NASDAQ from 1992 to 2020. In our sample all items must be available at time t. We exclude firms with negative market value or total assets (at). We use only the fiscal year a firm is in the CRSP at its fiscal year end, and exclude utilities firms (SIC codes 4900 o 4949) and financial firms (SIC codes 6000 to 6999) from the sample. The characteristics of variables are presented in table 5.3, the description of statistics are presented in table 5.4

Table 5.3: **The characteristics and measurement of variables**

This table reports the source and factor of variables.

[See appendix for table 5.3]

Table 5.4: **Statistical Description**

The table reports the number of observations, mean, standard deviation, minimum, and maximum of all variables in our regression.

Variable	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
investment	41,645	0.1168	0.0994	-0.2281	4.3019
CEOP_AVE	43,037	0.4794	0.2526	0	1
CEOP_PCA	43,037	-0.0002	0.8023	-1.6526	1.4460
D_ave	39,008	0.0496	0.2154	0	1.7961
D_wei	38,657	0.0598	0.2759	0	2.3403
D_apr	41,484	0.0959	0.4064	0	3.3556
TobinQ_I	42,382	1.9848	1.3280	0.7350	8.5783
NYP	43,037	0.4942	0.2901	0	1
FCF	43,037	0.2797	0.7341	-2.4144	4.3266

5.4 CEO Power and Debt Overhang

This paper takes firm level data as observations, discuss the possible influence of CEO power on the inefficient investment caused by debt overhang. The regression are run by fixed effect panel model.

5.4.1 CEO power and investment

We test our first hypothesis by examining the relation of corporate investment with the CEO power. We regress, for each year, the firm's normalized investment with CEO power.

$$Inv_{i,t} = \beta_0 + \beta_1 CEOP_{i,t} + \beta_4 TobinQ_{i,t} + \beta_5 NYP_{i,t} + \beta_6 FCF_{i,t} + u_{i,t} \qquad (5.12)$$

where investment (Inv) is the ratio of capital expenditures minus sales of plant, property and equipment to the start-of-period capital stock ($Inv = \frac{capxv - sppe}{ppegt}$), $CEOP$ is measured by the $CEOP\_PCA$, and $CEOP\_AVE$, following the research made by Baker and Wurgler (2004a), we include the $TobinQ^{I}_{i,t}$, and the corporate size measured by the market capitalization percentile NYP_{it} of firm i in fiscal year t, as control variables. The regression results are presented in table 5.5.

Table 5.5: **Panel regression of CEO power and investment**

This table shows coefficient estimates (standard error in parentheses) from running the fixed effect panel regression of investment on CEO power proxies, with unweighted average CEO power (CEOP_AVE) for model 1, 2, 3, and CEO power generated from principal components analysis (CEOP_PCA) for model 4, 5, 6. TobinQ_I is the indirectly measured average Tobin's Q, NYP is the market capitalization percentile of a firm using NYSEsize breakpoints, FCF is the normalized free cash flow winsorized one percent in each tail. The model 1 and 4 is the model control corporate fixed effect, model 2 and 5 is the model control both corporate fixed effect and time fixed effect, model 3 and 6 is the model using robust standard error, control corporate fixed effect. The symbols ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

	1	*2*	*3*	*4*	*5*	*6*
CEOP_AVE	0.0250***	0.0064***	0.0250***			
	(0.002)	(0.002)	(0.0029)			
CEOP_PCA				0.0062***	0.0010*	0.0062***
				(0.0006)	(0.0006)	(0.0009)
TobinQ_I	0.0136***	0.0114***	0.0136***	0.0137***	0.0114***	0.0137***
	(0.0005)	(0.0005)	(0.0011)	(0.0005)	(0.0005)	(0.0011)
NYP	0.0701***	0.0661***	0.0701***	0.0702***	0.0664***	0.0702***
	(0.0038)	(0.0037)	(0.0077)	(0.0038)	(0.0037)	(0.0077)
FCF	0.0083***	0.0092***	0.0083***	0.0083***	0.0092***	0.0083***
	(0.0009)	(0.0009)	(0.0024)	(0.0009)	(0.0009)	(0.0024)
Constant	0.0410***	0.0823***	0.0410***	0.0528***	0.0855***	0.0528***
	(0.0019)	(0.0046)	(0.0035)	(0.0018)	(0.0045)	(0.0034)
Robust std			control			control
Time effect		control			control	
Number of obs	41,714	41,714	41,714	41,714	41,714	41,714
R2 within	0.0571	0.1286	0.0571	0.0557	0.1284	0.0557

