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UNIVERSITY OF CALIFORNIA,
IRVINE

Essays in Financial Crisis and Capital Regulations

DISSERTATION

submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in Economics

by

Yi Liu

Dissertation Committee:
Professor Gary Richardson, Chair
Professor Jiawei Chen
Professor John Duffy

2017

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DEDICATION

To my wife Lun Li

and my family

in recognition of their support and love

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I would like to express my deepest appreciation to my committee chair, Professor Gary Richardson, for his guidance, encouragement, and continuous support. He motivated my ideas and endeavors, gave fast and detailed feedback on my writings, and guided me into right directions whenever I was heading toward wrong directions. It was the greatest opportunity to meet him and write my academic papers under his supervision as it spurred my research throughout the years at UC Irvine.

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ABSTRACT OF THE DISSERTATION

Essays in Financial Crisis and Capital Regulations

By

Yi Liu

Doctor of Philosophy in Economics

University of California, Irvine, 2017

Professor Gary Richardson, Chair

This dissertation studies the US housing market, banks' behavior under regulations and effects of bank capital constraint on the monetary transmission mechanism. It revolves around understanding the determination of the capital regulations on banks' optimal behavior, as well as quantifying the impact of these regulations on effectiveness of the monetary policy.

The first chapter, "The Impact of Local School Quality on Housing Price Volatility", studies the effects of local school quality on housing-price booms and busts under the impact of exogenous credit-supply shocks, using school-district-level data in California between 2000 and 2012. The analysis shows that school quality, as an important amenity and utility dividend, reduces the impact of the exogenous shocks and anchors local housing values. The empirical work verifies that better schools make housing prices less volatile. The findings match the analysis of previous research in financial markets, in which there is a similarly negative association between share prices volatility and dividend yields.

The second chapter, "How Do the Minimum Capital Requirements Affect Banking Competition and Profitability?", examines the effect of the Minimum Capital Requirements (MCR) on banks' competition and profitability. The theoretical model shows that, in competitive

market, banks trade off the costs and benefits of capital to maximize their profits. The MCR are thus likely to be an important factor on the bank's optimal choice and the target ratios increase with the MCR and decrease with banks' size. This paper also adopts the Industrial Organization (IO) approach to analyze the competitive effects of MCR on the oligopolistic market. Banks may collude to hold even higher capital ratios in the oligopolistic market since the capacity constraints caused by MCR reduce the competition. Using a sample of US banks from 2002 to 2015, the empirical works reveals that the relation between capital and profitability is nonlinear; it is depicted an inverted U shape.

The third chapter, "The Effects of Capital Constraints on the Transmission of Monetary Policy: Fama-MacBeth Test", analyzes the effects of bank capital constraint on the monetary transmission mechanism. The model demonstrates that the monetary transmission is stronger (loan supplies are more sensitive to changes in the monetary policy) if banks are well capitalized. The empirical Fama-MacBeth 2-step test reaffirms that (1) changes in monetary policy matter more for the lending of those banks with higher capital ratios; (2) The capital constraints are intensified during the period of tight money. Both effects are largely attributable to the smaller banks.

Chapter 1

THE IMPACT OF LOCAL SCHOOL QUALITY ON HOUSING PRICE VOLATILITY

1.1 Introduction

1.1.1 The Research Question

The recent boom and bust in the US housing market[1] has offered an ideal experiment in which to study the sources of volatility at both macro and micro levels. The boom and sequential bust triggered the stock market crash of 2008 and led to the Great Recession (Taylor 2009, Verick and Islam 2010, Farmer 2012). The volatility in housing markets has serious repercussions for economic stability and may entail important social costs (Arce, 2011).

[1] See Figure 1

Although the volatility of housing prices is a national phenomenon, there is remarkable heterogeneity across local communities. In California, the housing prices in the top school districts gained 109% during the boom period (2000-2007) and lost 11% during the bust period (2007-2012). At the same time, the bottom school districts gained 185% and lost 34%.[2]

A question that is of importance to understanding both housing markets and national economies is why house price volatilities vary markedly from one local community to another. The local unemployment rate, income level, historical trends, demographics, race, education, even natural amenities all potentially contribute to the local heterogeneity. Given that so much literature has already addressed the relationship between housing prices and school quality, I pose my research questions: Does school quality have effects on local house-price volatility? Was there a bubble in the boom-bust cycle, and if so, are bubble sizes associated with school quality?

This paper focuses on the relationship between local school quality and the price swings during the boom and bust periods in California from 2000 to 2012. Although previous researchers have spent considerable time attempting to understand the causes of the economic boom and bust periods, a full analysis of this era remains incomplete. My research contributes to the literature by exploring the link between house-price volatility and local amenities. My findings suggest that the boom-bust cycle during 2000-2012 was likely driven by a housing bubble, and further, that the housing bubble was larger and had a more devastating impact in poor-quality school district neighborhoods.

[2]Source: computed using ACS data

1.1.2 Why Price Volatility Matters?

Prices are the mechanism for rationing scarce resources. Thus, the volatility of prices is informative for economists in studying how scarce resources are allocated among agents. As it pertains to this investigation, asset-price volatility has been an important research topic in economics. Increased volatility of asset prices has already been concentrated in the minds of policymakers (Bernanke, 1999), and the boom and bust cycles in asset markets have been shown to have important effects on the real economy, with the potential to destabilize a national economy (Bernanke, 1999). Leamer (2007) provides evidence that housing contributes importantly to the business cycle. In addition, Stephen (2011) claims that volatility distorts housing choices and increases risk.

For mortgage lenders, houses serve as collateral for loans. Large swings in housing prices increase the risk for lenders (Stephen, 2011). Some of the risks taken by lenders during the period under review eventually led to serious financial consequences, driving some of them into bankruptcy. The financial crisis of 2008 was the worst economic situation the world had seen since 1933.

For a typical homeowner, the house is their single most important consumption good, and it is usually the dominant asset in their financial portfolio. Volatility increases homeowners' risks and hurts consumption smoothing (Stephens, 2011). An increase in asset-price uncertainty enlarges the financial risks associated with future asset returns (Han, 2010). This situation of first a boom period, followed by a bust period in housing prices often results in a major redistribution of wealth (Case & Shiller, 1988). Those who own their homes see their home equity increase, while those who do not own their homes face higher rents and a reduced probability of home ownership. During and after the Great Recession, beginning in 2007, the redistribution of wealth brought about greater inequality in the US. During this time, the share of total wealth owned by the top 1% of the US population grew from 34.6% to

37.1%, and that owned by the top 20% of Americans grew from 85% to 87.7%. The Great Recession also caused a drop of 36.1% in median household wealth, but a decrease of only 11.1% for the top 1%, which further widened the already existing gap between the top 1% and the lower 99% (Wolff, 2010).

Volatility extends the risk of having owners fall into arrears, resulting in a greater number of repossessions for more households (Stephen, 2011). One of the appeals of home ownership is the ability it offers households to accumulate wealth. However, this wealth is shared unequally. According to the National Association of Realtors (NAR), in the US in 2013, 27% of residents purchasing a home for the first time received a cash gift from their parents or other relatives for their down payments. As parental financial assistance has increasingly become necessary for younger generations to purchase their first homes, there has been a strong likelihood that wealth inequality will be transmitted down to each subsequent generation. Thus, household members excluded from home ownership at relatively young age may not be able to catch up to their peers by the time of retirement. This could create an increased burden on the government.

For both investors and developers, housing-price volatility generates an additional cost because it distorts other investment decisions (Brueckner & Pereira, 1997). When volatility discourages real estate investment, the demand for the local labor force is reduced. This situation thus hurts new home construction projects as well as associated sectors of the labor market. High housing prices also make it more difficult for companies to attract labors to the boom regions (Case & Shiller, 1988). Further, the bubble-burst era left many households "underwater", causing a "mobility trap" in the labor market. Viewed internationally, for example, at the end of 2008 in the UK, two million households holding mortgages would have found it difficult to move due to negative equity in their homes (Stephen, 2011). Therefore, it is clear that a more stable housing market provides greater social benefits overall.

1.1.3 The importance of school quality

The relationship between housing prices and local public goods and services has been widely studied in the literature. In many public economic models since Tiebout's seminal 1956 paper, researchers have placed school quality in a central position, as a major determinant of people's community choices. According to the National Center for Education Statistics (1995), 47% of parents chose their residence based in part on the public school that their child would attend. It is also widely believed that the parents' chosen school and surrounding community are significant forces in long-term educational and labor market outcomes. Choosing a school is the equivalent to choosing the vector of amenities that maximizes utility, given each household's own budget constraints. Since the housing prices adjust to clear the market, the impact of school quality on an local housing market is expected to be evident.

There are two ways to measure school quality. The first is the input-based measures, where the amount of money spent per pupil is an intuitively appealing rubric for measuring educational quality. The second method is the output-based measures, where students' test scores are used to measure the quality. California passed Proposition 13 in 1978, which was intended to equalize educational inputs in both rich and poor neighborhoods. Since spending per pupil is almost the same across California, this paper uses educational outcomes as the measurement tool for school quality.

The level of a school quality can be put into a basic overlapping generation (OLG) model. Better school performance, for example, usually makes both the parents and the children happy, and this can be viewed as an educational utility dividend in time t. In addition, this educational dividend can be considered as saved capital for the young generation. The strong correlation between school performance and labor-market outcomes has been widely studied in the field of labor economics. The better school performance the young generation achieves at time t, the more human capital the young generation can utilize in time $t+1$ to earn a greater income.

Superior school qualities not only draw attention across local communities but also generate strong international demand. According to the State Department's Bureau of Educational and Cultural Affairs, 819,644 students came to the United States to study abroad in the 2012-13 school year. Foreign students contribute about $24 billion annually to the U.S. economy and made US the number one destination for international study. About two-thirds of foreign students primarily pay their own way and become an economic boon to communities that host foreign students. Some parents even take earlier steps. In order to let their kids enjoy full US education, those parents bought houses in good school districts and sent their kids to the US educational system starting from middle school or even elementary school.

The existing literature dealing with the relationship between housing-price levels and school quality is predominantly focused on the first moment of price, while little effort has been expended on examining the effects of school quality on housing-price volatility. To begin to remedy this gap, I offer the following analysis to examine the relationship between the volatility of housing prices and school quality.

1.1.4 Literature Review and the General Hypothesis

The crucial factors to outline boom-bust housing cycles are supply and demand conditions in the local housing markets. The key determinants of housing demands are: (1) income, (2) the cost and availability of mortgage financing, (3) expectations about future rising home prices, (4) levels of employment, (5) general consumer confidence, and (6) local amenities. The supply side is mainly focused on the elasticity of supply.

In the paper by Haurin and Brasington (1996), the results indicate that public school quality has a great impact on real constant-quality housing prices. Further, Black (1999) claims that parents are willing to pay 2.5% more for their homes to gain a 5% increase in their children's standardized test scores. Jud and Watts (1981) estimate a model of housing prices that includes both school quality and racial composition among the attributes that determine housing values. They suggest the following: (1) school quality has a strong, significant, positive effect on property values; while (2) racial composition has a negative impact on property values.

Chiodo & Owyang (2010) find the relationship between quality of public schools and housing prices is nonlinear. They then argue that school quality can be considered a luxury good; therefore, at higher quality school, parents would be willing to pay more for the same marginal increase in school quality. Lee (2009) examines housing-price volatility in Australia and presents the following conclusions: (1) asymmetric shocks occur, and volatility increases in response to bad news; and (2) the linkage between inflation and housing-price volatility varies from one city to another. Lee and Lin (2013) present their theory and evidence regarding housing-price volatility, which highlights the role of "natural amenities" such as oceans and hills in neighborhood dynamics. They conclude that cities with dominant natural features exhibit internal spatial distributions of income that are dynamically stable. Their argument contains the following: (1) neighborhoods derive amenity values from both natural features and endogenous characteristics, such as safety and school quality; (2) high-income households outbid low-income households for neighborhoods with greater overall amenity value; and (3) persistent natural amenities anchor neighborhoods to higher incomes over time. Additionally, various papers study housing-market volatility through the perspective of supply. Malpezzi and Wachter (2005), for example, suggest that areas with more inelastic housing supplies face larger price swings.

This paper studies the demand-side because school quality generates demands from consumers. A more general hypothesis presented in this paper about housing-price volatility with respect to local amenities can be stated as follows: there is a negative association between housing-price volatility and local positive amenities.

1.2 General Theory on the Asset Price Volatility and Dividend

1.2.1 Theory on Stock Market

General investment theory suggests that investment returns come in two forms, capital gains and dividends. One who focuses on returns from dividends is called an income investor, while a growth investor is more sensitive to capital gains, measured by asset-price percentage changes. Since dividends grant the investor near-term cash flow, this money reduces future financial risk. The price volatility is the direct index of risk. Therefore, an asset with a dividend is expected to have less volatility.

Stock-price volatility has been widely studied in financial economics. Many researchers have investigated the association between share-price volatility and dividend policies. Gordon (1962), Diamond (1967), Miller and Modigliani (1961), and Travlos (2001) all showed a negative association between share-price volatility and dividends. Baskin (1989) gave an intuitive explanation, which he called "the duration effect". He argued that because a high dividend yield can be a signal of more near-term cash flow, a company with a higher dividend yield would be expected to have less volatility in its share price.

In the housing market, any positive amenity can be viewed as "utility dividends" for households; therefore a better school quality can be taken as a dividend for households in that district. Thus, a similar negative relationship between housing prices and school quality would be expected: housing prices in neighborhoods with high-quality schools are less sensitive to fluctuations in exogenous financial conditions, and thus would have lower-price volatility, all other things being equal. Although housing markets are quite different from financial markets in both form and function, one can find interesting similarities between them. Studying the underlying structural links between the two markets is a possible area of future research.

1.2.2 The Model

This model is based on Brueckner J. and Pereira A.'s paper "Housing wealth and the economy's adjustment to unanticipated shocks", 1997. The equation (4) in the above paper indicates that the rate of return to housing investment equals the return to financial investment, which is the no arbitrage condition:

$$p_t = \frac{R_{t+1} + p_{t+1}}{1 + r_{t+1}} \tag{1.1}$$

R_{t+1} indicates the rent. Assume an exogenous demand shifter inflates housing price to a new high. Equation 1.1 can be re-written as:

$$p_{t+1} - p_t = p_t r_{t+1} - R_{t+1} \tag{1.2}$$

Assume local amenity is A and higher A leads to higher R, so $\frac{\partial R_{t+1}}{\partial A} > 0$. Take partial derivative against A, holding initial price constant, we have

$$\frac{\partial(p_{t+1} - p_t)}{\partial A} = -\frac{\partial R_{t+1}}{\partial A} < 0 \tag{1.3}$$

So, the following statement holds: **Holding initial price constant, cities with high amenities should have lower price appreciation**, which matches my empirical regression works. At bust period, bubble was sequenced out, thus low-amenity area saw bigger bust. For example, inferior local school quality means lower A. Thus, the price growth in the inferior school communities is supposed to be higher. My regression supports the prediction and matches with Glaeser E., Gottlieb J. and Tobio K.'s paper "Housing Booms and City Centers" in which they claim that the impact of optimism on the prices (source of bubble) must be stronger for low human capital communities than for high human capital communities.

1.3 Descriptive Analysis – asymmetric shocks

1.3.1 Credit Supply Shock

The US mortgage markets have substantially changed in the past two decades. Comparing the traditional 30-year-fixed-rate mortgage, the adjustable rate mortgages (ARM) had grown to a peak of 40% share of total mortgage applications in 2005 (Freddie Mac Survey). In addition to ARMs, subprime loans, interest-only loans, and other non-conforming loans accelerated the expansion of the supply of credit in the first half decade of the 21st century. The exogenous credit supply served as the primary demand shifter and inflated the housing price to an historical high. However, the large fraction of subprime mortgages became delinquent or went into foreclosure starting in 2007. The high default rate forced lenders to tighten the credit supply. As a result, it was very difficult for new marginal borrowers to access the formerly available non-conforming loans. The aggregate demand shifted inward, and this eventually led to the collapse of the housing-market boom. The recession significantly worsened the US economy. US unemployment hit a high of 9.6% in the year 2010, which was the highest unemployment rate since the Great Depression (US Department of Labor). The fragile job market turned around to make the housing market even worse.

Between 2001 and 2006, the subprime-mortgage market had experienced explosive growth, and this is partly to blame for the growing housing bubble that occurred. Angell and Rowley (2006) and Kiffand and Mills (2007) state that the origin of the subprime-lending boom has often been attributed to an increased demand for so-called private label mortgage-backed securities (MBS) by both domestic and foreign investors. The dramatic growth of subprime loans led to deterioration in the mortgage market. Brueckner, Calem and Nakamura (2012) argue that subprime lending was both a consequence and a cause of the bubble conditions in the housing market. Thus, the overall picture might suggest that subprime lending and bubble conditions reinforced each other, and eventually led to the crisis that erupted in 2007.

The credit-supply shocks in the late 1990s generated two kinds of demands for housing: true demand and speculative demand. Economists have assumed that consumers are "rational", in that consumers choose housing and other items of consumption to maximize their overall satisfaction. Thus, true demand for housing arises from the amount of living space afforded by a house, the safety of the neighborhood, the school quality, the ease of commuting to work, and so forth. At times, however, some consumers depart from a true demand model. These individuals' demands for housing is driven not by the direct benefits of owning a particular house, but instead by an expectation that the price of the house will increase. This situation brings about what is called speculative demand. Speculative demand caused housing prices in many areas in the US to increase sharply, and at speeds that were far more than could be justified by fundamentals.

1.3.2 Boom

The impacts of credit shocks are asymmetric at the local level during both boom and bust periods. The positive credit-supply shock that began in late 1990's led to two major consequences. First, it helped marginal borrowers become homeowners. The percentage of the California population who owned their home in 2006 peaked at 60 percent[1]. Second, climbing home prices reinforced the relaxation of credit constraints and induced speculators to enter the housing market for a quick turnaround.

Case and Shiller (2003) conclude that buying for potential future price increases, rather than for the pleasure of residing in a particular home, is what a bubble is about. Real estate speculators often hold houses for resale purposes only, and do not expect to receive a dividend from owning a particular property, either in the form of rent or the houses' utility. For this reason, speculators are more sensitive to the prices, rather than general housing and neighborhood benefits. Since housing prices in low-quality school districts are usually cheaper than in their high-quality counterparts, poor-quality school district neighborhoods often become the targets of speculators. Another reason is the inventory availability. In good school neighborhoods, households have committed to their kids' continuous education. The climbing price alone usually won't induce them sell houses and move to other school districts. So there is much less inventory for speculators to work with in good-school neighborhoods. Thus, speculative buy-to-sell investments in the poor-quality school district neighborhoods, under the context of easy financing, may have become the optimal option for speculative investors, fueling an even bigger housing bubble. On the other hand, competition from true demand for higher school quality tends to filter out speculation to a certain degree.

[1]CAR: California Association of Realtors

1.3.3 Bust

The bust left many homeowners underwater, meaning that the value of their homes was lower than their original loan amounts. As of the second quarter of 2013, approximately 15% of California's homeowners were underwater on their homes[2]. However, as we shall see, the behavioral responses were quite different between the neighborhoods with superior schools versus those with inferior schools. In the superior school districts, households with a strong preference for their children's education paid premium prices at the beginning. As these households made long-term commitments to the education of their children early on, they were less affected by the temporary change in market conditions. The decision to remain in the neighborhoods where they purchased their homes was a relatively easy choice. On the other hand, the "underwater" homeowners in inferior school districts had fewer "dividends" to give up, thus their option values were higher and switching costs are lower. The decision to deviate was an optimal choice for many speculators and marginal borrowers. Hence, the massive decision to sell in the inferior school districts generated negative externalities, thus sharply pulling down housing prices.

The above analysis suggests that the housing bubble was bigger in poor-quality school districts. A separate bubble analysis will be provided in the Section 1.5 to confirm the analysis in an empirical fashion. Ultimately, this larger bubble in the poor-quality school districts led to greater market volatility. The empirical results match Shiller's (2005) argument, which states that an irrational bubble is the main driver for the boom.

[2]CAR: California Association of Realtors

1.4 Data

The data in this research come from three sources. All data are aggregated at the school-district level on an annual basis. The yearly API (Academic Performance Index), drawn from the California Department of Education (CDE), is used to measure the quality of the various school districts. The API is an annual measure of performance of schools and the districts. The CDE calculates the API and disseminates the results directly to schools and districts, as well as posting them on the official CDE website. The API is a single number on a scale of 200 to 1,000 indicating how well a school or a district performed on the previous spring's standardized tests, which measured students' scholastic aptitudes.

All other data, which include median housing prices, median incomes, populations, races, ages, private school rates, new buildings, vacancy rates, commuting times, and similar information, come from the American Community Survey (ACS) in the years 2005 to 2012. Housing prices, incomes and rent are expressed in inflation-adjusted dollars. The data of year 2000 comes from the NCES (National Center for Education Statistics). The data from 2001 to 2004 in the school districts level are not available in both the ACS and the NCES. A total of 316 school districts are employed in the regression. The 316 school districts cover about 87% of the entire California population, and belong to 12 different Metropolitan Statistical Areas (MSA).

The statistical description of variables which are used in this research is presented in Table 1.1. It indicates the range, the mean and standard deviation of variables used in this study. The ages, Black and Asian variables are used to represent neighborhood demographics. The school district population variable is used to control the size of school districts. Since demographics take time to change, and this paper only covers 12 years, the effects of demographics on housing price volatilities are expected to be insignificant. The percentage of new constructions is employed to represent the new housing supply. Another supply side control is the rental vacancy rate. A higher rental vacancy rate likely indicates oversupply in the community. Since job access affects housing prices, the "mean time of commuting to work" is used in the regression.

Some households choose private schooling. Their kids' academic performances are excluded from the API. Their housing location decisions are not based on public school quality. So the percentage of households who send their kids to private school is added to control for this variable. The more households choose private schooling, the less should be the effect of API on the housing market. Income, unemployment, populations and initial housing price levels are also used in the regressions as controls.

1.5 The Bubble Analysis

This section provides empirical evidences that there is more speculation, and therefore bigger bubbles, in low-quality school districts. Booming prices alone do not prove the existence of a bubble. A bubble exists only if prices increase more than what the economic fundamentals justify. The price-income ratio and price-rent ratio are two widely used indexes utilized to compute how far prices deviate from these economic fundamentals. Speculations are believed to be the source of bubbles. According to CAR (California Association of Realtors), in a normal, healthy housing market, all absentee buyers' transactions make up roughly 20% of all home sales. However, between mid-2005 and early 2006, the speculator transactions made up around 50% of all homeownership turnovers, including grant deed sales and trustee's sales.

1.5.1 Price-income Ratio

The term "bubble" is widely used but rarely clearly defined. Fair (1972) drew attention to the significance of the long-run equilibrium between housing prices and incomes. Income not only generates demand for housing, but also serves as the upper bound of the budget constraint. Following Case & Shiller (2003), I use the positive change of log price-income ratio for the proxy of bubbles. I claim that the greater the positive change of the log ratio in a local community, the bigger the bubble. Let housing price be donated by p, and income by y. The demand shocks drove the neighborhoods away from the previous price level and distorted the p/y ratio.

I expect that the bubble is bigger in low-quality school neighborhoods since there are more speculative buyers. Thus, the bubble is negatively correlated with school qualities. When the bubble burst, the absolute value of change of log(p/y) between 2007 and 2012 is also expected to be bigger in low-quality school neighborhoods (a bigger bust). These relationship is expressed as follows:

$$(Bubble)_{t+1,i,j} = \left|(log\frac{p}{y})_{t+1,i,j} - (log\frac{p}{y})_{t,i,j}\right| = \beta_0 + \beta_1 API_{t,i,j} + \beta_2 X_{t,i,j} + \phi_j + u_i \quad (1.4)$$

i indexes for school districts, j indicates MSAs, ϕ_j represents MSA-level fixed effects, β_1 is expected to be negative, $X_{t,i,j}$ are control variables, u_i is the error term.

1.5.2 Price-rent Ratio

Rent usually reflects the true demand for housing because it is almost impossible for renters to make speculative profit from re-leasing in a free market. Galloin (2004) showed that long-horizon regressions support the use of the price-rent ratio as an indicator of housing market value. The price-rent ratio is the yardstick for fundamental valuation (Ayuso & Restoy, 2003) and an alternative way to examine the bubble. Similar to equation 1.4,

$$(Bubble)_{t+1,i,j} = \left|(log\frac{p}{r})_{t+1,i,j} - (log\frac{p}{r})_{t,i,j}\right| = \beta_0 + \beta_1 API_{t,i,j} + \beta_2 X_{t,i,j} + \phi_j + u_i \quad (1.5)$$

ϕ_j is MSA-level fixed effects, β_1 is expected to be negative, $X_{t,i,j}$ are control variables and u_i is the error term.

The regression results are displayed in Table 1.2 and 1.3. Both regressions, after controlling the housing price level and including MSA fixed effects, suggest that the bubble is likely bigger in low-quality school neighborhoods. The coefficients of API and t-values are similar in the price-income ratio and price-rent ratio specifications.

1.6 Main Model and Regression Results

1.6.1 Re-examining the relationship between housing price level and API

Figures 2, 3, and 4 show the relationship between housing-price levels and the API in years 2000, 2007, and 2012, respectively. They match the results of previous research by showing that there is positive effect of school quality on housing prices (Haurin and Brasington (1996), Black (1999), Chiodo (2010)). In addition, a log price vs. log API regression, with MSA fixed effects included, is conducted to compute the elasticity of price with respect to API. In 2000, the elasticity is 1.62, which means a 1% increase in API would lead to a 1.62% increase in the housing price. In 2007, the peak year, the elasticity is 1.31. The reduction of elasticity makes sense, since the larger bubbles in low-quality schools helped shrink the housing price gap among school districts. However, in 2012, the elasticity is 2.39, indicating that the housing price gap among school districts grew after the financial crisis. The findings match previous research that the financial crisis increased the inequality in US society (Wolff, 2010). The housing market volatility hurt the poor more than the rich.

1.6.2 Econometric Model

The baseline, reduced form model includes separate regressions for each time period, which attempts to explain price changes over the boom and bust periods:

$$|lnprice_{i,j,2007} - lnprice_{i,j,2000}| = \beta_0 + \beta_1 API_{2000,i,j} + \beta_2 X_{i,j,2000} + \phi_j + v_i \qquad (1.6)$$

$$|lnprice_{i,j,2012} - lnprice_{i,j,2007}| = \beta_0 + \beta_1 API_{2007,i,j} + \beta_2 X_{i,j,2007} + \phi_j + u_i \qquad (1.7)$$

In 1.6 and 1.7, i indexes school districts, j indexes MSAs. The dependent variable is the log price change over the relevant period expressed as an absolute value. $X_{i,j}$ consists of school district level control variables: demographics, income, housing supply, unemployment, job commuting times, etc. To avoid endogeneity issues, all independent variables are measured at their initial levels for each period. Omitted variables, potential sources of bias, are absorbed in the MSA-level fixed effects, ϕ_j. v_i and u_i are the error terms.

1.6.3 Discussion of the Main Regression Results

Figures 1.3 and 1.4 show the relationship between log housing price difference (absolute values) and the API in the boom (2000-2007) and the bust (2007-2012), respectively. The negative linkage is clearly evident.

Turning to the regression results, since median housing prices, median income and the local unemployment rate are strongly correlated[1], to avoid the multicollinearity issue, I have put them into three separate regressions, while keeping all of the other variables the same. Tables 1.4 and 1.5 use income as one of the controls, Tables 1.6 and 1.7 use housing-price levels as one of the controls, whereas Tables 1.8 and 1.9 use unemployment as one of the controls.

Under all three specifications, we can conclude the following: (1) API negatively affect housing-price volatility, at a 1% significance level; and (2) API has a greater impact in the bust era than the boom era. A one standard deviation increase in API reduces the housing price percentage changes by 2.6 percentage points in the boom period, 4.6 percentage points in the bust period (under income control specification). The standard deviation of Y variable (percentage of price change) is 17% in the boom and 19% in the bust. So a one standard deviation increase in API reduces Y variable by 1/6 standard deviation in the boom period and reduces Y variable by 1/4 standard deviation in the bust period.

The coefficients of the demographic variables, measuring population, ages, Blacks and Asians are not expected to be significant since the time span is too short. However, the regression shows that percentage of over 65 and percentage of Asian have significant effects in the bust period, but not in the boom period. The housing prices in communities with more seniors or more Asians are more stable. The housing prices in communities with more Blacks are more volatile but the coefficient of the percentage of Blacks is not significant in the both periods. The population has positive effects on housing price changes in the boom period (not significant) but negative effect in the bust period (significant).

The new construction rate (the share of new construction in a community) has a positive effect in both periods. In the boom period, communities with more new constructions saw a higher price gain. However, when the housing market turned into the bust period, area with substantial new construction experienced a bigger bust.

[1]The correlation of housing price and income is about 80%; the correlation of income and unemployment is about -60 % in the data set.

One of the control variables employed in the regression is worthy of further discussion: the mean job-commuting time. Many households choose where to live based on available employment opportunities, as well as local amenities. Longer commuting times reduce households' utility, while walking to a job is considered as a utility dividend and a positive amenity. In my exploration, I consider that households are living in a simple economic environment, where everyone commutes to a Central Business District (CBD) to work. The communities closer to CBDs offer a positive amenity to their households in terms of commuting time. By my general hypothesis, as mentioned previously, housing prices in communities with longer commuting time are expected to be more volatile, so that the sign of the coefficient of the job commuting time should be opposite of API. My empirical results are consistent with this prediction; as displayed, they are significant at a 1% level. Therefore, both the factors of school quality and job-commuting times support the general hypothesis[2].

The vacancy rate has a negative effect in the boom period (significant at 5%) and a positive effect in the bust period (significant at 1%). The percentage of households who send their kids into private school has negative effects (significant at 1%) on the price change in the both periods. It makes sense because those households usually have higher income.

Table 1.10 shows the magnitude of the API effect: how much does a one standard deviation increase in the API reduce the housing price percentage change? The regression results show that the magnitude of API effect is comparable with the magnitude of following variables: income, job commuting time, percentage of new buildings, vacancy rate and percentage of the private schooling. API has stronger effect than the demographic variables: race, age, populations.

One way to view school quality is that the better-quality schools build "invisible walls" in their respective communities; the higher the wall, meaning the higher the API, the greater the buffer they grant to resist impacts from exogenous shocks. The "invisible walls" may make so-

[2] The correlation of the job commuting time and the API is very small (-4.4 %).

cioeconomic characteristics of communities increasingly diverge overtime. Erica Frankenberg (2009) argues that when social sorting is coupled with school district boundaries, boundary lines exacerbate existing segregation and inequality.

1.7 Conclusion

This project may provide several important contributions to the literature. First, it fills a particular gap in the field, as it specifically addresses the links between school quality and housing-price volatility. It is important to understand why housing prices are strongly volatile in some local communities, while less so in others. The empirical results clearly show a significant negative relationship between housing-price volatility and local school quality.

Second, this study can be used to better ascertain the impact of amenities on the elasticity of demand in terms of neighborhood dynamics. Neighborhood change is common and contentious. Positive amenities, such as safety, school quality, and easy commuting, serve as "dividends" for households; they reduce the impacts of exogenous shocks while anchoring neighborhood values over time. The exogenous-demand shifter drives housing prices away from their fundamentals and facilitates housing bubbles. However, the quality of better-performing schools builds shelters to reduce the sizes of housing bubbles at local levels.

Third, the results provide strong supporting evidence to match previous stock market studies (Gorden, 1962; Baskin, 1989) in which share-price volatility and dividends have a significant negative association. This work may help to offer a better understanding of the general theory of asset-price volatility and the underlying structural links between two markets.

Fourth, lenders can employ API scores to evaluate the overall risks of their loans. Since higher volatility means greater risk in financial markets, negative correlations between housing-price volatility and API scores can help lenders measure potential risks. As FICO scores indicate credit risks, API scores can help reveal asset risks associated with locations.

Fifth, investors and developers can carefully measure potential risks by studying the elasticity of both the demand and supply sides of the equation. Positive amenities generate inelastic demands for housing and anchor asset values, while inelastic supplies cause larger price swings.

Additionally, in future work, it would be useful for researchers and decision-makers in the public and private sectors to better understand the importance of education heterogeneity for neighborhood-based policies and outcomes.