Table 5.5 reports the results of the regression of corporate investment (inv), with unweighted average CEO power ($CEOP\_AVE$), or CEO power generated from principal components analysis ($CEOP\_PCA$), over the sample period from 1992 to 2020. The results suggest that all of three control variables, Tobin's Q ($TobinQ^{I}_{i,t}$), corporate size (NYP_{it}), and normalized free cash flow (FCF) are positively and significantly related with the investment. Indicate that firms with higher shadow price of capital, lager size, and increased free cash flow have motivation to increase investment. Our conclusion is same with previous research about corporate investment.

The results also indicate that the proxy of CEO power, both unweighted average CEO power ($CEOP\_AVE$) and CEO power generated from principal components analysis ($CEOP\_PCA$), are positively and significantly related with the corporate investment. This results support our hypothesis 1, provide further evidence for the view that empire building drives less monitored CEO to increase corporate investment.

5.4.2 CEO power and debt overhang

We test our second hypothesis by examining the relation of corporate investment with the CEO power and debt overhang. We regress, for each year, the firm's investment level with CEO power, debt overhang and the interactive term of CEO power with debt overhang:

$$\begin{aligned} Inv_{i,t} = \beta_0 + \beta_1 CEOP_{i,t} + \beta_2 Overhang_{i,t} + \beta_3 CEOP \cdot Overhang_{i,t} + \beta_4 TobinQ_{i,t} \\ + \beta_5 NYP_{i,t} + \beta_6 FCF_{i,t} + u_{i,t} \end{aligned} \tag{5.13}$$

where investment (Inv) is the ratio of capital expenditures minus sales of plant, property and equipment to the start-of-period capital stock ($Inv = \frac{capxv - sppe}{ppegt}$), $CEOP$ is measured by the $CEOP\_PCA$, and $CEOP\_AVE$, overhang is measured by the $Overhang^{APR}$, $Overhang^{WEI}$, and $Overhang^{AVE}$. Following the research made by Baker and Wurgler (2004a), we include the corporate size measured by the market capitalization percentile NYP_{it} of firm i in fiscal year t, as control variables. The regression results are presented in table 5.6.

Table 5.6: **Panel regression of CEO power (unweighted average), debt overhang and investment**

This table shows coefficient estimates (standard error in parentheses) from running the fixed effect panel regression of investment on unweighted average CEO power (CEOP_AVE), and the proxy ***D*** for debt overhang (debt overhang_AVE for model 1, 4, 7, 8, 9,10, debt overhang_WEI for model 2, 5, debt overhang_APR for model 3, 6). TobinQ_I is the indirectly measured average Tobin's Q (Tobin's Q by replacement), NYP is the market capitalization percentile of a firm using NYSE size breakpoints, FCF is the normalized free cash flow winsorized one percent in each tail. The model 1 to 6 is the regression control corporate fixed effect, model 7 and 8 is the regression control both corporate fixed effect and time fixed effect, model 9 and 10 is the regression using robust standard error, control corporate fixed effect. The symbols ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
CEOP	.0257***	.0257***	.0260***	.0247***	.0246***	.0250***	.0055***	.0056***	.0257***	.0247***
	(0.0020)	(0.0021)	(0.0020)	(0.0020)	(0.0021)	(0.0020)	(0.0019)	(0.0020)	(0.0030)	(0.0030)
D	-.0206***	-.0156***	-.0099***	-0.0070	-0.0045	-0.0023	-.0149***	-0.0009	-.0206**	-0.0070
	(0.0045)	(0.0035)	(0.0024)	(0.0046)	(0.0035)	(0.0024)	(0.0043)	(0.0044)	(0.0084)	(0.0089)
CEOPA#D	-.0280***	-.0196***	-.0155***	-.0276***	-.0194***	-.0150***	-.0187**	-.0187**	-0.0280	-0.0276
	(0.0100)	(0.0076)	(0.0052)	(0.0100)	(0.0076)	(0.0052)	(0.0095)	(0.0095)	(0.0201)	(0.0206)
TobinQ_I	.0190***	.0191***	.0191***	.0134***	.0134***	.0134***	.0168***	.0115***	.0190***	.0134***
	(0.0004)	(0.0004)	(0.0004)	(0.0005)	(0.0005)	(0.0005)	(0.0004)	(0.0005)	(0.0010)	(0.0012)
NYP				.0685***	.0701***	.0693***		.0667***		.0685***
				(0.0038)	(0.0039)	(0.0038)		(0.0037)		(0.0078)
FCF				.0029***	.0031***	.0038***		.0049***		0.0030
				(0.0010)	(0.0010)	(0.0010)		(0.0010)		(0.0027)
Constant	.0675***	.0674***	.0673***	.0433***	.0429***	.0427***	.1136***	.0852***	.0675***	.0433***
	(0.0013)	(0.0014)	(0.0013)	(0.0020)	(0.0020)	(0.0019)	(0.0045)	(0.0046)	(0.0025)	(0.0036)
Robust std								control	control	
Time effect						control	control			
Number of obs	38345	38006	40801	36121	35782	38453	38345	36121	38345	36121
R2 within	0.0676	0.0668	0.0663	0.0653	0.0650	0.0644	0.1538	0.1493	0.0676	0.0653