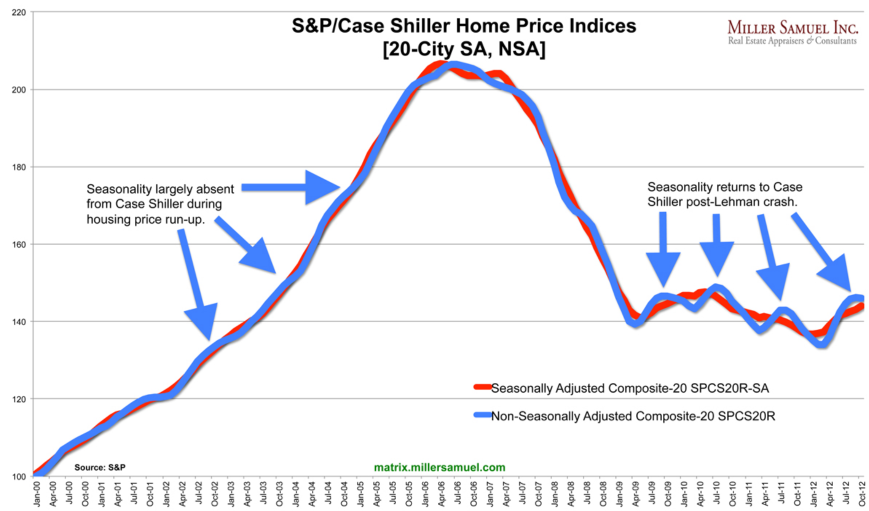


Figure 1.1: Case Shiller Index in US cities 2000 -2012

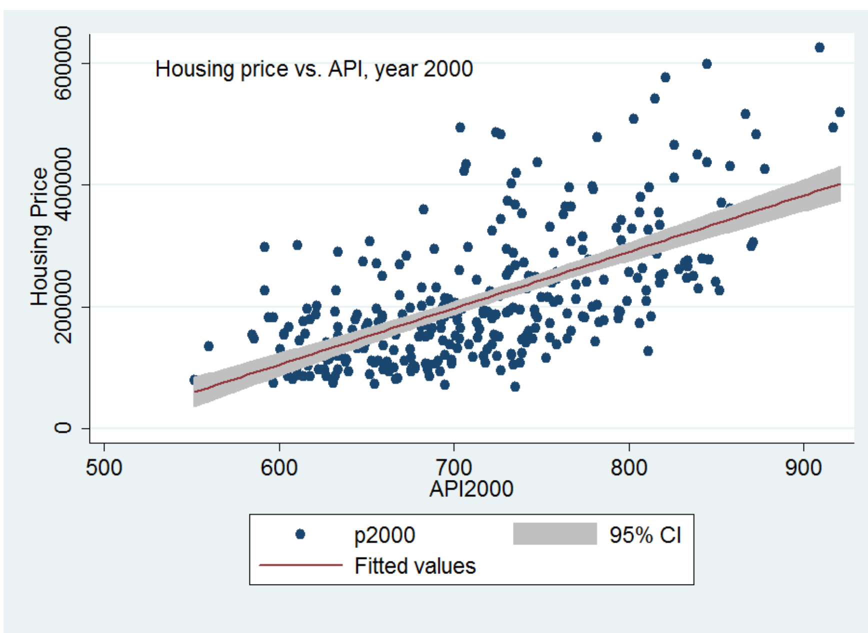


Figure 1.2: Housing Price vs. API, 2000

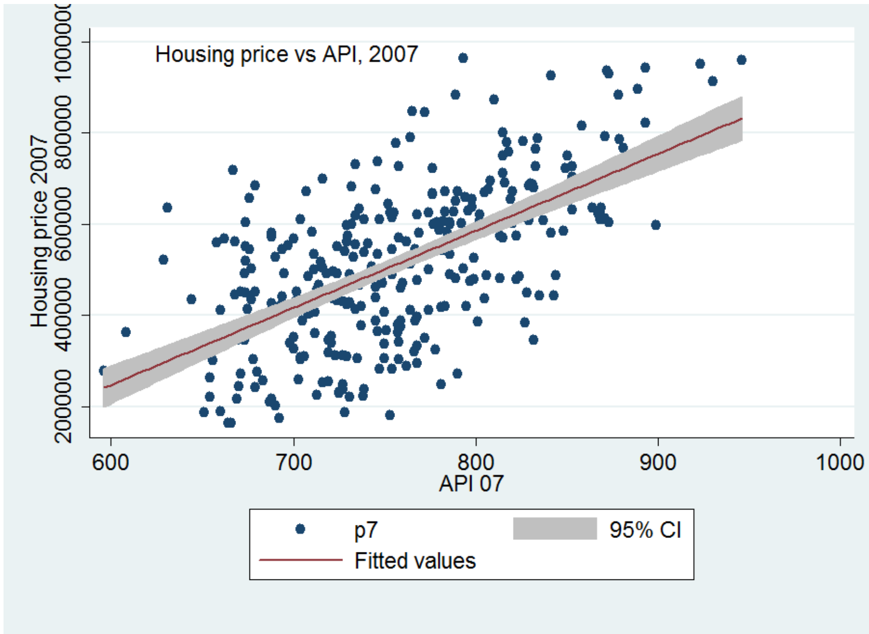


Figure 1.3: Housing Price vs. API, 2007

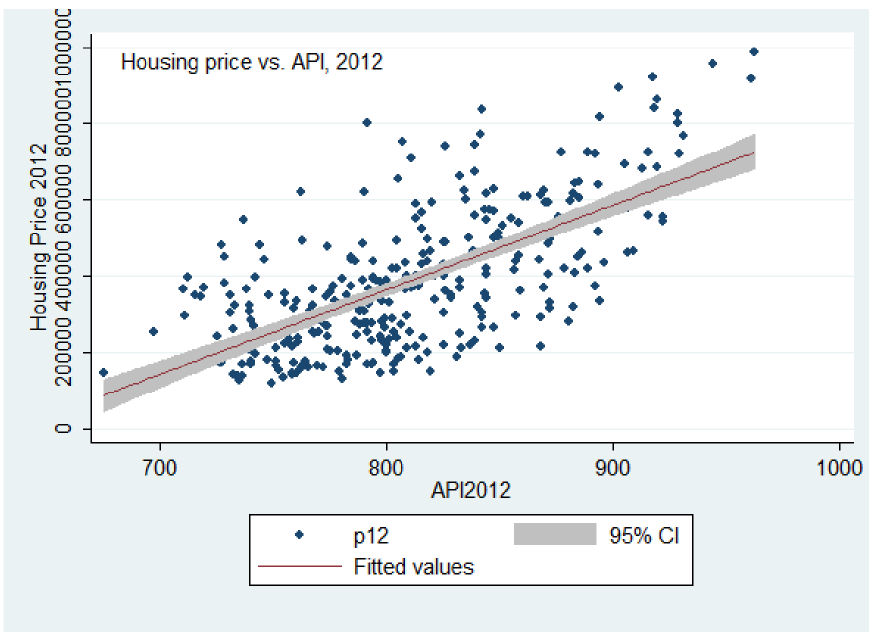


Figure 1.4: Housing Price vs. API, 2012

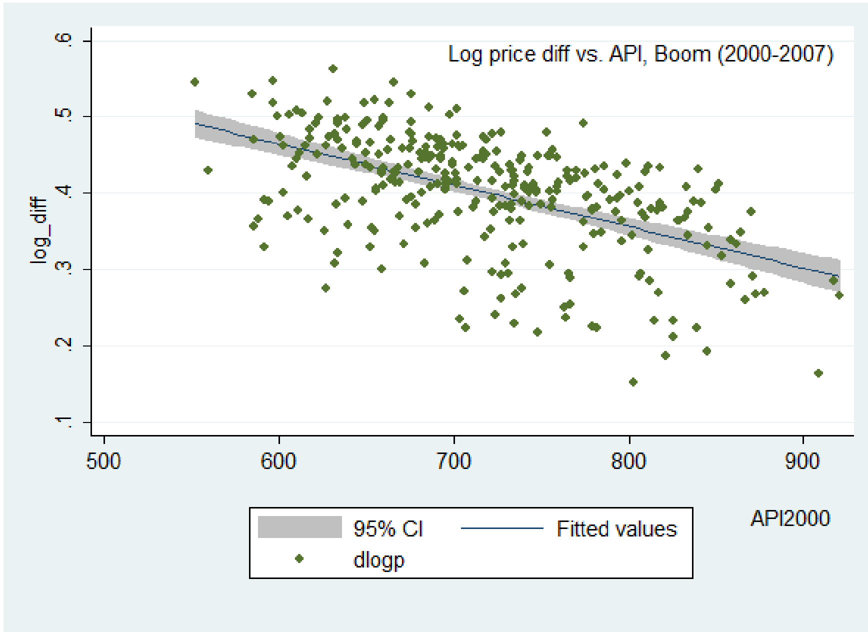


Figure 1.5: log price vs. API in boom (2000-2007)

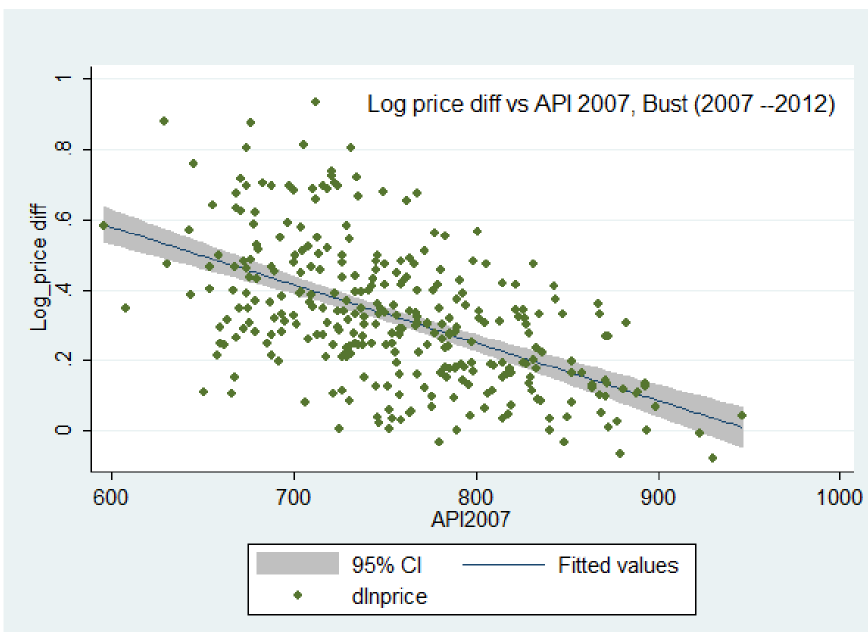


Figure 1.6: Log price vs. API in bust (2007 -2012)

Table 1.1: Summary Statistics of Housing Data

Variables	Mean	Std. Dev.	Min	Max
		Year 2000		
lnprice_diff	92 %	17 %	35 %	129%
API	718	74	552	921
% of over 65	10.5	4.1	2.3	30.2
% of Black	4.9	6.1	0	50.2
% of Asian	9.6	10.6	0.3	55.9
private school	9.6	4.7	1.2	27.4
pctbuilt	13.6	11.4	0.9	65
jobcommute	29.1	5.4	16.11	48.9
income*	51.2	15.1	27.2	110.9
housingprice	214733	109184	67900	626200
population*	94.5	262.3	12.2	4443.9
vacancyrate	5.2	5.9	0.6	57.3
unemployment	4.2	1.9	1.3	14.4
rent	799	213	405	1438
		Year 2007		
lnprice_diff	32 %	19 %	7.8 %	93.4%
API	757	65	596	946
% of over 65	10.8	3.8	3.2	26.7
% of Black	5.2	5.9	0	45.4
% of Asian	11.8	12.5	0.1	65.6
private school	13.5	6.0	2.7	48.9
pctbuilt	1.96	2.21	0	13.44
jobcommute	26.9	5.3	14.6	46.3
income*	62.5	17.7	31.9	124.2
housingprice	512770	176245	162700	963500
population*	101.4	267.8	20.0	4546.3
vacancyrate	4.8	2.1	0.5	13.9
unemployment	6.9	2.5	2.6	15.4
rent	1108	247	525	1883

Table 1.2: Bubble Analysis: Price-Income Ratio

$\|ln(p/y)\_diff\|$	Coef.	Std. Err.	t	$p > \|t\|$
		Boom (2000-2007)		
API_2000	-0.00029	0.0000827	-3.52	0.001
price2000	-1.01e-06	8.34e-08	-12.13	0.000
MSA fixed effects	Yes	N=316	F(13,302)=92.01	$Prob > F = 0.0000$
R-squared =0.7259				
		Bust(2007-2012)		
API_2007	-0.0010	0.00017	-6.08	0.000
price2007	-2.09e-07	9.61e-08	-2.17	0.031
MSA fixed effects	Yes	N=316	F(14,301)=26.54	$Prob > F = 0.0000$
R-squared =0.4263				

Table 1.3: Bubble Analysis: Price-rent Ratio

		Boom (2000-2007)		
$\|ln(p/r)\_diff\|$	Coef.	Std. Err.	t	$p > \|t\|$
API_2000	-0.0002891	0.0000899	-3.22	0.001
price2000	-8.07e-07	7.75e-08	-10.41	0.000
MSA fixed effects	Yes	N=316	F(14,301)=76.43	$Prob > F = 0.0000$
R-squared =0.5430				
		Bust(2007-2012)		
API_2007	-0.0012	0.00018	-6.58	0.000
price2007	-2.313e-07	9.89e-08	-2.33	0.020
MSA fixed effects	Yes	N=316	F(14,301)=29.48	$Prob > F = 0.0000$
R-squared =0.4258				

Table 1.4: Regression of log price diff. on API, 2000-2007, Boom [Control Income]

$\lvert logp_{2007} - logp_{2000} \rvert$	Coef.	Std. Err.	t	$p > t$
API 2000	-0.000347	0.000126	-2.75	0.006
% of over 65 2000	-0.00094	0.0017	-0.55	0.583
% of Black 2000	0.001483	0.001075	1.38	0.169
% of Asian 2000	-7.6E-05	0.000544	-0.14	0.888
income 2000	-3.31E-06	7.33E-07	-4.65	0.000
job commute 2000	0.00563	0.001399	4.02	0.000
% new built 2000	0.002687	0.000568	4.02	0.000
vacancy rate 2000	-0.00308	0.001333	-2.31	0.022
% of private school 2000	-0.00631	0.001513	-4.17	0.000
population 2000	1.96E-09	8.52E-09	0.23	0.818
_cons	1.2234	0.0844	14.49	0.000
MSA fixed effects	Yes	N=	316	
F(21,294)=	70.19	$Prob > F =$	0.000	
R-squred =	0.7361			

Table 1.5: Regression of log price diff. on API, 2007-2012, Bust [Control Income]

$\lvert logp_{2007} - logp_{2012} \rvert$	Coef.	Std. Err.	t	$p > t$
API 2007	-0.000688	0.000171	-4.02	0.000
% of over 65 2007	-0.008273	0.002067	-4.0	0.000
% of Black 2007	0.0016438	0.001357	1.21	0.227
% of Asian 2007	-0.001549	0.000544	-2.85	0.005
income 2007	-6.43E-07	7.10E-07	-0.9	0.366
job commute 2007	0.01392	0.001696	8.21	0.000
% new built 2007	0.0235	0.000625	3.77	0.000
vacancy rate 2007	0.01458	0.0041	3.49	0.001
% of private school 2007	-0.004678	0.001426	-3.28	0.001
population 2007	-2.19E-08	8.16E=09	-2.68	0.008
_cons	0.6160	0.1122	5.49	0.000
MSA fixed effects	Yes	N=	316	
F(21,294)=	49.1	$Prob > F =$	0.0000	
R-squred =	0.7055			

Table 1.6: Regression of log price diff. on API, 2000-2007, Boom [Control Price]

$\lvert logp_{2007} - logp_{2000} \rvert$	Coef.	Std. Err.	t	$p > t$
API 2000	-0.0000856	0.0000407	-2.10	0.036
% of over 65 2000	-0.0005167	0.0005958	-0.87	0.386
% of Black 2000	0.0003481	0.0003654	0.95	0.342
% of Asian 2000	-0.0000894	0.0001614	-0.55	0.580
price 2000	-4.16e-07	4.29e-08	-9.71	0.000
job commute 2000	0.0014883	0.0005817	2.56	0.011
% of new built 2000	0.000766	0.0002223	3.45	0.001
vacancy rate 2000	-0.00112	0.0006	-1.84	0.007
% of private school 2000	-0.006255	0.000582	-1.74	0.082
population 2000	7.33E-09	4.20e-09	0.23	0.818
_cons	0.5062	0.03148	16.08	0.000
MSA fixed effects	Yes	N=	316	
F(21,294)=	142.32	$Prob > F =$	0.000	
R-squred =	0.8009			

Table 1.7: Regression of log price diff. on API, 2007-2012, Bust [Control Price]

$\lvert logp_{2007} - logp_{2012} \rvert$	Coef.	Std. Err.	t	$p > t$
API 2007	-0.0003008	0.0000642	-4.68	0.000
% of over 65 2007	-0.00347	0.0007987	-4.35	0.000
% of Black 2007	0.000784	0.000579	1.35	0.177
% of Asian 2007	-0.0006161	0.0002387	-2.58	0.010
price 2007	-2.71e-08	3.10e-08	-0.87	0.383
job commute 2007	0.00589	0.0007226	8.16	0.000
%new built 2007	0.006204	0.001797	3.45	0.001
% of private school 2007	-0.001982	0.0005563	-3.57	0.001
population 2007	-8.70e-09	3.31e-09	-2.62	0.009
_cons	0.2694	0.04389	6.14	0.000
MSA fixed effects	Yes	N=	316	
F(21,294)=	49.12	$Prob > F =$	0.000	
R-squred =	0.7056			

Table 1.8: Regression of log price diff. on API, 2000-2007, Boom [Control Unemployment]

$\lvert logp_{2007} - logp_{2000} \rvert$	Coef.	Std. Err.	t	$p > t$
API 2000	-0.00085	0.00011	-7.74	0.000
unemployment rate 2000	0.00009	0.006	0.02	0.988
job commute 2000	0.0044	0.0014	3.09	0.002
%new built 2000	0.0023	0.00058	4.03	0.000
vacancy rate 2000	-0.0029	0.0011	-2.53	0.012
% of private school 2000	-0.0076	0.0015	-4.88	0.000
population 2000	2.49e-06	8.07-e06	0.31	0.758
_cons	1.46	0.103	14.11	0.000
MSA fixed effects	Yes	N=	316	
F(21,294)=	112.17	$Prob > F =$	0.000	
R-squred =	0.7126			

Table 1.9: Regression of log price diff. on API, 2007-2012, Bust [Control Unemployment]

$\lvert logp_{2007} - logp_{2012} \rvert$	Coef.	Std. Err.	t	$p > t$
API 2007	-0.00083	0.00013	-6.12	0.000
unemployment rate 2007	0.0125	0.0048	2.60	0.010
job commute 2007	0.0148	0.0016	9.45	0.000
% new built 2007	0.003	0.0007	4.36	0.000
vacancy rate 2007	0.0125	0.0038	3.44	0.001
% private school 2007	-0.0045	0.0014	-3.21	0.001
population 2007	-0.00002	8.95e-06	-2.25	0.025
_cons	0.468	0.129	3.62	0.000
MSA fixed effects	Yes	N=	316	
F(21,294)=	126.19	$Prob > F =$	0.000	
R-squred =	0.6945			

Table 1.10: Magnitude of API Effects – Control Income

	Boom (2000-2007)	SD of Y variable = 17 % point	
Variables	Coef.	One SD of Variable	Impact
API	-0.00035	74	-2.6 % point
% of over 65	-0.00094	4.1	-0.4 % point
% of Black	-0.001483	6.1	0.9 % point
% of Asian	-7.6E-05	10.6	-0.1 % point
income	-3.31E-06	15100	-5 % point
job commute	-0.00563	5.4	3 % point
% of new built	-0.00269	11.4	3.1 % point
vacancy rate	-0.0031	5.9	-1.8 % point
% of private school	-0.0063	4.7	-3 % point
population	1.96E-09	262300	0.1 % point

	Bust (2007-2012)	SD of Y variable = 19 % point	
API	-0.0007	65	-4.6 % point
% of over 65	-0.008	3.8	-3 % point
% of Black	-0.0016	5.2	0.8 % point
% of Asian	-0.0015	12.5	-1.9 % point
income	-6.43E-07	17700	-1.1 % point
job commute	-0.014	5.3	7.4 % point
% of new built	-0.024	2.21	5.3 % point
vacancy rate	0.015	2.1	3.2 % point
% of private school	-0.0047	6	-2.8 % point
population	-2.19E-08	267800	-0.6 % point

Chapter 2

HOW DO THE MINIMUM CAPITAL REQUIREMENTS AFFECT BANKING COMPETITION AND PROFITABILITY?

2.1 Introduction

2.1.1 The Research Question

The financial crisis, which started in the US in 2007, has had a significant effect on the world economy. The global financial crisis from 2007-09 highlighted the need for banking systems to be less leveraged, more liquid, more transparent and less prone to take on excessive risk

(Cohen, 2013). Today, it is widely recognized that the global financial crisis involved more than just subprime mortgage securitization in the US having gone astray (Hellwig, 2009). One of the main lessons from the crisis was that the banking system held insufficient capital (Schanz et al., 2011). The inadequacy of the existing prudential regulatory arrangement has spurred various initiatives for reform. In July, 2010, the US enacted the Dodd-Frank Wall Street Reform and Consumer Protection Act. In July, 2015, the Federal Reserve stated that the eight largest banks in the country should maintain an additional layer of capital to protect against losses. Some measures were already in place to provide such protection: The Basel Accord I (1988) and II (2004) imposed bank capital regulations to enhance international standards that controlled how much capital banks must hold to guard against the financial and operational risks that banks face. Then, in response to the deficiencies in financial regulation revealed by the financial crisis of 2008, the Basel Accord III (2010–2011) was developed. Basel III was intended to strengthen bank capital requirements by increasing bank liquidity and decreasing bank leverage. Tier 1 capital (equity capital) should constitute the minimum 6% of Risk-Weighted-Asset (RWA). This is called the minimum capital requirements (MCR). Because equity is scarce and more expensive than debt financing, many researchers therefore expect banks to operate close to their required minimum capital ratios. However, Berger(2010) identified the capital ratio trend in the US banking holding companies (BHCs) from 1992 to 2006, which challenged popular belief (See Figure 2.1).

Figure 2.2 shows the most recent capital ratios sorted by bank size in 2016 Q2. The largest banks hold a tier one ratio at the 12.5 level, which is similar to that propsed by Berger. However, smaller banks hold much higher tier-one ratios than the minimum requirement.

The industry data suggests that banks' capital ratios is well above the MCR. The buffer serves as a cushion for both market risk and competition parameters. The existing literature lays out three purposes of capital requirements: (1) it serves as a buffer against unexpected losses, (2) it reduces incentives for incurring risks to burden creditors or taxpayers, and

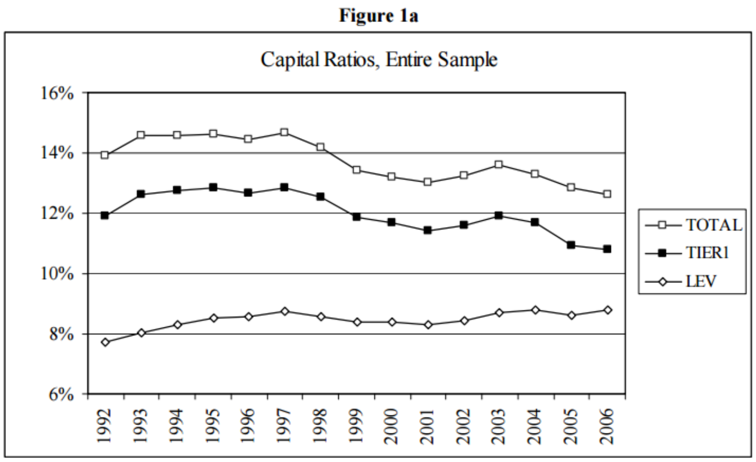


Figure 2.1: Actual Capital Ratios vs. MCR (6%,). Source: Allen Berger, 2010

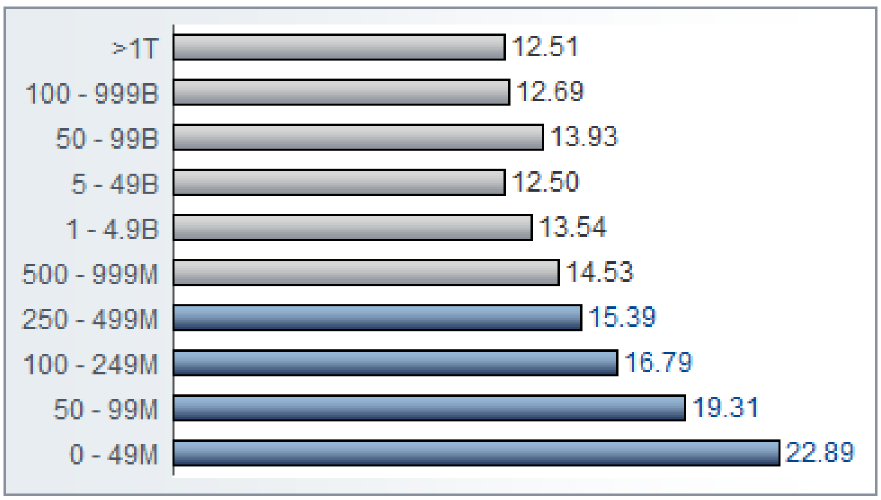


Figure 2.2: Capital Ratios vs Bank Sizes

(3) it provides supervisors with room for intervention before the bank becomes insolvent. However, relatively little attention has been given to address the role of the MCR on the banks' optimal ratio choices. This paper presents a theoretical model to answer the following question: how does the minimum capital requirement (MCR) affect the bank competition and profitabilities? The analysis reaches the conclusion that the MCR generates an additional marginal cost for banks, providing an important influence on banks' optimal choice on capital ratios. The MCR also creates competitive inequities among bank sizes: It favors bigger

banks.[1]

This paper is also the first to provide empirical evidences to prove the following assertions: (1) There is an inverted U-shape relationship between bank profits (measured by *Return On Equity*: ROE) and capital ratios (measured by tier one capital rarios); (2) optimal ratios decrease with banks' size. (3) optimal ratios are an increasing function of the MCR.

The layout of the paper is as follows: Section 2.2 briefly discusses the history of banking regulation and establishes how this paper relates to the literature on the capital ratios. Section 2.3 discusses the benefits and costs of capital ratios. Sections 2.4 discusses a representative bank in competitive market. Section 2.5 explains the data, methodology, results, and robustness of the findings. Finally, Section 2.6 concludes. Appendix B explores banks' collusive behavior in the oligopolistic market.

2.2 History of Regulation and Related Literature

2.2.1 History of Banking Regulation

The Banking industry has been among the most heavily regulated sectors in the US. US bank regulators have long sought to look for the correct minimum levels of capital. Capital regulation in the form of minimum capital requirement (MCR) is the most popular instrument in the current banking regulation. In the early 20th century, the US national banking system started to implement the minimum capital requirements on the amount of capital, which was determined by the population of the town in which a bank was operating. From the 1930s to the 1970s, market structure, asset allocation rules and interest

[1] Goldman Sachs CEO explained how higher regulatory costs are crushing the competition: "More intense regulatory and technology requirements have raised the barriers to entry higher than at any other time in modern history", said Mr. Blankfein. "This is an expensive business to be in, if you do not have the market share in scale." (The WSJ, "Regulation Is Good for Goldman", Feb. 11, 2015).

rates were the main focus points for banking regulation and supervision. Between the 1950s and the 1970s, US regulators intended to compute the minimum capital level for all kinds of categories of assets. In 1981, US regulators implemented explicit capital ratios. Regulators required a 5.5% minimum ratio of "primary capital" - common and perpetual preferred stock, surplus, undistributed profits, and capital reserves - to total assets, and they imposed a 6.0% minimum ratio of "total capital"- primary capital plus certain subordinated notes and debentures, other preferred stock, and mandatory convertible debt to assets. In 1988, under the Basel Accord, regulators imposed both a traditional leverage requirement and risk-based requirements. However, by the mid-1990s, regulators learned that bank had played the game through regulatory arbitrage that undermined the intent of the Basel risk adjustments. Since then, the Basel II system has been introduced to construct and implement an overall regulatory framework around 3 pillars: risk-based capital requirement, discretionary supervisory discipline, and increased market transparency. Although there are more than 50 years of regulatory effort based on minimum capital requirements, the theoretical banking literature is sharply divided about the effects of capital requirements on bank behavior.
Jackson et al. (1999), Wang (2005), VanHoose (2006), Santos (2001), and Stolz (2002) all provided empirical evidence and broader implications of capital regulation for economic stability and monetary policy. Over the last decade, capital requirement has replaced reserve requirements as the main constraint on banks. Since 1990, the Federal Reserve has reduced the amount of required reserves (Chami, 2001). The same declining trend has also been found in some European countries (Sellon, 1996).

In December, 2011, The U.S. Federal Reserve announced to implement all of the Basel III rules. Basel III is a global, voluntary regulatory framework on bank capital adequacy, stress testing, and market liquidity risk, agreed upon by the members of the Basel Committee on Banking Supervision in 2010-11.

Figure 2.3 shows the quantity and quality of capital requirements under Basel I, II and III.

Basel I, Basel II, and Basel III Capital Requirements
(Percent of risk-weighted assets)

	Basel I	Basel II	Basel III 1/
Quantity of Capital			
Minimum Total Capital	8.0	8.0	8.0
Capital Conservation Buffer 2/	n/a 3/	n/a	2.5
Minimum Total Capital Plus Conservation Buffer	n/a	n/a	10.5
Countercyclical Buffer 2/	n/a	n/a	0–2.5
Global Systemically Important Banks (G-SIB) Surcharge 2/	n/a	n/a	1–2.5
Minimum Total Capital Plus Conservation Buffer, Countercyclical Buffer, and G-SIB Charge	8.0	8.0	11.5–15.5
Leverage Ratio 4/	n/a	n/a	3.0
Quality of Capital			
Minimum Common Equity Capital 5/	n/a	n/a	4.5
Minimum Tier 1 Capital	4.0	4.0	6.0
Hybrid Capital Instruments with Incentive to Redeem 6/	Eligible	Eligible	Not eligible

Sources: BIS 2011 and 2013.

Figure 2.3: Basel I, II and III Capital Requirement

2.2.2 Literature Review

The extant literature on financial regulation is extensive. Jean Tirole in particular has made several important contributions to the subject of financial regulation. The very first question under examination here is why financial intermediaries need to be regulated at all. Several major issues exist in the financial sector, including inefficient bank runs and contagion resulting in bank panics. A common theme in Tirole's work is the design of financial regulation that optimally trades off ex post efficiency (i.e, intervening to avoid systemic crises) with ex ante efficiency (i.e, mitigating the moral-hazard problems that first produced the prospect of crises) (The Royal Swedish Academy of Sciences, 2014). Most countries have introduced a governmental safety net (Schliephake & Kirstein, 2012), which includes deposit insurances and lender of the last resort practice. However, the undesirable secondary effect of the safety net, pointed out by Greenbaum and Thakor (1995) is as follows: The moral hazard engendered by one form of regulation, namely deposit insurance, creates the need for other forms of regulation, such as capital requirements. The actual impact of a regulatory capital requirement on the individual behavior of banks is disputed in the banking literature. Comprehensive reviews of the theoretical literature regarding the impact of capital requirement regulation have been provided by Berger, Herring, and Szeg (1995); Santos (2001); and Van Hoose (2007). Although the theoretical predictions are ambiguous, there is a general consensus in the literature that higher capital has a positive direct effect on the balance sheet structure, as discussed by Van Hoose (2008). This bank default reducing effect is most often analyzed in a perfect competitive environment, but it is also valid in a Bertrand oligopoly. Carletti (2008) points out that the majority of papers on banking regulation merely compare the equilibria of the two extreme market structures: a monopoly case and perfect competition. These models therefore lack the consideration of strategic interaction between financial intermediaries.

Berger (2008) investigated three alternative hypotheses to help explain why banks hold much higher capital ratios than the supervisor would permit. (1) Earning Retention: firms may face difficulty raising equity capital on short notice, and hence prefer to retain earnings as a precaution against unknown future needs. (2) Economic Capital: banks may match their capital ratios to perceived risk exposures and to the benefits of maintaining a specific standing in credit markets. (3) Acquisition Plans: Acquisition-minded banking organizations may maintain additional capital in order to obtain some "dry powder", should attractive investment opportunities arise. Imperfect competition is an important feature of most banking sectors: Berger et al. (2000) find empirical evidence that banks in the United States made consistent profits between 1970 and 1997. Barajas et al. (2010) apply the RossePanzar (1987) H-test to the data of the holding companies of large banks and reject the two extreme hypotheses of competitive and monopolistic behavior in the banking industry. A few theoretical papers that actually consider strategic interaction among banks model imperfect competition as oligopolistic, quantity-setting models in the Cournot fashion. VanHoose (1985) analyzes the effects of increased bank competition on the ability of a central bank to pursue monetary policy. Pecchenino (1983) offers models of heterogenous banks that differ in risk tolerance and make decisions concerning both the size and risk level of their portfolios, while their individual actions have spillover effects on the actions of other banks. Boyd and De Nicolo (2005) model imperfect competition for loans a la Cournot in order to analyze the impact of competition on the risk that a bank takes when borrowers are able to influence the risk level of the bank's assets. Rime (2005) models the Cournot loan market competition to analyze the coexistence of the very risk-sensitive capital regulation under the internal ratings-based approach in Basel II and the more risk-insensitive requirements under the standard approach. He shows that sophisticated banks will specialize in low-risk customers, whereas unsophisticated banks specialize in high-risk loan customers. The application of oligopolistic quantity competition to loan supply, in which banks offer a certain amount of loans to the market and then demand for loans determines the equilibrium loan rates, appears counterintuitive. In fact, one expects banks to offer loan contracts that specify the loan rates, while prospective borrowers look for the best loan contract conditions and demand the loan from the bank with the best conditions (e.g., lowest interest rates).

A bulk of empirical studies have investigated the structure-conduct-performance (SCP) relationship in commercial banking markets. Rhoades (1977), Rhoades (1982), and Gilbert (1984) concluded that there is a positive correlation between local market concentration and profts and that the concentrated markets may be more conductive to collusion and therefore less efficient and less equitable. The market structure conduct and performance (SCP) framework was derived from the neoclassical analysis of markets. SCP was the brain child of the Harvard school of thought, was popularized during the period of 1940-60, and led to anti-trust legislation. The Chicago school of thought (1960-80) emphasized the rationale for firms to become big through price theory and econometric estimation.

From 1980-90, game theory took center stage with an emphasis on strategic decision making and the Nash equilibrium concept. After 1990, empirical IO lead to complex modeling of technological changes, merge analysis, entry-exit, and identification of market power. Milne (2002) suggested that the market treat banks as forward-looking optimizers, balancing the benefits of their lending decision against the costs of a regulatory breach. Thus, rational banks balance costs and benefits across the entire balance sheet when subjected to capital regulation. Estrella (2004) developed a theoretical framework in which banks adjust their debt structure. Under Estrella's model, banks first must meet a minimum risk-based capital requirement, and then banks must raise funds in the debt market. Finally, banks obtain signals regarding their performance that they may or may not fully pass along to regulators. There are three outcomes to this scenario: (1) banks cannot raise sufficient funds to invest in an asset and close down, (2) banks meet the minimum constraint and issue debt, and (3) banks have sufficient capital to invest without issue debt. When category (1) occurs, market share is taken by (2) and (3). The outcome of the interaction of the three categories of banks would change the bank market structure.

When banks are constrained by capital requirements, regulator-determined capital and market capital are not equal. Diamond and Rajan (2000) studied the role of moral hazard problems on the liability side of banks balance sheets. They point out that the short-run effects of binding capital requirements are a credit crunch for cash-poor borrowers and smaller loan repayments for cash-rich borrowers. Besank and Kanatas (1996) mentioned that capital regulation cuts into shareholders surplus. This creates potential for an agency problem to arise when the bank must issue new equity to meet a capital adequacy requirement. Thus, faced with the dilution of surplus, inside shareholders have less incentive to monitor loans, so the probability of loss on loans increases.

2.3 The Benefits and Costs of Bank Capital

From the financial stability perspective, higher bank capital levels have several benefits, but they also add additional costs for banks. The minimum capital requirements may affect the way banks behave, and thus also affect their profits.

2.3.1 Benefits

First, capital is used to absorb losses and reduce the probability of failure. Freixas and Rochet (1997) point out that bank capital is usually thought to serve two main purposes: (1) Holding of capital improves risk-sharing by the bank. Having a capital buffer allows the bank to avoid selling assets at fire-sale prices in the event of a sudden increase in withdrawals. (2) Bank capital provides an incentive-alignment function. When bank equity holders have skin in the game, they have an incentive to exert effort to ensure the performance of the bank assets, and they also have an incentive not to take excessive risks. Second, higher capital helps banks attract funds and obtain a cheaper funding rate (Holmstrom and Tirole, 1997). Higher capital also helps to maintain long-term customer relationships (Allen, 2011). A bank with a higher capital ratio has a greater chance of surviving in the future and has a greater incentive to monitor borrowers (Allen, Carletti and Marquez, 2011).

2.3.2 Costs

The traditional Modigliani-Miller (1958) proposition doesn't apply to the banking industry, because the fractions arise from the tax deductibility of the interest rate, bankruptcy costs, or agency problems. Equity issuance is subject to underwriting fees, usually 5-7%. There are signaling costs (Myers and Majluf, 1984); issuing equity may require substantial discounts when incumbent investors and managers have information about the firm that new equity investors do not have. Furthermore, debt has a more favorable tax treatment than equity (De Mooji, 2011). Equity can be more costly due to various frictions; a decrease in leverage does not lower the required return on equity.

Some investors value liquid and nominally safe assets, such as bank debt, for the liquidity insurance and convenience (Bryant, 1980; Diamond and Dybvig, 1983; Gorton and Pennacchi, 1990; Caballero and Krishnamurthy, 2008).

Without capital requirements, banks hold a certain amount of capital due to market incentive (Calomiris and Powell, 2001). On the asset side, banks have more choices in portfolios. On the liability side, higher capital increases banks ability to obtain more funds because of the risk-sharing effect between the share holders and depositors. But every financial crisis raises the question of banks moral hazard; the market discipline may not be enough to constrain the banks risky behaviors. The amount of capital as a buffer against economic shocks may not be sufficient to ensure banking stability. Therefore, governments intervention becomes necessary.

2.4 The Model

2.4.1 Model Setup

This section studies the optimal capital ratio choice of a representative bank in the competitive market when the MCR is imposed by the government. The model is based on te work of Tanaka(2002). To simplify the application, the minimum required reserves are ignored from the original model. It also includes several additional factors, such as funding costs, based on the analysis in the previous section. The banks have two types of capital: shareholders' own money – equity capital K with discount rate ρ and deposit D which offers deposit rate r_d. The funds raised by the Banks can be invested in two assets: risk-free assets C and risky assets L, yielding a net return r_l with uniform distribution $[0, r_l^m]$, which is exogenously determined by business cycles. The bank's balance sheet is: $K + D = C + L$.

The bank face capital ratio requirement: $k_0 (0 \leq k_0 \leq 1)$. [2]

At t=1, the bank comes up with equity capital K, collects deposit D and chooses optimal L to maximize the expected profit.
At t=2, the bank faces a regulatory penalty V if

$$\frac{K_2}{L} < k_0 \tag{2.1}$$

$$K_2 = K + \epsilon, \quad where \quad \epsilon \sim iid(0, \sigma^2) \tag{2.2}$$

ϵ is a random component. If the bank makes profits, $\epsilon > 0$, the retained earning can increase

[2] currently, Tier 1 ratio $k_0 = 6\%$

capital. If there is an unexpected loss, $\epsilon < 0$, the bank suffer a reduction in its capital base. Since $K = C + L - D$, there are two possible stochastic sources for ϵ: D and L. [3]

The *ex ante* probability of facing a regulatory penalty,

$$p(\frac{K_2}{L} < k_0) = p(\frac{E_{t=1}(K_2)}{L} < k_0) = p(\frac{k_0 L}{K} > 1), \qquad where \quad 0 \leq p \leq 1 \tag{2.3}$$

Assume $p'_K < 0$, $p''_K > 0$, the probability of facing a regulatory penalty decreases at an accelerating rate as k/L ratio departs from k_0 (Estrella, 2004). Assume $p'(L) > 0, p''(L) > 0$. The probability of facing a regulatory penalty increases at an accelerating rate as k/L ratio approaches k_0.

Assume in this model that the bank takes the whole sale funding D with interest rate r_D. [4] The whole sale deposit ratios are negatively associated with banks' capital ratios.

$$\frac{\partial r_d}{\partial K} < 0, \quad \frac{\partial r_d}{\partial L} > 0, \tag{2.4}$$

The whole sale depositors and equity holders have risk-sharing relationship. The higher capital ratios show that banks are safer, therefore generating cheaper funding costs.