Table 5.6 reports the results of the regression of corporate investment (inv), unweighted average CEO power ($CEOP\_AVE$), and debt overhang over the sample period from 1992 to 2020. Model 1, 2, and 3 shows the firms' correlation coefficients between investment, three different overhang proxies and the CEO power proxies, only take Tobin's Q as control variable. Model 4, 5, and 6 shows the firms' correlation coefficients between investment, three different overhang proxies, and the CEO power proxies, take Tobin's Q, market capitalization percentile NYP_{it} , and normalized free cash flow FCF as control variable.

Table 5.7 reports the results of the regression of corporate investment (inv), CEO power generated from principal components analysis ($CEOP\_PCA$), and debt overhang over the sample period from 1992 to 2020.

Table 5.7: **Panel regression of CEO power (principle component analysis), debt overhang and investment**

This table shows coefficient estimates (standard error in parentheses) from running the fixed effect panel regression of investment on CEO power generated from principle component analysis (CEOP_PCA), and the proxy ***D*** for debt overhang (overhang_AVE for model 1, 4, 7, 8, 9,10, overhang_WEI for model 2, 5, overhang_APR for model 3, 6). TobinQ_I is the indirectly measured average Tobin's Q, NYP is the market capitalization percentile of a firm using NYSE size breakpoints, FCF is the normalized free cash flow winsorized one percent in each tail. The model 1 to 6 is the regression control corporate fixed effect, model 7 and 8 is the regression control both corporate fixed effect and time fixed effect, model 9 and 10 is the regression using robust standard error, control corporate fixed effect. The symbols ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
CEOP	.0064***	.0064***	.0064***	.0061***	.0060***	.0061***	0.0008	0.0008	.0064***	.0061***
	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0009)	(0.0009)
D	-.0332***	-.0243 ***	-.0170***	-.0197 ***	-.0134***	-.0093***	-.0159***	-0.0018	-.0223***	-0.0087
	(0.0028)	(0.0022)	(0.0014)	(0.0029)	(0.0023)	(0.0015)	(0.0043)	(0.0044)	(0.0084)	(0.0089)
CEOPA#D	-.0056*	-.0037 *	-.0032**	-.0063**	-.0043*	-.0035**	-.0163*	-.0162*	-0.0238	-0.0234
	(0.0031)	(0.0020)	(0.0016)	(0.0031)	(0.0023)	(0.0016)	(0.0095)	(0.0095)	(0.0201)	(0.0205)
TobinQ_I	.0191***	.0191***	.0193***	.0135***	.0134***	.0135***	.0169***	.0115***	.0191***	.0135***
	(0.0004)	(0.0004)	(0.0004)	(0.0005)	(0.0005)	(0.0005)	(0.0004)	(0.0005)	(0.0010)	(0.0012)
NYP				.0686***	.0701***	.0693***		.0670***		.0686***
				(0.0039)	(0.0039)	(0.0038)		(0.0037)		(0.0079)
FCF				.0029***	.0031***	.0037***		.0049***		0.0029
				(0.0010)	(0.0010)	(0.0010)		(0.0010)		(0.0027)
Constant	.0796***	.0796***	.0795***	.0550***	.0544***	.0544***	.1163***	.0879***	.0796***	.0550***
	(0.0010)	(0.0010)	(0.0010)	(0.0018)	(0.0018)	(0.0018)	(0.0044)	(0.0045)	(0.0022)	(0.0034)
Fe/re									control	control
Time effect						control	control			
Number of obs	38345	38006	40801	36121	35782	38453	38345	36121	38345	36121
R2 within	0.0661	0.0654	0.0648	0.0638	0.0635	0.0629	0.1537	0.1492	0.0661	0.0639