The bank's objective function is:

$$\max_{L,K} \Pi = r_l L - D r_d - p(\frac{k_0 L}{K})V - \rho K \tag{2.5}$$

[3]One scenario is bank run. When a large number of customers withdraw cash from deposit accounts with a financial institution at the same time because they believe that the financial institution is insolvent. The banks can first use cash C to satisfy the withdrawal. But when banks run out of cash, they need to fire-sell their assets to meet their withdrawal demand. The loss from the fire-sell is absorbed by banks' equity capital. Another scenario is the borrowers' default.

[4]For retail deposits, banks issue deposits elastically at the given interest rate. The equilibrium quantity and rate of deposit is determined by the money market equilibrium, which will not affect the marginal analysis of this model in term of capital level. The reason for this is that retail depositors don't take capital ratios into their consideration.

S.t.

$$K + D = C + L \tag{2.6}$$

The Bank's first-order condition with respect to K is

$$\underbrace{r_d + r_d'(K)K + \frac{k_0 L}{K^2} p' V}_{MB} = \underbrace{\rho}_{MC} \tag{2.7}$$

The equation 2.7 shows that for any given level of loan amount, an increase of MCR (k_0) would cause banks to raise up capital level to satisfy the first order condition.

The Bank's first order condition with respect to L is

$$\underbrace{r_l}_{MB} = \underbrace{r_d'(L)L + r_d + \frac{k_0}{K} p' V}_{MC} \tag{2.8}$$

The equation 2.8 shows that for any given level of capital level, an increase of MCR (k_0) would cause banks to curtail loan level to satisfy the first order condition.

The optimal ratio is given if K* and L* are solved.

$$T^* = \frac{K^*}{L^*} \tag{2.9}$$

Note, when the MCR (k_0) increases by the Basel Accord, banks' strategies are (1) to increase capital levels, (2) to curtail loan level, (3) or both.[5]

There exists an optimal capital ratios that maximizes banks' profit, and this optimal ratio is an increasing function of the MCR.

[5]Which strategy to use depends on banks' idiosyncratic condition.

2.4.2 Comparative Statics

Since for most banks, an increase of equity in he short run is difficulty and costly, the comparative statics for optimal loan supply are given as follows: [6]

$$\frac{\partial L^*}{\partial K} > (\frac{1}{k_0})(\frac{p' + \frac{k_0 L}{k} p''}{p''}) > 0 \tag{2.10}$$

$$\frac{\partial L^*}{\partial k_0} = -(\frac{K}{k_0^2})(\frac{p' + \frac{k_0 L}{k} p''}{p''}) < 0 \tag{2.11}$$

$$\frac{\partial L^*}{\partial V} = -(\frac{K}{k_0})(\frac{p'}{p''} V) < 0 \tag{2.12}$$

$$\frac{\partial L^*}{\partial r_l} = (\frac{K}{k_0})^2(\frac{\pi}{p''} V) > 0 \tag{2.13}$$

Thus, the above results clarify the optimal loan choice. The optimal loan increases on the capital level K and the loan interest r_l, but decreases on the capital adequacy requirement k_0 and regulatory penalty amount V.

[6] See Appendix A for Proof.

2.4.3 Characterization of Marginal Cost Changes

The total cost of the bank is $TC = Dr_d + p(\frac{k_0 L}{K})V + \rho K = (L+C-K)r_d + p(\frac{k_0 L}{K})V + \rho K$. Since in the short-run, an increase of equity to match the regulatory requirement is very costly (Romer, 2012), the additional fund to support marginal supply comes from the deposit. So, the marginal cost can be expressed as the following

$$MC = \frac{\partial[(L+C-K)r_d + p(\frac{k_0 L}{K})V] + \rho K}{\partial L} = r_d + r_d' L + \frac{k_0}{K} p' V \tag{2.14}$$

Note that the marginal cost increases on k_0, L and V, but decreases on K. [7]

First, if there were no minimum capital requirements, the third item in MC would have been dropped. All banks are facing less marginal cost. Since the third one is totally exogenous, the MC curve will shift up after the minimum capital requirements is implemented by regulators. When the MC curve shifts up, the consequence would be less output (less loan supply in banking case) and higher equilibrium price.

Second, under the same capital level K, an increase in loan amount L will have two sequences: (1) increase the funding cost (the second item), (2) increase the probability of violating the MCR and thus the regulatory cost (the third item).

Third, without a loss of generality, banks' total asset is proportional to its capital level (see Figure 2.4). Thus, the capital level K can be used as a proxy for bank size. According to Equation 2.10, a fall in capital increases the probability of facing a regulatory penalty for any given level of loan supply.

[7] Thakor(1996) argues that if the additional cost of raising equity are higher than relative to other sources, then the bank may refrain from further lending and prefer to invest in marketable securities than in loans.

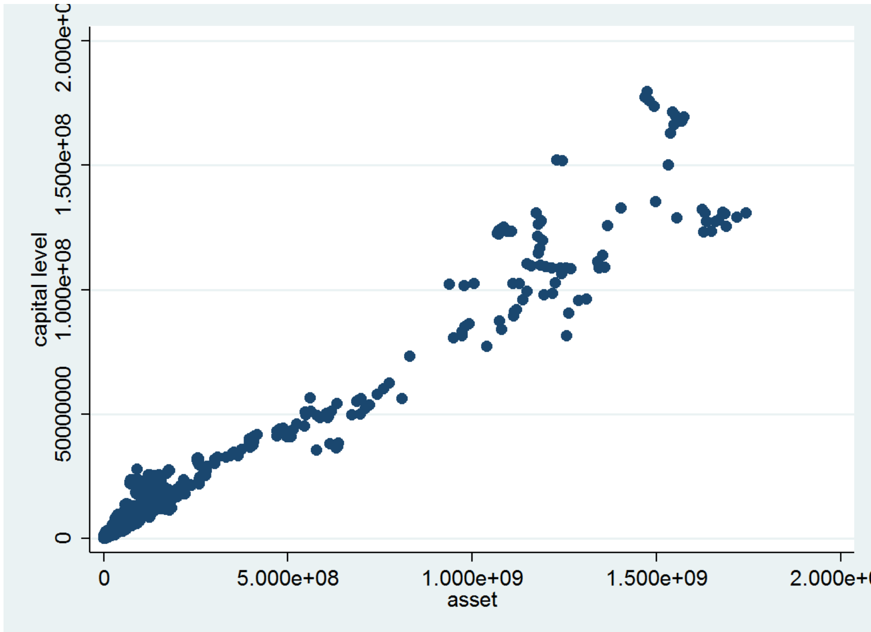


Figure 2.4: Asset vs Capital Relationship

Figure 2.5 shows the ratio-loan space, where the curves are iso-capital curves. Let the y axis be ratio $\frac{K}{L}$, and the x axis be loan amount. Then the iso-capital curve is $y * x = K$. Assume that there are two banks with K=50 and K=500, respectively. Without the MCR, both banks can move freely along the iso-capital curve to allocate their own optimal ratios. The small bank has smaller K, but it can increase deposit D to satisfy the loan demand at its will. However, after the MCR is imposed by regulators, the capacity constraint issue is generated for both banks.

The first derivative of y (the capital ratio, $\frac{K}{L}$) wrt x and cross derivative of y wrt x (loan amount) and K are showing as the follows:

$$\frac{\partial y}{\partial x} = -\frac{K}{x^2} < 0 \tag{2.15}$$

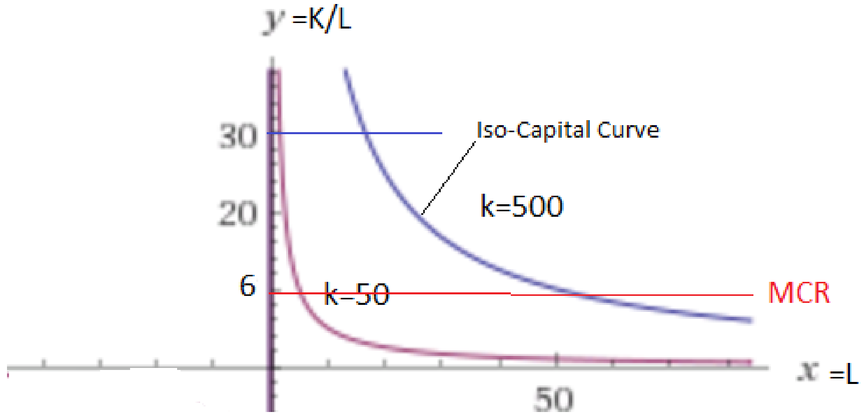


Figure 2.5: Ratio-loan space

$$\frac{\partial^2 y}{\partial x \partial K} = -\frac{1}{x^2} < 0 \tag{2.16}$$

The higher K level makes the iso-capital curve flatter, while the fall in K level makes the iso-capital curve steeper. The MCR generates more constraint for the smaller bank because its iso-capital curve is much steeper. Put differently, one additional loan for the small bank will drive its capital ratio to sharply decline and approach the MCR quickly.

So, the MCR provides larger banks with comparative advantages because of the smaller marginal cost.

It is easy to demonstrate that if two banks merge, the higher combined capital level makes marginal cost smaller.

The increased marginal cost effects from MCR likely makes the merge more attractive, because the marginal cost of merged banks is less than that of each of the banks before merging.

2.4.4 Summary of Effects of MCR

1. MCR regulation is equivalent to an additional cost that is decreasing in the level of capital.

2. One-size-fits-all MCR generates capital size advantage.

3. MCR makes M&A more attractive.

4. MCR causes the capacity constraint issue.

5. MCR has a strong influence on banks' optimal ratio choices.

However, in practice, estimating the optimal level of bank capital is likely impossible *ex ante*, because it requires accurately estimating the effect of bank capital on the cost and credit, the probability of violating regulations, and the impact of credit availability and banking crises on output and output volatility. Facing the MCR, banks have only two choices: (1) close the operation or merge with other banks or (2) choose optimal ratios, which must be above the MCR, to maximize the profits. If their internal optimal ratios are below the MCR, then the long-term relation between capital ratios and profits are negative, thus banks may choose (1). If their internal optimal ratios are above the MCR, the introduction of the MCR would increase banks' marginal cost. Banks likely would choose (2) but look for a higher capital ratio as the new equilibrium. [8] When banks capital ratios are close to the MCR, raising their capital toward new, higher equilibria had better earning. This is because the higher capital not only reduces the probability of the regulatory cost, but also helps banks to reduce their funding costs. However, if banks overshoot their optimal capital ratios, the benefits of holding higher capital would diminish, and the costs will dominate the benefits. Then the relation between capital ratios and profits becomes negative. Therefore,

[8] The math model shows that the optimal ratio is an increasing function of the MCR.

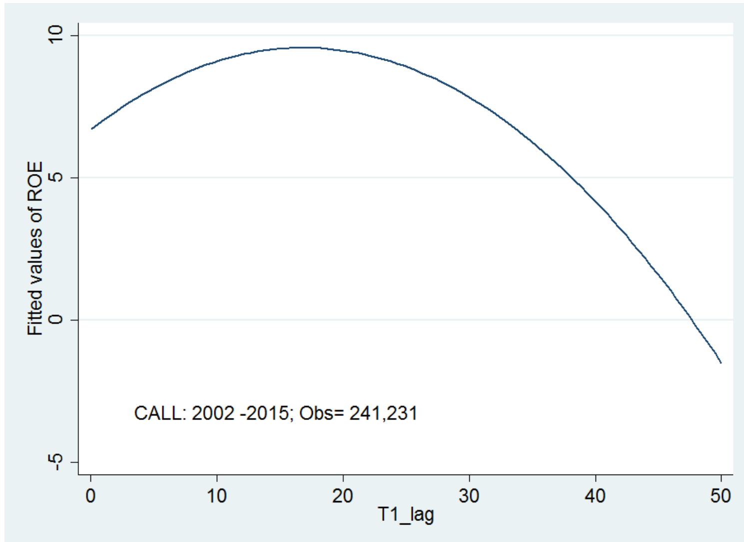


Figure 2.6: Capital Ratios vs ROE. Source: CALL data, 2002 – 2015

the relation of capital ratios and profits is nonlinear; It should be an inverted U shape instead.

HYPOTHESIS: *The relationship between bank profits (ROE) and capital ratios(T1) is nonlinear; it's an inverted U shape instead.*

2.5 Empirical Works

The main specification follows the work of Berger(1995). The expected empirical findings are as follows: (1) the relation between banks' profits and capital ratios are nonlinear, (2) banks' optimal ratios decrease with bank size, and (3) banks optimal ratios increases with the minimum capital requirements.

2.5.1 Data

The dataset is taken from The Federal Financial Institutions Examination Council (FFIEC). The FFIEC was established on March 10, 1979, pursuant to title X of the Financial Institutions Regulatory and Interest Rate Control Act of 1978 (FIRA), Public Law 95-630. The FFIEC creates The Uniform Bank Performance Report (UBPR), which is an analytical tool created for bank supervisory, examination, and management purposes.

On the individual bank level, there were 8,219 banks in the 4th quarter of 2002; only 4,952 survived during 2002–2015, and 3,267 banks became inactive.

	2002Q4	Survived 2002Q4-2015Q4	Inactive
No. of Banks	8,219	4,952	3,267
Survived		1	0

The survivors form 4,952 (i) x 53 (t) balanced panel data sets. I drop all inactive banks from the sample. [9] The inactive banks become inactive for several reasons: they may merge with other banks, become branches of large banks or they simply failed. I also drop extreme

[9] I also conduct the regression by including all inactive banks. The results are the same.

observations of ROE and T, defined as those which are greater than three standard deviation from the mean in each year. Table 2.1 shows the summary statistics for all control variables.

2.5.2 Model Specification

The regression Model is based on (Berger, 1995).

$$ROE_{i,t+1} = \alpha_1 + \alpha_2 T_{1i,t} + \alpha_3 T_{1i,t}^2 + \alpha_4 ln(asset)_{i,t} + \Gamma' X_{i,t} + \epsilon_{i,t+1} \quad (2.17)$$

ROE is return On equity. Figure 2.7 shows the US bank historical ROE. The model deals with lagged regressors. While $ROE_{i,t}$ may affect $T_{1i,t}$, $ROE_{i,t+1}$ does not affect $T_{1i,t}$. $T_{1i,t}$ is the tier one ratio (tier one capital/risk-weighted-assets). ln(asset) is the natural logarithm of bank average assets during time t (quarter). i indexes the individual bank, t indexes year-quarter, $X_{i,t}$ is the vector of control variable, and ϵ is white noise. The vector of control variables$X_{i,t}$ include variables found to be helpful in explaining both capitals and profits. I include individual bank, time effects, asset size effect and the following variables:

Credit Risk: The level of portfolio risk. Credit risks should be positively correlated with ROE, since higher risk is linked to higher return to share holder.

Overhead Expense: Non-interest expense as a percentage of average assets. This is to control how efficiently the bank run its business. The higher the overhead expense, the less the ROE is.

Gain or Loss from Securities Sale: Realized gains(losses) on the sale of Securities as a percent of average assets. Banks may sell some of their securities to satisfy their demand for liquidity. They should be positively correlated with ROE.

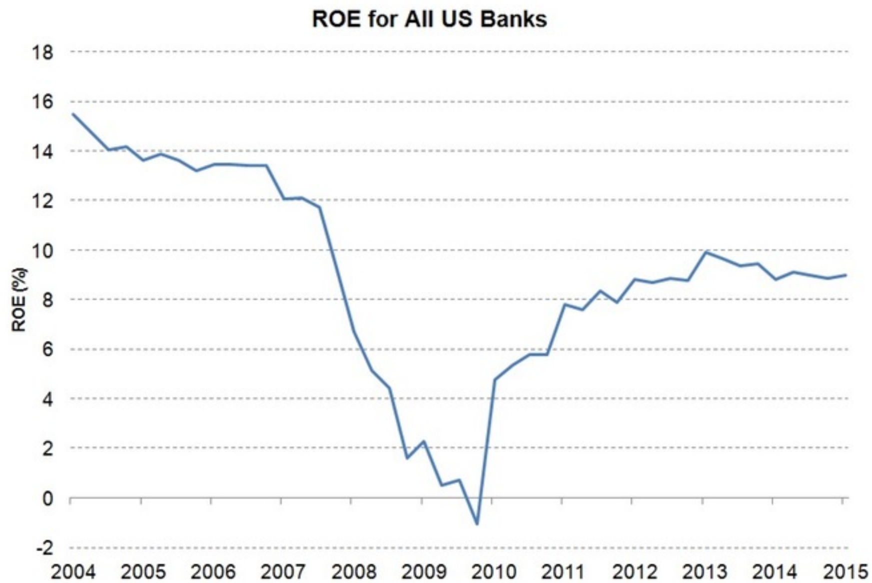


Figure 2.7: US bank Return On Equity, Source: FDIC

Interest Expense to Average Earning Assets: This is to control banks funding costs: the r_d in the math model. The coefficient is expected to be negative.

The specification also includes quarter (seasonal) fixed effects and year fixed effects.

2.5.3 Results: Capital Ratio and bank profit

The Figure 2.8 shows the density distribution of the capital ratios among the sample banks.

The figure 2.9 shows the distribution of the banks' return on equity (ROE).

First, the evidence that there exist an optimal capital ratio is provided. Panel regressions with fixed-effect and random-effect are conducted, and a Hausman test is performed to determine which model is more appropriate for the panel data. Table 2.2 shows that, under both models, the effects of tier-one capital ratios on bank ROE are dynamic and nonlinear. The coefficient of tier-one capital ratio is positive and significant at the 1% level. The coefficient

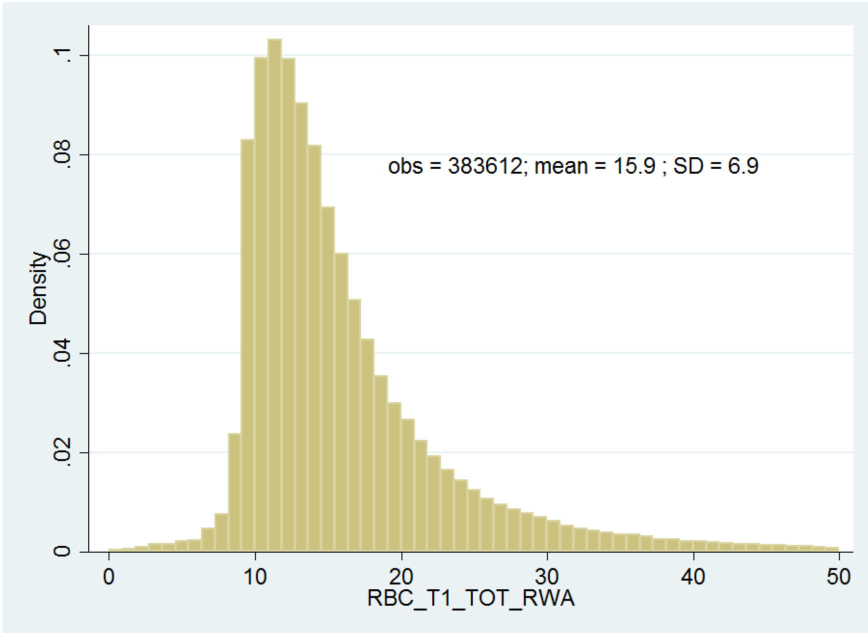


Figure 2.8: Distribution of Bank T1 ratio

of the square of tier-one capital ratio is negative and significant at the 1% level. Second, the Hausman test shows that the individual-level bank fixed-effect is appropriate. This makes sense because idiosyncratic banks privately adjust their optimal ratios to maximize the return on equity.