For control variables, we found the Tobin's Q positively and significantly related with the investment level, indicate that firms with higher shadow price of capital tend to increase investment, which in line with previous research. The NYP positively and significantly related with the investment, indicate that lager firm tend to have higher investment ratio. The normalized free cash flow positively and significantly related with the investment, indicate that firms with higher free cash flow tend to have higher investment ratio.

Table 5.7 also provide evidence for our hypothesis 2. The coefficient of CEO power is positively and significantly related with the investment level. suggest that firm with higher CEO power tend to have higher investment ratio. The debt overhang is negatively and significantly related with the investment, support the previous research that the effect of debt overhang may cause insufficient investment. The interactive term of CEO power and debt overhang is negatively and significantly related with the investment, indicate that higher CEO power could amplify the negative effect of debt overhang. This results support our hypothesis that a concentrated decision structure drive the corporate strategy less concern about the interest of other stakeholders or the overall interest.

5.5 Robustness Tests

In this section we undertake a number of additional tests to check the robustness of our empirical results discussed above. The following table descripe some of new factors we introduced in robustness tests.

Table 5.8: **The Characteristics and Measurement of variables for robust tests**

[See appendix for table 5.8]

5.5.1 Periods of financial crisis

In statistic description part we found that corporate investment have strong connection with macroeconomic fluctuation. To test if our conclusion sensitive to financial crisis, we construct a dummy variable, which is equal to one for the following years, and zero otherwise:(1) from 1990 to 1991, the United States saving and loan crisis; (2) from 2001 to 2003, during the burst of the dot-com bubble; and (3) the 2007-2008 subprime crisis. We include this dummy variable and repeat our analysis. Results presented as table 4.7, we find that all our conclusions remain the same.

Table 5.9: **Panel regression of CEO power, debt overhang and investment with directly measured Tobin's Q**

This table shows coefficient estimates (standard error in parentheses) from running the fixed effect panel regression of investment with unweighted average CEO power (CEOP_AVE) for model 1, 2, 3, and CEO power generated from principal components analysis (CEOP_PCA) for model 4, 5, 6, and the proxy ***D*** for debt overhang (overhang_AVE for model 1, 4, overhang_WEI for model 2, 5, overhang_APR for model 3, 6). Financial_crisis is a dummy variable equals to 1 if financial crisis exist in this period, and 0 otherwise. TobinQ_D is the directly measured average Tobin's Q, NYP is the market capitalization percentile of a firm using NYSE size breakpoints, FCF is the normalized free cash flow winsorized one percent in each tail. The model 1 to 6 is the regression control corporate fixed effect. The symbols ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

	1	*2*	*3*	*4*	*5*	*6*
CEOP	0.0251***	0.0249***	0.0254***	0.0062***	0.0061***	0.0062***
	(0.0020)	(0.0021)	(0.0020)	(0.0006)	(0.0006)	(0.0006)
D	-0.0019	-0.0011	0.0011	-0.0118***	-0.0071***	-0.0048***
	(0.0048)	(0.0037)	(0.0025)	(0.0031)	(0.0025)	(0.0016)
CEOPA#D	-0.0220**	-0.0135*	-0.0127**	(0.0046)	(0.0026)	-0.0028*
	(0.0108)	(0.0081)	(0.0057)	(0.0033)	(0.0024)	(0.0017)
financial_crisis	0.0020**	0.0019*	0.0025**	0.0020**	0.0019*	0.0025**
	(0.0010)	(0.0010)	(0.0010)	(0.0010)	(0.0010)	(0.0010)
TobinQ_I	-0.0002***	-0.0002***	-0.0002***	-0.0002***	-0.0002***	-0.0002***
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NYP	0.1325***	0.1337***	0.1332***	0.1329***	0.1341***	0.1336***
	(0.0037)	(0.0037)	(0.0037)	(0.0037)	(0.0037)	(0.0037)
FCF	0.0100***	0.0101***	0.0111***	0.0100***	0.0101***	0.0111***
	(0.0011)	(0.0011)	(0.0011)	(0.0011)	(0.0011)	(0.0011)
Constant	0.0422***	0.0422***	0.0414***	0.0541***	0.0540***	0.0534***
	(0.0020)	(0.0020)	(0.0020)	(0.0018)	(0.0018)	(0.0018)
Number of obs	31660	31383	33603	31660	31383	33603
R2 within	0.06	0.06	0.06	0.06	0.06	0.06