2.5.4 Results: Capital Ratios and Size

A scatter plot illustrating the relation between capital ratios and bank size, under different bank class, is provided in Figure 2.10. The negative correlation is clearly displayed.

Table 2.3 displays the regression result of capital ratios on bank size. The coefficient is negative and significant on 1% level. It confirms that the capital ratios decrease with banks size.

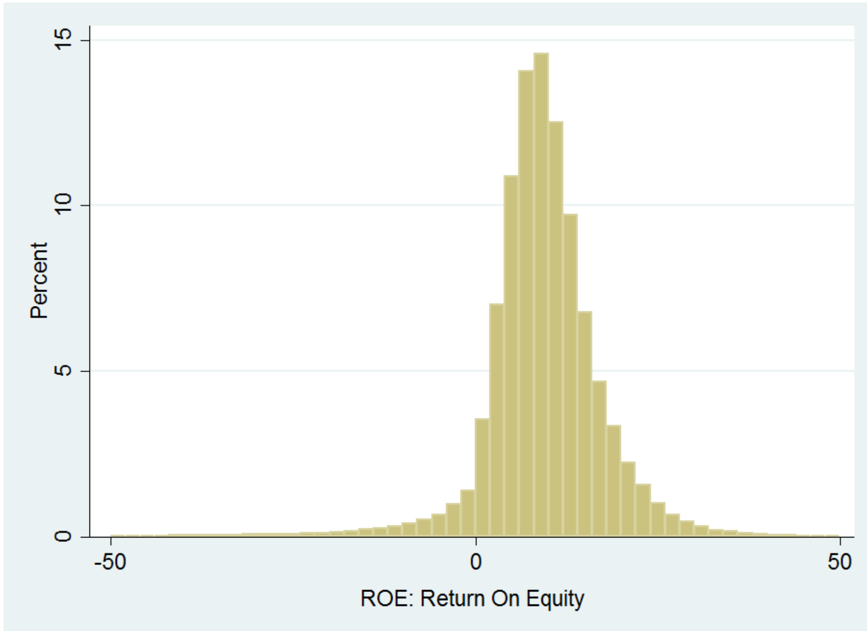


Figure 2.9: The distribution of bank ROE

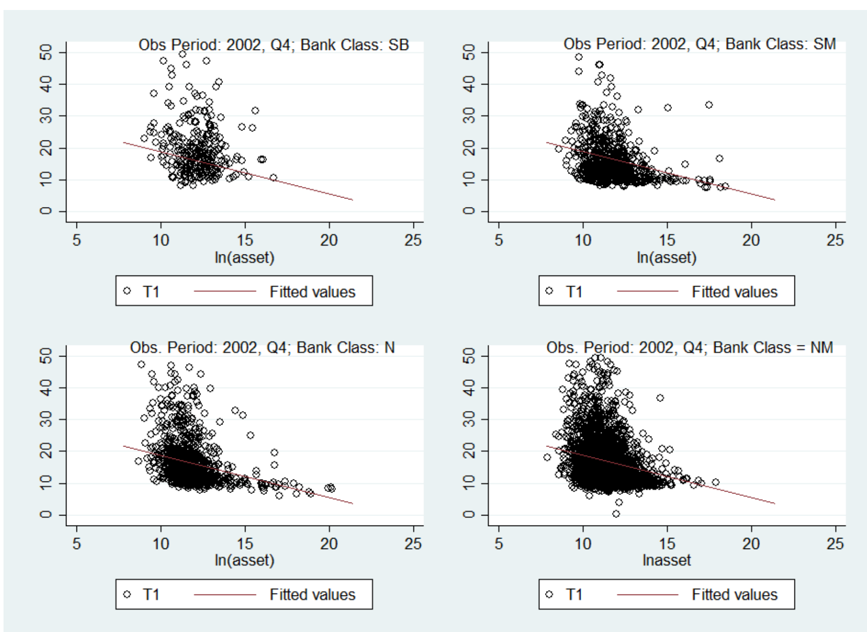


Figure 2.10: Capital Ratios and Bank Size

2.5.5 The Optimal Capital Ratio- Empirical Estimates

The theoretical model in Section 2.4 suggests that the bank chooses an optimal ratio to trade off between the costs and benefits. However, in practice, choosing an accurate optimal ratio *ex ante* is likely an impossible task. This section provides pure empirical estimates based on the historical banking data. Reviewing the econometric model, the bank chooses an optimal capital ratio to maximize the expected profits for the next periods. By observing its profit during each period, the bank would adjust its target ratio. Recall:

$$ROE_{i,t+1} = \alpha_1 + \alpha_2 T_{1i,t} + \alpha_3 T_{1i,t}^2 + \alpha_4 ln(asset)_{i,t} + \Gamma' X_{i,t} + \epsilon_{i,t+1} \tag{2.18}$$

Take first-order condition on $T_{1i,t}$

$$\frac{\partial ROE_{i,t+1}}{\partial T_{1i,t}} = \hat{\alpha_2} + 2\hat{\alpha_3} T_{1i,t} = 0 \tag{2.19}$$

Then the optimal ratio is given by:

$$\hat{T_{1i,t}} = \frac{\hat{\alpha_2}}{-2\hat{\alpha_3}} \tag{2.20}$$

The regression from the historical data gives the coefficients of the capital ratio T and T^2. The above equation is a rough estimate of the optimal ratio at which we poll all observations together.

By plugging in the fixed effect regression results, the point estimate of the optimal capital ratio is:

$$\hat{T}_1 = \frac{0.30}{2 * 0.073} = 20.5 \tag{2.21}$$

Which is similar to the findings in the existing literature. (Dagher, 2016: 15–23%) and the Fed Reserve Proposal of TLAC (total loss-absorbing capacity) of 18% or greater.

I also break the sample into 4 sub-samples based on bank charter classes [10]. A classification code assigned by the FDIC based on the institution's charter type (commercial bank or savings institution), charter agent (state or federal), Federal Reserve membership status (Fed member, Fed nonmember)and its primary federal regulator (state chartered institutions are subject to both federal and state supervision).

- N = commercial bank, national (federal) charter and Fed member, supervised by the Office of the Comptroller of the Currency (OCC).
- SM = commercial or savings bank, state charter and Fed member, supervised by the Federal Reserve (FRB).
- NM = commercial bank, state charter and Fed nonmember, supervised by the FDIC or OCC.
- SB = savings banks, state charter, supervised by the FDIC.
- As of July 21, 2011, the FDIC supervised state-chartered thrifts and OCC-supervised federally chartered thrifts. Prior to that date, state or federally chartered savings associations were supervised by the Office of Thrift Supervision (OTS).
- OI = insured U.S. branch of a foreign chartered institution (IBA).

[10] see website: https://research.fdic.gov/bankfind/glossary.html

My sample data contains 4 bank classes: N, NM, SB, and SM. Table 2.4 shows the regression results and the point estimate of the optimal capital ratios. The national charted banks (N) are estimated to have an optimal capital ratio of 8.46. The state-charted commercial banks with Fed nonmember (NM) are estimated to have an optimal ratio of 21.58. The state-charted savings banks (SB) are estimated to have an optimal ratio of 24.34. The state-charted commercial or savings banks with Fed member (SM) are estimated to have an optimal ratio of 22. The results confirm that larger national banks take less capital ratios and enjoy higher leverage powers.

2.5.6 Banks Optimal Ratios and Basel III

Basel III, which took effect in 2011, increased the Minimum Tier 1 Capital from 4% to 6%. This policy change set up a good experiment to test how banks respond to the changes of the MCR by Basel III. I break the sample data into two time windows: (1) 2002-2010 and (2) 2011-2015. Using the same econometric model above, I conduct the point estimate of the optimal capital ratios for each of these two periods.

Figure 2.11 shows the banks' ROE distribution before and after the implementation of Basel III.

Table 2.5 shows the regression results for both time windows. The point estimate of the optimal capital ratio does increase from 16.96 (before Basel III) to 25.0 (after Basel III). However, the increase may arise from the combined effects of Basel III and the lesson from the financial crisis in 2007–2009. So I cannot automatically conclude that Basel III caused higher ratios, but at least it is suggested.

Figure 2.12 indicates a move of the distribution of Tier 1 risk-weighted capital ratios which became more tightly distributed around a center of 11% to 12% in 2006, comparing with a

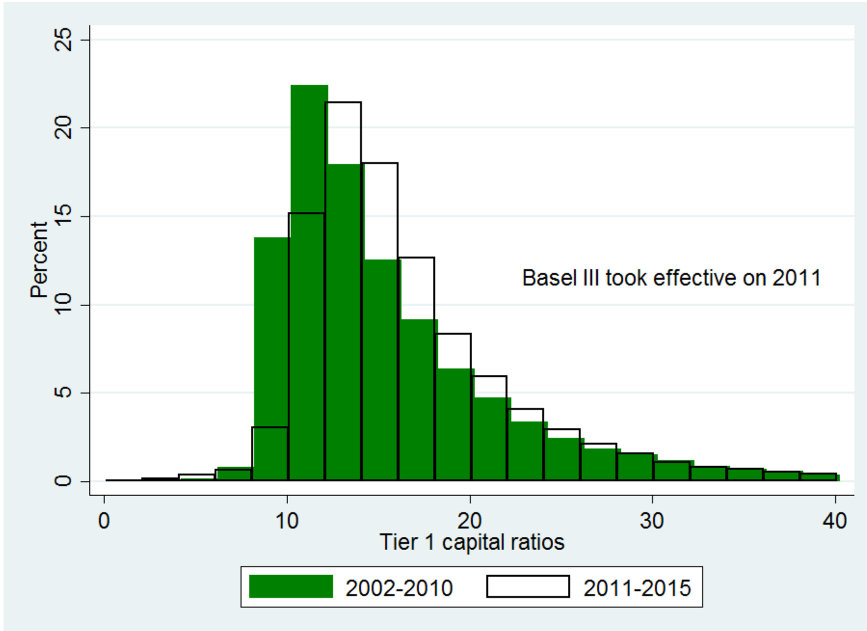
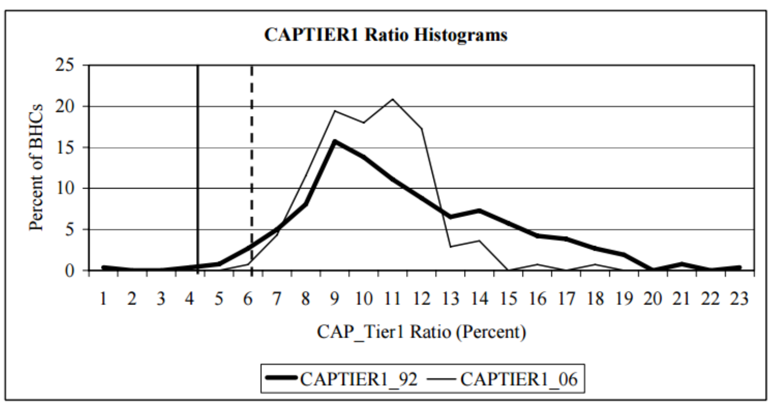


Figure 2.11: T1 distribution before and after Basel III

center of 8% in 1992. The effect of Basel II (2004) likely push banks' optimal ratios to a new, higher equilibrium.



Note: The solid and dashed vertical lines represent, respectively, the adequately capitalized and well-capitalized regulatory minimums.

Figure 2.12: Capital Ratios 1992 Vs 2006. Source: Allen Berger, 2010, BHCs only

2.6 Conclusions and discussions

This project sheds light on the economic roles of the Minimum Capital Requirements (MCR) on banks competition and profitability.

First, the MCR is equivalent to an additional marginal cost to banks.

Second, banks trade off costs and benefits of capital at the margin. When facing the additional marginal cost, the model shows banks either raising a capital level or cutting off the loan supply or both; thus, banks move toward a higher new equilibrium.

Third, however, if banks overshoot their capital ratios, the benefits of holding a higher capital declines sharply and banks' profits will be eroded. There exist optimal capital ratios privately held by each bank.

Fourth, the additional marginal cost arising from the MCR decreases with bank size. The one-size-fits-all regulation favors big banks.

Fifth, the empirical works in this paper provide evidence to support the following statements: (1) the relation between profits (ROE) and capital ratios (tier one ratios) are nonlinear, as it's an inverted-U shape, and there exists an optimal capital ratio to maximize the return on equity. (2) The capital ratios decrease with bank sizes. (3) The optimal ratios increase when the MCR increases. (4) The point estimate of optimal ratios are in the range of 8.46-24.34, depending on bank charter classes. The overall estimate (pool all banks together) is 20.5, which is similar to the existing literature (15-23%), and the Fed Reserve total loss-absorbing capacity (TLAC) is 18% or greater.

Table 2.1: Summary statistics for Individual-level Panel Data

This table presents summary statistics for the sample of 4,952 individual banks from 2002 to 2015 used in the panel estimate.The data are taken from the Uniform Bank Performance Report (UBPR).

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**
ROE	9.30	9.23	-99.9	98.58
T lag	16.1	6.54	0.1	49.95
T^2 lag	302	295	0.01	2495
ln(asset)	11.975	1.33	7.82	21.442
overhead	3.309	5.32	-8.958	403.29
credit risk	0.679	0.138	0.11	10.11
security gain	0.023	0.2	-25.98	7.52
interest expense	1.42	0.918	-0.011	141.56

Table 2.2: Individual Banks, Panel Lag Model

DP: Return On Asset ROE_{t+1}	(1) FE	(2) RE GLS
T	0.30***(0.073)	0.28*(0.071)
T^2	-0.073***(0.0013)	-0.0073***(0.0012)
$ln(asset)$	1.43***(0.28)	0.85(0.15)
credit risk	7.6***(1.1)	7.04***(1.02)
overhead	-0.198***(0.088)	-0.15***(0.072)
security gain	2.79***(0.29)	2.79***(0.23)
interest expense	-0.84***(0.51)	-0.86***(0.48)
Quarter FE	Yes	Yes
Year FE	Yes	Yes
Hausman Test	✓	
R^2 (overall)	0.06	0.07
$Prob > F$	0	
$Prob > chi^2$		0
No. OBS	255,981	255,981

Robust Std. Err. for clusters in Bank Id

Table 2.3: Bank size and capital ratio, Individual Banks, by bank classes

	Bank Class			
Tier one ratio	N	NM	SB	SM
ln (asset)	-1.2***	-1.29***	-1.34***	-0.87***
	(0.11)	(0.13)	(0.34)	(0.23)
Fixed Effects				
Year	Yes	Yes	Yes	Yes
Quarter	Yes	Yes	Yes	Yes
SE adjusted for Clusters				
MSA	Yes	Yes	Yes	Yes
Observations	21,879	70,432	11,139	19,514
R-square	0.13	0.067	0.05	0.061

Bank Classes:

N = commercial bank, national charter and Fed member

SM = commercial or savings bank, state charter and Fed member

NM = commercial bank, state charter and Fed nonmember

SB = savings banks, state charter

Table 2.4: Point Estimate of Optimal Ratios using FE Panel Regression by bank classes

	Bank Class			
DP: ROE_{t+1}	N	NM	SB	SM
T	0.11***	0.315***	0.297***	0.186***
	(0.037)	(0.02)	(0.051)	(0.041)
T^2	-0.0065***	-0.0073***	-0.0061	-0.0042***
	(0.00074)	(0.00042)	(0.00096)	(0.00084)
Quarter FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
$\hat{T} = \frac{\hat{\alpha_2}}{-2\hat{\alpha_3}}$	8.46	21.58	24.34	22
Observations	45,476	155,748	14,304	38,233
ROE mean	9.45	9.66	4.77	9.47
ROE Std	8.97	9.35	6.49	8.36

Bank Classes:
N = commercial bank, national charter and Fed member
NM = commercial bank, state charter and Fed nonmember
SB = savings banks, state charter
SM = commercial or savings bank, state charter and Fed member

Table 2.5: Individual Banks, before and after Basel III

DP: Return On Asset ROE_{t+1}	(1) 2002-2010, FE	(2) 2011-2015, FE
T	0.19***(0.091)	0.60*(0.15)
T^2	-0.0056***(0.0016)	-0.012***(0.0026)
$ln(asset)$	-0.5(0.41)	-3.73***(0.85)
credit risk	4.92***(1.34)	6.16***(1.74)
overhead	-0.24***(0.082)	-0.18***(0.23)
security gain	2.8***(0.25)	2.1***(0.45)
interest expense	-0.22***(0.31)	-4.18***(0.56)
Quarter FE	Yes	Yes
Year FE	Yes	Yes
R^2 (overall)	0.06	0.030
$Prob > F$	0	
$Prob > chi^2$		0
No. Obs	157,768	98,213
$\hat{T} = \frac{\hat{\alpha_2}}{-2\hat{\alpha_3}}$	16.96	25.0

*** Robust Std. Err. for clusters in Bank Id

Table 2.6: Regression of capital ratio on lagged HHI, State-Average Data, 2002–2015

For data availability, state-level average of capital ratios are taken for 46 states. The state-level HHI are from the FDIC website. https://www5.fdic.gov/sod/

Tier One Capital	Coef	Std Error	
lagged HHI	0.00064***	0.00013	
lagged ln(Market Size)	0.338***	0.094	
lagged Number of Peers	0.0014	0.0037	
year FE	yes		
state FE	yes		
observations	552		
F(59,492)=	26.01	$Prob > F =$	0.000
adj R-squred =	0.7281		

Chapter 3

THE EFFECTS OF CAPITAL CONSTRAINTS ON THE TRANSMISSION OF MONETARY POLICY: FAMA-MACBETH TEST

3.1 The Research Question

How monetary policy affects the real economy is one of main research in the last two decades in Microeconomics. The effect of monetary policy on interest rates and through interest rates on lending and credit is the focal point of the traditional monetary transmission. A growing literature argues that lending will be constrained by bank's equity capital(Bernanke, 2000). This paper is goaled to answer this question: whether there are important cross-sectional differences in the way that banks with varying capital ratios respond to monetary policy shocks? This paper uses Fama-MacBeth 2-step regression with 300,000 bank-quarter observations to study the effects of monetary policy on individual bank lending.

The model in this paper leads to the key hypothesis: $\frac{\partial^2 L_{i,t}}{\partial k_{i,t} \partial r_t} < 0$, where $L_{i,t}$ is a bank-level measure of lending activity, $k_{i,t}$ is a measure of capital ratio, and r_t the federal funds rate[1], which serves as the monetary policy indicator. Note $\frac{\partial L_{i,t}}{\partial r_t} < 0$ is already well known that lower federal fund rate is followed by increase of loan supplies.

3.2 The Model

In a competitive market, a risk-neutral representative bank makes investment decision in a two-period frameworks. At $t = 1$, the bank comes with their own equity capital K and collects deposit D, then make the investment decision on two different assets: risky asset loan L and return-guaranteed asset government bonds B. At $t = 2$, the return on all assets are realized, and the bank is facing the audit.

The MCR, $k_0 (0 \leq k_0 \leq 1)$, is examined by the regulators at $t = 2$. If the capital-to-risk asset ratio is found to be below the MCR, a regulatory penalty V is carried out by the regulator. The regulatory capital, K^R, is the sum of the bank's original equity capital K and the capital gains (or losses), given by ϵ, which fluctuates with unpredictable market conditions. Assume, *ex ante*, ϵ is independently and symmetrically distributed around a zero-mean, so that the regulatory capital is :

$$K^R = (1 + \epsilon)K, \qquad where \qquad \epsilon \sim iid(0, \sigma^2) \tag{3.1}$$

[1] Wu-Xia index can be used to capture MP in the Zero Lower Bound period

The penalty condition (the capital-asset ratio is less than K_0) can be expressed as:

$$\frac{k_0}{\frac{K^R}{L}} = \frac{k_0 L}{K^R} > 1 \tag{3.2}$$

Note, $E_{t=1}(K^R) = k$. Donate $p(0 \leq p \leq 1)$ be the probability of the penalty, which can be expressed as $p(\frac{k_0 L}{K})$, where $p' > 0$. Assume further $p'' > 0$, $p''' = 0$ It implies that the probability of the penalty increases at an accelerating rate as the ratio approaches the MCR.

Donate r_L and r_B be the contractual return on loans and bonds, r_D is deposit interest. π is the exogenous success probability of risky loan.[2] The bank's objective function can be written as:

$$\max \Pi = \pi r_L L + r_B B - r^D D - p(\frac{k_0 L}{K})V \tag{3.3}$$

$$\text{subject to} \qquad K + D = L + B \tag{3.4}$$

The first-order condition for loan amount is :

$$\frac{\partial \Pi}{\partial L} = \pi r_L - r_B - (\frac{k_0}{k})p'V = 0 \tag{3.5}$$

The second order sufficient condition is satisfied because $p'' > 0$

$$\frac{\partial^2 \Pi}{\partial L^2} = -(\frac{K_0}{K})^2 p'' V < 0 \tag{3.6}$$

[2]The success probability can be viewed as associated with the macro economical condition.

3.2.1 The Interest Elasticity of Loan Supply

The effect of the capital level on the interest elasticity of loan supply is examined in this section. Since the bond rate r_B is positively correlated with the fed rate, r_B is used to be a proxy of the fed rate. By totally differentiating first-order condition – equation 3.5 with respect to r_B, obtain:

$$(\frac{\partial^2\Pi}{\partial L^2})(\frac{dL^*}{dr_B}) + \frac{\partial^2\pi}{\partial L\partial r_B} = 0 \tag{3.7}$$

It is easy to demonstrate that

$$\frac{\partial^2 Ł^*}{\partial K\partial r_B} < 0 \tag{3.8}$$

The proof is the following:

Totally differentiate the equation 3.7 w.r.t K:

$$[\frac{\partial^3\Pi}{\partial L^3}(\frac{dL^*}{dK}) + \frac{\partial^3\Pi}{\partial L^2\partial K}](\frac{dL^*}{dr_B}) + \frac{\partial^2\Pi}{\partial L^2}(\frac{\partial^2 L^*}{\partial r_B\partial K}) + \frac{\partial^3\Pi}{\partial L^2\partial r_B}(\frac{dL^*}{dK}) + \frac{\partial^3\Pi}{\partial L\partial r_B\partial K} = 0 \tag{3.9}$$

Since $p''' = 0$, we have

$$\frac{\partial^3\Pi}{\partial L^3} = \frac{\partial^3\Pi}{\partial L^2\partial r_B} = \frac{\partial^3\Pi}{\partial L\partial r_B\partial K} = 0 \tag{3.10}$$

Equation 3.9 can be re-written as:

$$\frac{\partial^2 L^*}{\partial r_B\partial K} = \frac{(\frac{\partial^3\Pi}{\partial L^2\partial K})(\frac{dL^*}{dr_B})}{-(\frac{\partial^2\Pi}{\partial L^2})} \tag{3.11}$$

The sign is negative because the followings are known:

$$\frac{\partial^3 \Pi}{\partial L^2 \partial K} = \frac{2k_0}{K^3} p'' V > 0 \tag{3.12}$$

$$\frac{dL^*}{dr_B} < 0 \tag{3.13}$$

$$\frac{\partial^2 \Pi}{\partial L^2} < 0 \tag{3.14}$$

So, the following is held:

$$\frac{\partial^2 L^*}{\partial r_B \partial K} = \frac{(\frac{\partial^3 \Pi}{\partial L^2 \partial K})(\frac{dL^*}{dr_B})}{-(\frac{\partial^2 \Pi}{\partial L^2})} < 0 \tag{3.15}$$

Proposition *An increase in bank capital level will make the loan supply more sensitive to changes in the interest rates.* (The effect of the monetary policy is stronger.)

3.3 Empirical Works

3.3.1 The Fama-MacBeth Two-Step Regression Approach

A. The Two-Step Regression Approach

The basic goal of this paper is to measure the quantity $\frac{\partial^2 L_{i,t}}{\partial k_{i,t} \partial r_t}$, for banks in different size classes. Following (Kashyap & Stein, 2000), this paper implements with a two-step procedure. In the first step, a cross-sectional regression separately run for each size class and each time period t: the log change (percentage change) in the loan amount $L_{i,t}$ against (1)four lags of itself; (2)one period lag of the capital ratio $k_{i,t-1}$; (3) a Federal Reserve-district dummy variable (a geographic control). That is, this paper estimates:

$$\Delta ln(L_{i,t}) = \sum_{j=1}^{4} \alpha_{t,j} \Delta ln(L_{i,t-j}) + \beta_t k_{i,t-1} + \sum_{k=1}^{12} \Phi_{k,t} FRB_{i,k} + \epsilon_{i,t} \tag{3.16}$$

The key interest from this regression is the estimated coefficient on $k_{i,t-1}$, denoted by β_t. This coefficient β_t can be thought of as a measure of the intensity of capital constraints in a given size class at time t. Note $\beta_t = \frac{\partial L_{i,t}}{\partial k_{i,t}}$, which captures the degree to which lending is capital constrained at any time t – those constraints are intensified during period of tight money, or higher fed rate.

The second step takes for each size class the β_t, and use them as the dependent variable in a purely time-series regression. In univariate specification, the right-hand-side variable is the contemporaneous value and three lags of the monetary measure M_t

$$\beta_t = \eta + \sum_{j=0}^{3} \phi_j M_{t-j} + \mu_t \tag{3.17}$$

In bivariate specification, the right-hand-side variable include: (1)the contemporaneous value and three lags of the monetary measure M_t; (2)the contemporaneous value and three lags of real GDP growth;

$$\beta_t = \eta + \sum_{j=0}^{3} \phi_j M_{t-j} + \sum_{j=0}^{3} \gamma_j \Delta GDP_{t-j} + \mu_t \tag{3.18}$$

B. The hypothesis of ϕ and γ

The hypothesis for ϕ is, for the smallest class of banks, in the tight money period (higher index), the intensity of the capital constraint is higher, so the sum of the ϕ should be **positive**. However, the hypothesis for γ is a little more complicated because there is potential biases in the correlation of β_t and r_t.

There are two stories on the estimated γ coefficients on GDP changes (Kashyap and Stein, 2000). The first one is called "heterogeneous risk aversion" story, wherein some banks are more conservative than others, thus hold higher capital ratios. An increase in GDP favors riskier borrowers, who are affiliated with less conservative banks, who in turn have lower value of $k_{i,t-1}$. Thus an increase in GDP has a more positive impact on the lending of lower $k_{i,t-1}$ banks, which implies a negative γ.

Alternatively, consider the "rational buffer stocking" story: all banks have the same risk aversion, but some have more opportunities to lend to riskier borrowers than others. In this case, those banks choose to increase their capital ratios to hedge the potential credit risk. Therefore, the γ coefficients on GDP changes is positive.

This paper is goaled to answer which story is true by empirical works.

3.3.2 Data

Bank-Level Data

The dataset comes from two resources: (1)The banks' **quarterly** performance data is from The Federal Financial Institutions Examination Council (FFIEC). It was established on March 10, 1979, pursuant to title X of the Financial Institutions Regulatory and Interest Rate Control Act of 1978 (FIRA), Public Law 95-630. FFIEC creates The Uniform Bank Performance Report (UBPR), which is an analytical tool created for bank supervisory, examination, and management purposes. (2) The federal reserve website gives out **quarterly** fed fund rate, Wu index, GDP changes and housing index.

Totally, over 6000 individual banks performance data are collected on the quarterly basis, from 2002 4th quarter to 2015 4th quarter (53 quarters). Altogether, 311,963 observations form an unbalanced panel data. The cutoff of small banks is $500 million, which give us 263,494 observation. The bank class are categorized as less than 500 million, 500 million to 1 Billion, 1-500 Billion and over 500 Billion.

Table 3.1: Capital Ration for Banks of Different Size as of 2002 Q4, staring Quarter

	Below 500 million	500 million-1 Billion	1-500 Billion	Above 500 Billion
Number of banks (5260)	5003	235	225	2
Mean Assets ($ millions)	118.1	683.0	11,800	594,000
T1 Capital Ratio (%)	11.78	14.34	8.87	6.15

Table 3.2: Capital Ration for Banks of Different Size as of 2015 Q4, ending Quarter

	Below 500 million	500 million-1 Billion	1-500 Billion	Above 500 Billion
Number of banks (6237)	4859	674	700	4
Mean Assets ($ millions)	170.4	703.1	11,700	1,620,000
T1 Capital Ratio (%)	12.64	10.92	10.55	8.96

Measures of Monetary Policy

A good indicator of the stance of monetary policy M_t is needed for the test. One of good measure is the federal funds rate. However, From December 16, 2008, to December 15, 2015, the effective federal funds rate was in the 0 to 1/4 percent range targeted by the Federal Open Market Committee. In this "zero lower bound" (ZLB) environment, the de facto expansionary monetary policy was not captured by the traditional federal fund rate, thus a number of researchers used shadow rate models to characterize the term structure of interest rates (Kim and Singleton (2012) and Bauer and Rudebusch (2013)) or quantify the stance of monetary policy (Bullard (2012) and Krippner (2013)). The figure 3.1 shows the Wu and Xia (2015) model of the shadow rate. This paper uses wu-xia index as the monetary policy indicator, with higher values corresponding to the tight money.

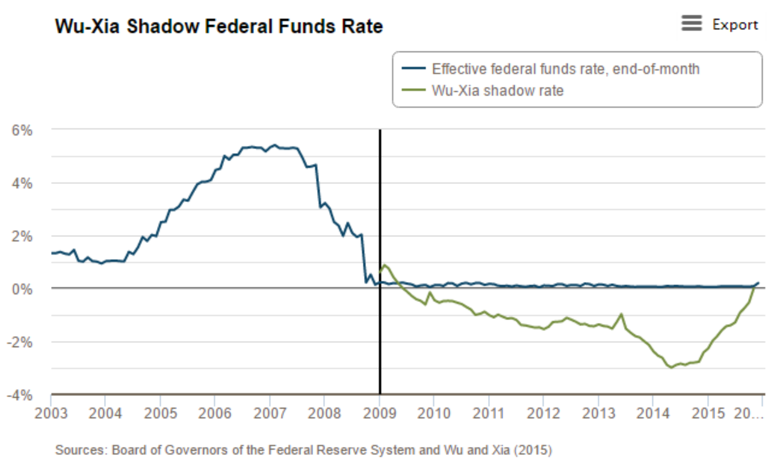


Figure 3.1: Wu-Xia Index vs Fed Rate

3.3.3 Baseline Results

A. The coefficient β_t

Since the smaller banks are least likely to be able to frictionlessly raise uninsured finance, the effect of monetary-policy should be stronger for small banks. The largest banks are easier to raise uninsured finance (i.e from their parent holding companies), which would make them less dependent on monetary policy. Figure 3.2 shows the histogram and summary statistics of the first-step regression results: β_t of the small banks. As expected, β_t are positive for the most of time – i.e. higher capital ratios lead to more sensitivity of loan supply to monetary policy shocks.

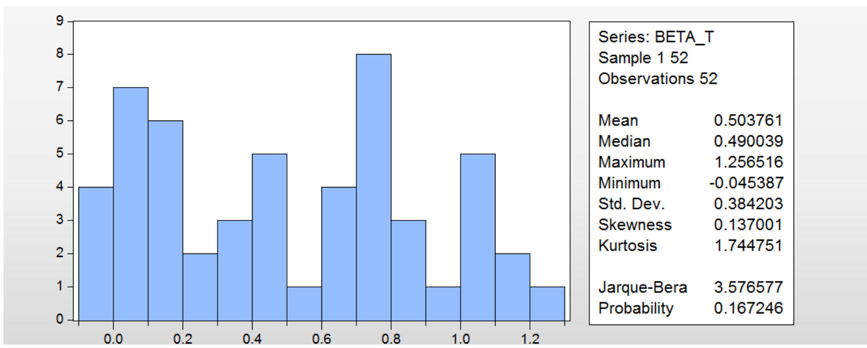


Figure 3.2: β_t Histogram of Smallest Banks

Figure 3.3 shows the histogram and summary statistics of the first-step regression results: β_t of the largest banks (over 500 billion). The sign of β_t are mixed.

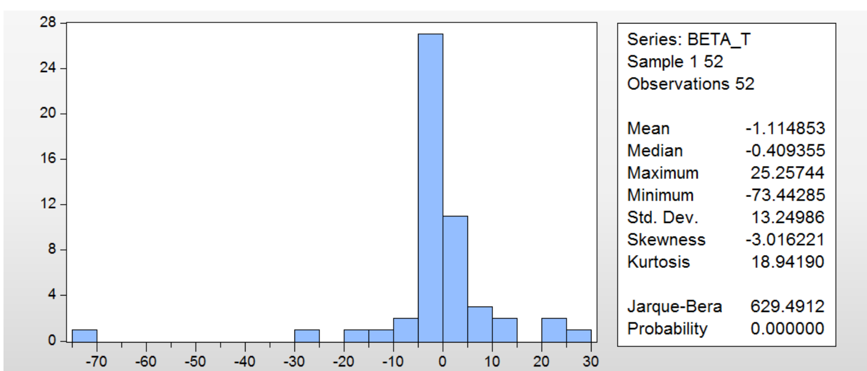


Figure 3.3: β_t Histogram of Biggest Banks

B. The coefficient ϕ

The math model shows that the capital constraint are intensified during period of tight money, mainly for small banks. So the sign of ϕ is positive.

Figure 3.4 displays the time-series plot between β_t, fed rate and Wu index for the banks under 500 million dollars and over 500 billions. For this graph, one can concludes:

1. For smallest banks, in the tight money period (higher index), the intensity of capital constraints are stronger.

In the ZLB period, the federal fund rate failed to show the de facto expansionary monetary policy. However, the positive correlation is still held before the ZLB period.

2. For largest banks, the correlation between monetary policy indicator and the intensity of capital constraints are not clear.

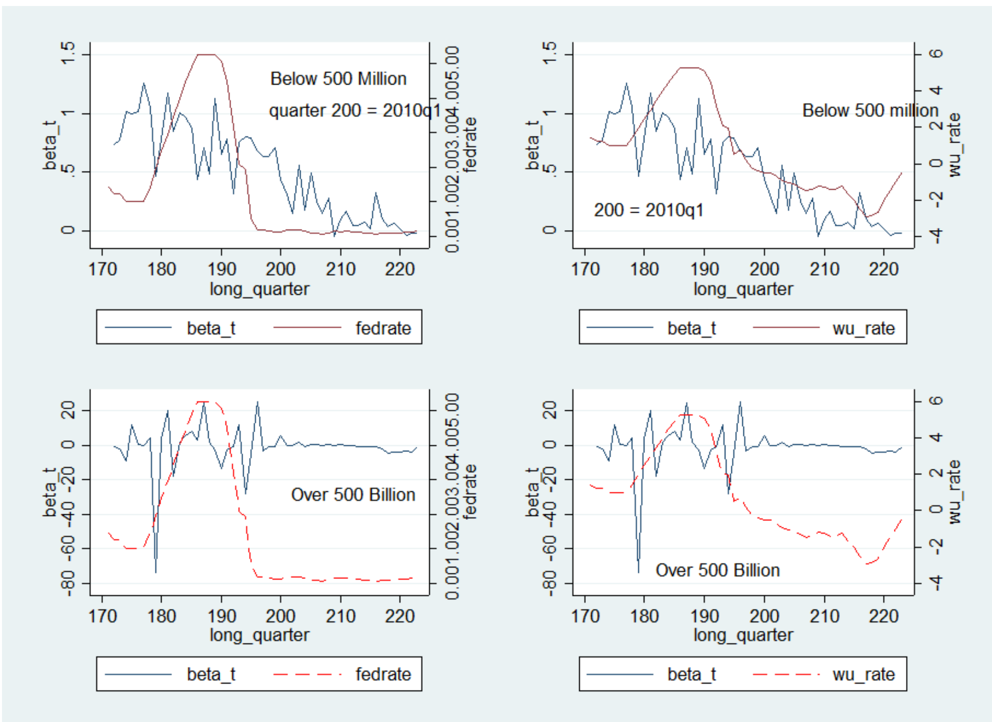


Figure 3.4: Time Series of β_t, Wu-Xia Index and Fed Rate

Tables 3.3 and 3.4 present the results of the second-step regressions. Table 3.3 gives the sum of the ϕ coefficients on the relevant monetary indicator. For smallest banks (under 500 million) the coefficient ϕ is positive as we expect. However, for largest banks (over 500 Billion), the coefficient ϕ is negative.