5.5.2 Alternative measure of Tobin's Q

Consider the $TobinQ_t^I$ is an indirect measure of the average Q, we build $TobinQ_t^D$ as an alternative clean measure of the shadow price of capital to the firm. Following the definition, the average Q is calculated by the average market value plus the debt value dividend by the replacement cost of capital stock, given as following:

$$TobinQ_t^D = \frac{D_t + E_t - INV_t}{K_t} \tag{5.14}$$

where $TobinQ_t^D$ represent the Tobin's Q observed directly, D_t is the market value of firm's debt in time t, E_t is the market value of firm's equity in time t, INV_t is the value of firm's inventory in time t, and K_t is the replacement value of the capital stock in time t. The equation $D_t + E_t - INV_t$ represent the market value of the capital stock.

Following Whited (1992) we use the perpetual inventory method to convert the book value of capital stock into its replacement value. we estimate the useful life of capital goods in any year by equation:

$$L_t = \frac{PPE_{t-1} + CAPX_t}{DEPR_t} \tag{5.15}$$

where L_t is the useful life of capital goods at time t, PPE_t is the reported value of net property, plant and equipment at time $t-1$, $CAPX_t$ is the capital expenditures of property, plant and equipment exclude acquisitions at time t, and $DEPR$ is the depreciation in time t. We set the replacement value of capital stock equals to the book value of gross plant, property, and equipment for the first year the firm appears on the tape.

$$K_t = K_{t-1}\left(\frac{P_t}{P_{t-1}}\right)\left(1 - \frac{2}{L}\right) + CAPX_t \tag{5.16}$$

where P_t is the deflater for non-residential investment in time t, L is the average useful time of capital goods, and $\frac{2}{L}$ represent the double declining depreciation method. Consider the extreme value caused by small replacement value of the capital stock, we winsorized the tail of $TobinQ_t^D$ by one percentile. Results are presented in table 4.8

Table 5.10: **Panel regression of CEO power, debt overhang and investment with the control of financial crisis**

This table shows coefficient estimates (standard error in parentheses) from running the fixed effect panel regression of investment with unweighted average CEO power (CEOP_AVE) for model 1, 2, 3, and CEO power generated from principal components analysis (CEOP_PCA) for model 4, 5, 6, and the proxy D for debt overhang (debt overhang_AVE for model 1, 4, debt overhang_WEI for model 2, 5, debt overhang_APR for model 3, 6). TobinQ_D is the directly measured average Tobin's Q, NYP is the market capitalization percentile of a firm using NYSE size breakpoints, FCF is the normalized free cash flow winsorized one percent in each tail. The model 1 to 6 is the regression control corporate fixed effect. The symbols ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

	1	*2*	*3*	*4*	*5*	*6*
CEOP	0.0251***	0.0250***	0.0254***	0.0062***	0.0061***	0.0061***
	(0.0020)	(0.0021)	(0.0020)	(0.0006)	(0.0006)	(0.0006)
D	-0.0018	-0.0010	0.0011	-0.0117***	-0.0070***	-0.0047***
	(0.0048)	(0.0037)	(0.0025)	(0.0031)	(0.0025)	(0.0016)
CEOPA#D	-0.0220**	-0.0135*	-0.0127**	(0.0046)	(0.0026)	-0.0028*
	(0.0108)	(0.0081)	(0.0057)	(0.0033)	(0.0024)	(0.0017)
TobinQ_D	-0.0002***	-0.0002***	-0.0002***	-0.0002***	-0.0002***	-0.0002***
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NYP	0.1321***	0.1334***	0.1327***	0.1325***	0.1337***	0.1332***
	(0.0037)	(0.0037)	(0.0037)	(0.0037)	(0.0037)	(0.0037)
FCF	0.0099***	0.0101***	0.0110***	0.0099***	0.0101***	0.0110***
	(0.0011)	(0.0011)	(0.0011)	(0.0011)	(0.0011)	(0.0011)
Constant	0.0428***	0.0428***	0.0421***	0.0547***	0.0546***	0.0542***
	(0.0020)	(0.0020)	(0.0020)	(0.0018)	(0.0018)	(0.0018)
Number of obs	31660	31383	33603	31660	31383	33603
R2 within	0.0645	0.0643	0.0633	0.0627	0.0625	0.0615

The results suggest all our conclusions remain the same, except the sign of Tobin's Q. The regression results in table 4.8 indicate that with the higher shadow price of capital, corporate tend to have less investment, which is in opposite with previous research and therotical predictions.

5.5.3 Endogeneity

Consider the possible existence of endogenous problem, we use lagged value of debt overhang in the regression model. The results are presented in 5.11

Table 5.11: **Panel regression of CEO power and investment**

This table shows coefficient estimates (standard error in parentheses) from running the fixed effect panel regression of investment on lagged CEO power proxies, with one period lagged unweighted average CEO power (CEOP_AVE_LAG) for model 1, 2, 3, and one period lagged CEO power generated from principal components analysis (CEOP_PCA_LAG) for model 4, 5, 6. TobinQ_I_LAG is the indirectly measured average Tobin's Q with one period lag, NYP is the market capitalization percentile of a firm using NYSEsize breakpoints, FCF is the normalized free cash flow winsorized one percent in each tail. The model 1 and 4 is the model control corporate fixed effect, model 2 and 5 is the model control both corporate fixed effect and time fixed effect, model 3 and 6 is the model using robust standard error, control corporate fixed effect. The symbols ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

	M1	*M2*	*M3*	*M4*	*M5*	*M6*
CEOP_AVE_LAG	0.0273***	0.0105***	0.0273***			
	(0.002)	(0.002)	(0.003)			
CEOP_PCA_LAG				0.0127***	0.0094***	0.0127***
				(0.0006)	(0.0006)	(0.0010)
TobinQ_I_LAG	0.0179***	0.0107***	0.0136***	0.0176***	0.0107***	0.0177***
	(0.0005)	(0.0005)	(0.0012)	(0.0005)	(0.0005)	(0.0012)
NYP	0.0634***	0.0546***	0.0701***	0.0634***	0.0546***	0.0635***
	(0.0041)	(0.0041)	(0.0102)	(0.0041)	(0.0041)	(0.0102)
FCF	0.0073***	0.0122***	0.0083***	0.0073***	0.0122***	0.0073***
	(0.0013)	(0.0013)	(0.0027)	(0.0013)	(0.0013)	(0.0027)
Constant	0.0510***	0.0743***	0.0510***	0.0599***	0.0778***	0.0599***
	(0.0102)	(0.0054)	(0.0018)	(0.0107)	(0.0053)	(0.0018)
Robust std			control			control
Time effect		control			control	
Number of obs	39287	39287	39287	39287	39287	39287
R2 within	0.0642	0.0926	0.0631	0.0641	0.0926	0.0642

The coefficient of CEO power is positive and significant in all 6 models, The coefficient of Tobin Q is positive and significant in all 6 models, the results are in line with our previous conclusions, suggest that There are no endogenous issues that can affect the regression results.

Next we test the endogenous problem for CEO power and debt overhang in the regression of section 5.4. We use lagged value of debt overhang in the regression model. The results are presented in 5.12

Table 5.12: **Panel regression of investment on CEO power**

This table shows coefficient estimates (standard error in parentheses) from running the fixed effect panel regression of investment with unweighted average CEO power (CEOP_AVE) for model 1, 2, 3, and CEO power generated from principal components analysis (CEOP_PCA) for model 4, 5, 6, and the proxy ***D_LAG*** for lagged debt overhang (overhang_AVE for model 1, 4, overhang_WEI for model 2, 5, overhang_APR for model 3, 6). TobinQ_I is the indirectly measured average Tobin's Q, NYP is the market capitalization percentile of a firm using NYSE size breakpoints, FCF is the normalized free cash flow winsorized one percent in each tail. The model 1 to 6 is the regression control corporate fixed effect. The symbols ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