Table 3.3: Two-Step Estimation of Equations: Sum of Coefficients on Monetary-policy Indicator

$\sum_{j=0}^{3} \phi_j$	Univariate	Bivariate
< 500 M	0.23	0.21
> 500 B	-0.21	-0.38

Table 3.4: Two-Step Estimation of Equations (3.16), (3.17), (3.18): Full Details

	Monetary-policy indicator				Change in GDP			
Lag	0	1	2	3	0	1	2	3
Univariate								
< 500 M	0.12***	-0.21	0.56	-0.24				
($R^2 = 0.82$)	(0.017)	(0.11)	(0.24)	(0.12)				
> 500 B	-5.40	-3.31	22.89	-14.38				
($R^2 = 0.14$)	(5.69)	(9.15)	(9.12)	(5.83)				
Bivariate								
< 500 M	0.13***	-0.38***	0.80***	-0.34***	1.84	2.14	-0.15	1.71
($R^2 = 0.57$)	(0.13)	(0.14)	(0.13)	(0.13)	(1.96)	(1.89)	(1.90)	(1.70)
> 500 B	-5.9	-0.77	21.65***	-15.36***	-19.59	-107.8	-12.78	60.06
($R^2 = 0.18$)	(6.19)	(9.66)	(9.45)	(6.26)	(-0.22)	(-1.19)	(-0.14)	(0.70)

Note: Standard errors are in parentheses.

B. The coefficient γ for smallest banks

For smallest banks, the γ coefficient on GDP are for the most part positive, which is consistent with the rational buffer-stocking story. Unfortunately, the coefficient of γ is not significant. There might be two reasons: (1) the total observation is only 52, not enough. (2) the period 2002q4 – 2015q4 is a special housing boom and burst period. So GDP in equation 3.18 can be substituted by Housing Index (source: St. Louise Fed). The regression of β_t on contemporaneous value of both Wu index and Housing index are displayed below.

The numbers in parenthesis are t-values, with 1% significant level.

$$\beta_t = \underset{(5.37)}{\eta} + \underset{(8.92)}{\phi} WuIndex + \underset{(-4.49)}{\gamma} HousingIndex + \mu_t \tag{3.19}$$

The higher housing index reduced the β_t: the intensity of capital constraint. It makes perfect sense because during housing boom period, banks are less constrained by their capital levels when they are facing the vigorous loan demand for housing.

C. The coefficient γ for largest banks

For largest banks, the γ coefficient on GDP are for the most part negative, which is consistent with the heterogeneous risk aversion story. Unfortunately, the coefficient of γ is not significant. The regression result using both Wu index and Housing index are following and the numbers in parenthesis are t-values, not significant at all:

$$\beta_t = \underset{(-0.47)}{\eta} + \underset{(0.04)}{\phi} WuIndex + \underset{(0.42)}{\gamma} HousingIndex + \mu_t \tag{3.20}$$

The regression results from largest banks show that our mathematic model and prediction works for small banks but not for largest banks. So the lending will be less constrained by bank's capital level for largest banks, which suggests:

$$\frac{\partial^3 L_{i,t}}{\partial k_{i,t} \partial r_t \partial S_{i,t}} > 0 \tag{3.21}$$

where S denotes the size of banks.

Tables 3.3 and 3.4 present the results of the second-step regressions. Table 3.3 gives the sum of the ϕ coefficients on the relevant monetary indicator.

3.4 Conclusions and discussions

This chapter employed Fama-MacBeth 2-step model to test how monetary policy impacts the lending behavior of individual banks, given that each bank has heterogeneous level of capital ratios, as opposed to aggregated lending.

The Fama-MacBeth 2-step model exploits both cross-sectional and time-series aspects of the bank-level data. In the first step, the regression is cross-sectional regression: for each time period (in this paper, it's quarter), β_t is the coefficient of the cross-sectional regression on the individual-bank level. In the second step, time-series regression is taken out, with β_t being the dependent variable and monetary policy index being the explain variable.

The sign and magnitude of β_t captures the degree to which lending is capital constrained at any given time t. The time-series results indicates the intensify of the capital constrained are different under different monetary policy regime.

First, the math model shows that the sign of β_t is positive: the lending of well capitalized banks are more sensitive to the changes of monetary policy. My empirical works shows that the above is true for the class of small banks and statistically significant. But for the big banks ($500 B and above), the sign of β_t is mixed. The intuition is largest banks have an easier time raising uninsured finance, which would make their lending less dependent on monetary-policy shocks, irrespective of their internal capital level.

Second, β_t is regressed under two bivariate specification: (1) Wu index + GDP; (2) Wu index + housing index. The empirical works shows that for small banks the coefficient of wu index, ϕ is positive and significant: the intensify of capital constraint is stronger in the tight money period (higher index). For large banks, ϕ is positive but not significant.

This project finds both effects are largely attributable to the smaller banks. (1) the lending of those banks with higher capital ratios is more sensitive to changes in monetary policy; (2) the capital constraints are intensified during the period of tight money.

Table 3.5: Capital Ratios for Banks of Different Size as of 2002 Q4, staring Quarter

	Below 50th	50th-75th	75th-95th	Above 95th
Number of banks (5260)	5003	254	1	2
Mean Assets ($ millions)	139.8	8,560.18	499,000	594,000
T1 Capital Ratio (%)	11.9	8.9	7	6.15
Liquidity Ratio (%)	9.74	6.54	7.70	10.21

Table 3.6: Capital Ratios for Banks of Different Size as of 2015 Q4, ending Quarter

	Below 50th	50th-75th	75th-95th	Above 95th
Number of banks (6237)	5909	325	0	1
Mean Assets ($ millions)	317.79	27,500	NA	1.91e+06
T1 Capital Ratio (%)	12.3	10.4	NA	8.84
Liquidity Ratio (%)	9.64	6.59	NA	26.33

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Appendices

A Comparative Statics of Capital Level

By totally differentiating first-order condition $\frac{\partial \Pi}{\partial L} = 0$ with respect to K, obtain:

$$(\frac{\partial^2 \Pi}{\partial L^2})(\frac{dL^*}{dK}) + \frac{\partial^2 \Pi}{\partial L \partial K} = 0 \tag{A.1}$$

Solve for $\frac{dL^*}{dK}$,

$$\frac{dL^*}{dK} = -\frac{\partial^2 \Pi}{\partial L \partial K} / (\frac{\partial^2 \Pi}{\partial L^2}) \tag{A.2}$$

$$\frac{\partial^2 \Pi}{\partial L \partial K} = -\frac{K_0 V}{K^2}(p' + \frac{p'' K_0 L}{K}) \tag{A.3}$$

Recall, $\frac{\partial^2 \Pi}{\partial L^2} = -(\frac{K_0}{K})^2 p'' V - r_d'' < -(\frac{K_0}{K})^2 p'' V$, so we have

$$\frac{dL^*}{dK} > (\frac{1}{K_0})(\frac{p' + \frac{K_0 L}{K} p''}{p''}) > 0 \tag{A.4}$$

Similarly, other comparative statics are obtained.

B Oligopolistic Market: From Bertrand to Cournot-Nash

The chapter 2 model treats the banking market as a fully competitive market. In fact, the banking industry is far from being a competitive market. The US banking industry is on the trend of consolidation. In 2015, the five biggest firms controlled 44% of the $15.3 trillion in assets held by U.S. banks; see Figure B.1:

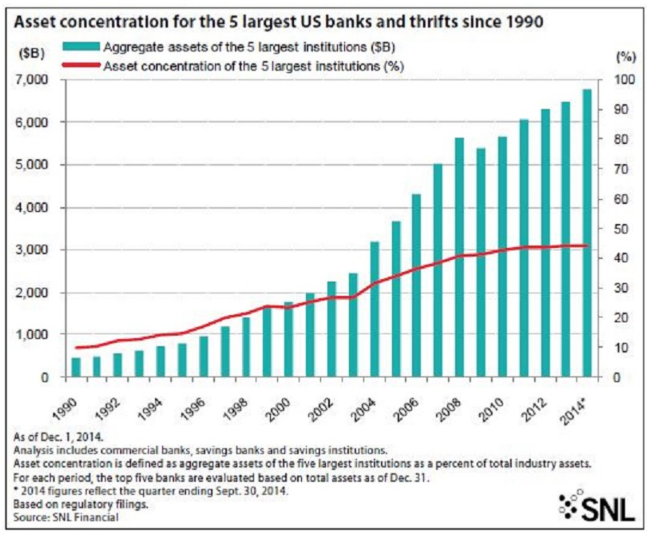

Figure B.1: Biggest 5 bank Takes 44% Asset. Source: SNL Financial

In addition to the increased marginal cost effect, there is a second effect that has been less considered in the banking literature: the collusive enhancing effect. This section explores the banks' collusive behaviors in the oligopolistic market.

B.1 Pure Bertrand is a winner-take-all auction

We start with the Bertrand Model, assuming that banks compete on the loan interest rate r_L. The pure Bertrand model is considered as price choices are made simultaneously by firms with constant returns to scale technologies. If the product is homogeneous, all demand will go to the firm charging the lowest prices. It is as if the lowest bidder win the auction and the winner takes all. Assume that firms i and j face a demand function given by $q(p)$, where $q'(p) < 0$ and the two firms share the same technologies and the marginal cost c is same. When two firms compete prices, the demand facing firm i is given by

$$q_i(p_i, p_i) = \begin{cases} q(p_i) & if \quad p_i < p_j \\ \frac{1}{2}q(p_i) & if \quad p_i = p_j \\ 0 & if \quad p_i > p_j \end{cases} \tag{B.5}$$

To some degrees, we can assume that the bank loan is a homogeneous product. Banks will continue to undercut each other by offering lower loan interest rate r as long as there are profits to be made. The perfectly competitive outcome is reached at $r_i = r_j = c$.

B.2 MCR Leads to Capacity Constraint

The Minimum Capital Requirement (MCR) will cause banks to face capacity constraint. Recall that the banks' balance sheet is $K + D = L + B$. Without the MCR, banks can expand their balance sheet by unlimitedly collecting deposit from the public, assuming the banks' equality capital K is constant. But after the MCR, the maximum loan amount is reached at $L_{max} = \frac{K}{k_0}$. If banks are willing to continue suppling more loan, they have only two options: (1) issue more stocks to increase equity capital K *ex ante*, which is very expensive, or (2) face huge fine V *ex post* by the regulators. Thus the capacity constraint issue is generated. See the figure B.2 for details.

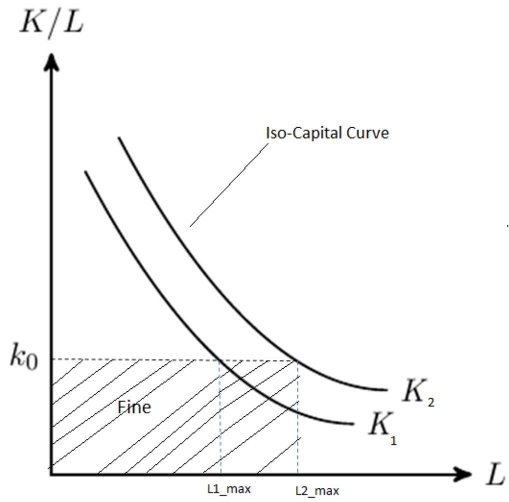

Figure B.2: Maximum Loan Amount Bounded by k_0

B.3 Bertrand with capacity constraint turns into Cournot Outcome

Capacity constraint is one special case of decreasing return. The basic idea that Bertrand competition with capacity constraint might lead to a Cournot outcome goes back to Edgeworth (1925), who emphasizes that due to exogenous capacity constraints, Bertrand oligopolists may not be able to serve the whole market demand and therefore would not undercut each other in prices until a competitive equilibrium is reached. Kreps and Scheinkman (1983) generalize this idea for an endogenous capacity choice. In their two-stage model, the oligopolists first optimally choose their capacities, followed by a competition in prices, which is strictly constrained by the prior capacity decision. Kreps and Scheinkman conclude that, when firms commit to a certain capacity of production before price competition takes place, the capacity and prices chosen in equilibrium are identical to the Cournot equilibrium. The question remains if such a rigid capacity constraint can be applied in the case of lending competition among banks.

If firms take the Cournot form, firms compete in quantity. Firm i chooses q_i to maximize $\pi = [p(q_i + q_j) - c]q_j$. The first order condition is given by $p'q_i + p + c = 0$. Since $p' < 0$, therefore $p_i = p_j > c$. Thus there is no distorting market power in the Bertrand model but the Cournot model implies that there is distorting market power. In the real world, firms seem to choose prices. But when firms face capacity constraints, the equilibrium is as if oligopolists played a Cournot game and prices are higher than marginal cost (Kreps and Scheinkman (1983). Peek and Rosengren(1995) examine the link between regulatory actions and the bank's loan supply – they find that banks subjected to formal regulation curtailed their loan more sharply. Bernanke and Lown (1991) found a strong coefficient between the bank capital asset ratio and the bank lending growth.

The following analysis examines the effect of capacity constraint on the possible tacit collusion. Assume a duopoly case, bank i and j both face a capacity constraint q_0, which is less than the entire market demand D, i.e. $q_0 < D$. Banks simultaneously set their price $0 < p_i < p_j$ and the marginal cost is set to be zero. The first q_0 demand is satisfied by bank i, and thus its profit is:

$$\pi_1^b = p_i q_0 \tag{B.6}$$

The residual demand is satisfied by j and its profit is:

$$\pi_2^b = p_j(D - q_0) \tag{B.7}$$

Bank i may deviate from p_i, and collude with bank j at the price p_j level to share the market D if the profit from sharing is higher. The shared profit is:

$$\pi_1^s = \pi_2^s = p_j \frac{D}{2} \tag{B.8}$$

If $\pi_1^s > \pi_1^b \quad (p_j \frac{D}{2} > p_i q_0)$, which implies $p_j > p_i \frac{2q_0}{D}$, bank i will raise its price to p_j. The equilibrium is no longer the Bertrand outcome ($p_j = p_i = 0$). The capacity constraint issue makes the tacit collusion possible under certain conditions, and in the repeated games, the collusive behaviors are more credible.

After bank i raises its price from p_i to p_j, bank j will not undercut bank i. Otherwise, bank j becomes bank i in the first scenario. Bank j either stays at price p_j to collude with bank i or raises price to take the residual demand. The actual decision depends on the social demand $D(p)$, each bank's capacity, etc. It may lead to mixed strategies with a multiplicity of other equilibria.

B.4 Bank's Prisoner's Dilemma Facing Capacity Constraint

One can consider a simple duopoly game in the prisoner's dilemma frame work. The bank i ($i = 1, 2$) needs yo make a decision on the capital ratio, high(far from the MCR) or low (close to the MCR). Since the high ratio means a lower loan amount, the actual decision is lower loan amount (keep charging a higher price). On the other hand, the lower ratio means "supply more loan, cut prices to steal the competitors market ". When both banks choose the higher ratio, the aggregated loan supply is reduced, thus leading to a higher profit. When both banks choose the lower ratio, the aggregated loan supply increase, thus leading to lower profit.

If this is a self-interest game, the Cournot-Nash is (Low, Low) and the outcome is a Pareto-inferior outcome. However, if this is a coordination game, the Cournot-Nash is (High, High) and the outcome a Pareto-superior outcome. Without capacity constraint, each bank has the incentive to "defect" to choose low ratio, which is high loan supply, to steal the market share. On the other hand, if both banks understand each of them is facing capacity constraints and is very costly to change production level, then it's relatively easier to reach tacit collusion and strategically stay as (High, High).

The above scenario is a "one-shot" game. But in real time, actual market interaction demonstrate a repeated nature. In the repeated Prisoner's Dilemma, the cooperative outcome is the Cartel solution and the punishment can be the Cournot output. Let π_i^* be the Cartel payoff, π_i^d as the payoff from deviating, π_i^c as the punishment output(Cournot output), and π_i^b as the payoff from the opponents' cheating. It is easy to see that $\pi_i^d > \pi_i^* > \pi_i^c > \pi_i^b$. A more general payoff matrix of the game is shown in Table B.1.

Table B.1: Banks' Prisoners Dilemma, General Case

Bank A \ Bank B	High Ratio	Low Ratio
High Ratio	$(\pi_1^*, \quad \pi_2^*)$ (2nd Best, 2nd Best)	$(\pi_1^b, \quad \pi_2^d)$ (Worst, Best)
Low Ratio	$(\pi_1^d, \quad \pi_2^b)$ (Best, Worst)	$(\pi_1^c, \quad \pi_2^c)$ (3rd Best, 3rd Best)

In the infinite repeated game, the strategies that support Cartel solution are as follows: play Cartel unless the opponent cheats; if he cheats, choose the Cournot output. Whether the Cartel output is sustainable as a subgame perfect equlibrium depends on if the following condition is satisfied:

$$\pi_i^d + \delta\frac{\pi_i^c}{1-\delta} < \frac{\pi_i^*}{1-\delta} \tag{B.9}$$

Solving δ, the condition is:

$$\delta > \frac{\pi_i^d - \pi_i^*}{\pi_i^d - \pi_i^c} \tag{B.10}$$

As long as δ is large enough – i.e. the discount rate is sufficiently small – the above condition will be satisfied. When the government introduces(increases) the capital requirement, it aims to improve the stability of the banking industry, thus increases the charter value of banks. Hendriks (2011) provided empirical evidence of a positive relationship between the charter value and capital ratio. Banks become more patient and forward-looking and δ is indeed large enough to prevent banks from deviation. Abreu(1986) shows that one period of punishment followed by a return to the Cartel solution will be sufficient to maintain the Cartel output.

By agreeing to Pareto-superior actions, banks reduce the loan amount, therefore generating three consequences: (1) banks charge higher interest rate on loan, r_L increases, (2)banks reduces the demand for deposit D, which means a lower deposit interest rate, r_d and (3) total asset size shrinks. The bank profit, the two interest differential $r_L - r_d$, thus goes up.

In an oligopolistic market, banks may collude to reduce the supply of the credit and hold even higher capital ratios.

Table 2.6 shows that in the state level, the correlation between lagged market concentration (measured by HHI [3]) and capital ratios are positive and significant.

[3]This is a standard measure of competition used in antitrust analysis and research in the US. Deposits are used to calculate HHI for this purpose because it is the only variable for which location is known (Berge, 2012).