	1	*2*	*3*	*4*	*5*	*6*
CEOP	0.0235***	0.0231***	0.0236***	0.0061***	0.0060***	0.0061***
	(0.0020)	(0.0020)	(0.0019)	(0.0006)	(0.0006)	(0.0006)
D_LAG	-0.0161***	-0.0148***	-0.0096***	-0.0504***	-0.0371***	-0.0262***
	(0.0053)	(0.0039)	(0.0027)	(0.0032)	(0.0026)	(0.0016)
CEOPA#D_LAG	-0.0727***	-0.0479***	-0.0354***	-0.0198***	-0.0124***	-0.0094***
	(0.0118)	(0.0085)	(0.0060)	(0.0036)	(0.0026)	(0.0018)
TobinQ_I	-0.0003***	-0.0003***	-0.0003***	-0.0003***	-0.0003***	-0.0003***
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NYP	0.1275***	0.1292***	0.1249***	0.1278***	0.1295***	0.1252***
	(0.0037)	(0.0037)	(0.0036)	(0.0037)	(0.0037)	(0.0036)
FCF	0.0086***	0.0087***	0.0097***	0.0086***	0.0087***	0.0097***
	(0.0011)	(0.0011)	(0.0011)	(0.0011)	(0.0011)	(0.0011)
Constant	0.0434***	0.0433***	0.0446***	0.0546***	0.0542***	0.0557***
	(0.0020)	(0.0020)	(0.0019)	(0.0018)	(0.0018)	(0.0017)
Number of obs	29212	28959	31020	29212	28959	31020
R2 within	0.0797	0.0783	0.0796	0.0782	0.0768	0.0781

The coefficient of debt over-hang is negative and significant in all 6 models, the results are in line with our previous conclusions, suggest that There are no endogenous issues that can affect the regression results.

5.5.4 Reverse Causality

Reverse causality refers either to a direction of cause-and-effect contrary to a common presumption or to a two-way causal relationship in, as it were, a loop. Reverse causality is a type of endogenous problem bring bias to either the regression coefficient and the standard error. In our regression, the investment level is dependent variable and the Tobin's Q is the independent variable, bring reverse causality issues because firms have a high Tobin's Q might because they have more high yield investment opportunities. To test if our regression is robust, we apply penal model Granger causality test (Dumitrescu and Hurlin, 2012) to test if this two variables have reverse causality issues, the results are presented in 5.13

Table 5.13: **DH Granger non-causality test**

[See appendix for table 5.13]

5.6 Conclusion

In this chapter we focus on the ease of the negative effect of asset bubble, specifically debt overhang, from the perspective of corporate structure. Debt overhang is one of the most severe consequences caused by the asset price bubbles, lead to the overhang of corporate debt, and slower the economic recovery from a recession (Kalemli-Özcan et al, 2022). We explored if the change of management power structure will help to ease the investment inefficiency problem bring by debt overhang, which is an important channel for corporate structure to affect the macroeconomic performance (Lamont, 1995; Moyen, 2007), or help economic recovery from financial crisis.

The literature has discussed a lot about how to mitigate the effect of debt overhang (Andrabi and Di Meana 1994; Snyder, 1998. Diamond and He, 2014), but our research is so far first discuss this topic from the perspective of corporate management. We provide evidence that CEO with higher power are likely motivated by their personal interests of empire building to invest more than shareholder's will. When their interest have no conflict with shareholders, with the increase of CEO power the negative effect of debt ovehang on investment become stronger, suggest that corporate with centralized decision power are less consider overall interest other than shareholder's interest.

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Chapter 6

Conclusions

After the 2008 subprime crisis, the Federal Reserve lowered the federal funds rate to 0.25%, while simultaneously initiating quantitative easing (QE) as an unconventional measure, primarily injecting liquidity into the financial system through the purchase of government bonds and mortgage-backed securities (MBS). During this period, through project of QE1, QE2, and QE3, the total assets of the Federal Reserve increased from below 1 trillion in 2008 to over 4 trillion in 2013 (Bloomberg data base). After the European debt crisis, Europe also adopted a negative interest rate policy in 2014. The world entering an era of zero or negative interest rates, with the United States, Europe, and Japan being the major global economies representing this trend. In pursuit of stimulating economic growth, central banks' control over long-term interest rates suppressed risk premiums, artificially distorting financial market judgments on risk pricing. During this period, rapid increases in global asset prices could be observed. Financial stability is now an objective for policymakers. The issue remains about whether central banks should change the conduct of monetary policy to achieve this goal. The answer to this question critically hinges on the influence of monetary policy on asset prices. Consequently, central banks need to know if asset price movements are desirable or when monetary policy has negative side-effects. This paper deals with this issue and assesses the impact of monetary policy shocks on asset price bubbles.

In Chapter 2, we build a model based on OLG model and CBDT, find that asset price bubble could stably exist in easing monetary policy condition. Our model suggests that, without easing monetary policy, the emergence of bubbles will cause utility losses. Thus, households who follow the rational expectation would exclude bubbles in the long-term equilibrium. On the other hand, easing monetary policy will mitigate the problem of investment distortion caused by asset bubbles. Investors' investment in bubble assets will no longer crowd out investment in productive assets because firms can always obtain financing at a fixed real cost of capital. In this condition, the emergence of bubbles will no longer cause a negative utility shock, and therefore households could invest in bubble assets. Our model enhances the understanding in the relation between, asset bubbles and monetary policy. Our theory points out the potential risks of easing monetary policy as it disappears the negative impact of asset bubble on production, and therefore enable it to exist in long term equilibrium.

The limitation of our research concentrated at assumption part. Firstly, we assume that investors' expectations and adjustments regarding asset values are based on the CBDT. However, the depiction of investor behavior by the CBDT model may not necessarily align with real-world scenarios. In the future research, it is necessary to discuss whether the existence of asset price bubbles caused by loose monetary policy will continue under more general circumstances. Secondly, we assume that central bank's easing monetary policy adjusts interest rates through controlling the money supply. However, in practice, monetary policies based on quantity and interest rates may not fully align, and there are significant differences between traditional and non-traditional monetary policies. Therefore, there should be more detailed discussions in the future.

In Chapter 3, We provide empirical evidence that the upward movement of asset mispricing is significantly affected by easing monetary policy. This conclusion is supported by both firm-level and market-level US stock market empirical analysis covered from 1954 to 2019. For firm level analysis, the coefficients of FFR are negative, suggest that easing monetary policy has a significant positive effect on the raising of bubble components, the regression exhibits a confidence level of 99%. The regression which include all control variables suggest that 1% decrease of federal funds rate will increase 0.49% stock price of bubble component. For market level analysis, the results suggest that one standard deviation increase in the FFR lowers the change of the bubble component Δbm by 1.4% in the next month, and then slowly decline over time but continue to exhibit negative effects of greater than 1% on Δbm up to 18 months. Our findings are robust in different models (fixed effect panel regression and SVAR), different calculation of bubble indicator (one month or three month US treasury return), and different representative of monetary policy (FFR or M2G). Our research has developed a method of using ex post rational price to study the movements of bubble components (mispricing). The findings in this study provides valuable evidence for the development of the theory about asset bubble and monetary policy.

The main limitation of this chapter lies in the lack of convincing observations regarding asset price bubbles. We measure bubbles in the US stock market by looking at the difference between asset price growth and growth of fundamentals, under the strong assumption of risk neutrality. Hence, any departures of asset prices from such measures of fundamental value are attributed to bubbles. The extent of this measurement error and employing more persuasive methods to measure asset price bubbles will be important for future research.

In Chapter 4, we discussed mitigating debt overhang from the perspective of corporate governance, which is one of the primary consequences of the burst of asset price bubbles and a significant reason for the lackluster recovery of economy following an economic crisis. Our analysis based on fixed effect panel model cover data from 1992 to 2020, find that the interactive term of CEO power and debt overhang is negatively (10 out of 10 different regressions presenting a negative coefficient.) and significantly (8 out of 10 regressions exhibits a confidential level of above 90%) related with the investment, indicate that higher CEO power could amplify the negative effect of debt overhang. Our results are robust in different measurement of CEO power, control the period of financial crisis, the different measurement of Tobin's Q ratio, and the endogenous test by lagged value. Our research suggest that corporate with centralized decision power are less consider overall interest other than shareholder's interest, therefore with the increase of CEO power the negative effect of debt overhang on investment become stronger.

The second chapter provides a new theoretical basis for the easing monetary policy's effect on the emergence of asset price bubbles, the third chapter provides empirical evidence of monetary policy on asset mispricing. The results of both chapter 2 and 3 suggest that the easing monetary policy could fueling asset price bubbles, but further research is needed. Following the burst of asset price bubbles, the passive increases in corporate debt burden leads to insufficient investment, which well known as debt overhang. The fourth chapter provides a new perspective which through corporate governance to alleviate the issue of debt overhang. Through three chapters, we systematically and thoroughly discuss the possible effects of monetary policy on asset price bubbles, and provides evidence that reducing the degree of corporate power concentration may help firms reduce the degree of debt overhang.

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