Capital Regulations and The Rise of Shadow Banking

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[Preliminary and incomplete]

Abstract

The Basel III regulations mandated a significant increase in the required level of banks' own capital holding. Using a new micro-level dataset of corporate credit for the largest firms in South Korea in years 2013-2019, we document a 25% decline in credit from regulated banks, and an increase of similar magnitude from non-bank lenders. We use our data to estimate a strongly negative relationship between corporate lending and minimum capital requirements. For identification, we exploit a gradual implementation of the reform in Korea and control for various confounding factors. To understand this finding, we build a quantitative model with heterogeneous banks who accumulate equity and invest in risky loans. In addition, heterogeneous firms may endogenously choose to become a non-bank lender who does not face regulations. We find that an increase in the capital requirement similar to that of Basel III can justify the decrease in regulated bank lending, as well as the rise in shadow lending of the magnitude documented in our data.

Keywords: Banking regulations, shadow banks, heterogeneous agents

JEL Classification Numbers: E44, E50, G21

1 Introduction

The financial crisis of 2008-2009 was marked with spectacular bank failures and subsequent government bailouts. This led to calls for a global reform of banking regulation that would align the banks' incentives more closely with those of their stakeholders and the society. The resulting Basel III standards, agreed upon in 2010, increased the amount of own capital that banks must hold as share of assets from 2% previously to over 7% now. As of 2019, the implementation of these reforms has just been completed in most countries or is still ongoing. However, little is understood about the macroeconomic effects of such changes, both theoretically and empirically. One particularly controversial implication of tighter capital requirements is that the demand for risky loans may be channeled through unregulated shadow banks. Acharya et al. (2013) argue that shadow banks are set up by commercial banks in order to reduce capital requirements, resulting in concentration of risk in the financial sector during the 2007-09 financial crisis. On the other hand, in the lens of Ordonez (2018), shadow banking is a result of self-selection by financial institutions with asymmetric investment opportunity under blunt capital requirements. In the recent empirical literature, there is growing evidence that links shadow banking activity to stricter supervision (Buchak et al. 2018a, Irani et al. 2018).

In this paper, we investigate the relationship between capital regulations and shadow banking using a new micro-level dataset of all credit of the largest 2200 firms in South Korea. Our panel starts in 2013Q2 and goes until 2019Q1, covering the entire period of Basel III implementation in that country. In addition to regulated banks, we also observe credit from non-bank lenders such as insurance companies or investment funds. We document that over the last five years, credit extended by regulated banks declined by 25%. At the same time shadow sector lending increased by a similar amount and by now makes up for close to 60% of total credit granted to the largest Korean firms. We show that the shadow bank sector expanded also in terms of the sheer number of lenders who mostly consist of insurance companies or investment funds. Secondly, during the course of Basel III implementation in Korea we observe a steady rise in the posted capital ratios of regulated banks, with a median increase of about 2 percentage points. The increase in capital ratios is prominently correlated with the introduction of penalties for non-compliance with Basel III standards in Korea. The goal of this paper is hence to formally establish a link between these two coinciding phenomena, both theoretically and empirically.

In order to better understand the impact of changes in minimum capital requirements on the credit growth from regulated banks, we adopt an estimation strategy in the spirit of Khwaja and Mian (2008). Given that firms in our data generally borrow from multiple banks at the same time, we incorporate firm fixed effects in our regressions to control for idiosyncratic shocks to firms' demand for loans. Controlling for changes to banks' liabilities on the other hand allows us to control for potential shocks to deposits. The main regressor of interest is the the change in minimum capital requirements which exhibits enough variation over time and across banks due to the gradual implementation of Basel III in Korea, as well as the special treatment of Systemically Important Banks by the reform. We find that changes in the capital requirements are strongly and negatively associated with firm-level credit growth, where one percent increase in the capital ratio floor leads to 0.8 percent reduction in credit growth. We also regress credit growth on the changes in realized bank capital ratios and find a similarly negative and significant relationship. As a robustness check, we design a placebo test and show that capital ratio requirements are not related to credit growth before the regulation. In the final piece of analysis we investigate is shadow banks became more likely to lend to firms in Korea than regulated banks during the time of Basel III implementation. To find out, we run a similar regression with the inclusion of time fixed effects interacted with a dummy for whether the lender is a shadow bank. We find that credit growth from shadow banks indeed surpassed that from regulated banks over time and the largest change, strikingly, coincides with the imposition of penalties for violating the Basel III requirements in Korea.

To understand how higher capital requirements affect banks' decision to reduce credit supply, we proceed to build a dynamic general equilibrium model with heterogeneous workers, firms and banks. Banks consume dividends and accumulate equity by optimally allocating their portfolio of risky assets (such as corporate loans) and risk-free ones, as well as raising deposits from workers and firms. Every period, a bank's assets value is hit with an idiosyncratic shock which may put them at a risk of violating the capital constraint and suffering a penalty. In equilibrium, banks optimally build an equity buffer above the required minimum, which depends on the equilibrium interest rates paid on risky assets and deposits. This result is in line with the reality of most financial systems where banks post capital ratio much in excess of the required minimum, and still tend to occasionally fail the stress tests. We show that capital requirements affects predominantly small banks, causing their policy functions for investment and deposits to be non-linear with respect to equity.

The model also features heterogeneous entrepreneurs who hire labor and accumulate capital to fulfill their productive ideas. Entrepreneurs with high productivity but low on cash turn up to the banks for loans, while entrepreneurs with extra funds may deposit them in checking accounts. The key innovation of our model is that we also allow entrepreneurs to operate a *shadow bank*. This entails incurring a fixed cost and facing the same loan value risk as regular banks, but in exchange firms can earn a higher interest rate on their savings. We find that the firms who are not very productive, but own a high stock of wealth, endogenously choose to become a shadow bank in the model. Crucially, shadow banks are not bound by capital regulations and thus can expand in the situation where the reform causes traditional banks to reduce their lending.

We compute a stationary equilibrium of the model in which all aggregate variables are invariant. The distribution is well-defined due to the concavities in banks' policy functions. We use the model to conduct a Basel III reform experiment. We increase the capital requirement by 5 percentage points and calculate the resulting stationary equilibrium. We find that while the overall amount of outstanding loans does not change that much, there is a dramatic shift from regulated banks towards shadow banks, whose share in the loans market increases from one quarter to over 60%. At the same time, in line with our data findings, a larger fraction of firms decide to become a shadow banks. This shift is caused by the adjustment of general equilibrium interest rates. A higher loans rate encourages more entrepreneurs to incur the costs and lend their funds directly to other firms, while a lower deposit rate discourages firms from simply storing their financial assets with the banks. In the ongoing work, we use the model to conduct a counterfactual experiment in which we analyze the impact on the corporate credit market if shadow banking were to become illegal.

1.1 Literature review

This paper is related to several strands of a growing literature on the effects of capital regulations on regulated bank markets and their spillovers to shadow banking. On the empirical side, Irani et al. (2018) analyze the market for syndicated corporate loans in the United States and find a strong causal effect of the Basel III on increased shadow bank market share. Relative to their work, our paper analyzes the effects of Basel III on primary bank-firm credit accounts in South Korea, covering the full period of the reform implementation. Buchak et al.(2018a, 2018b) focus on the rise of shadow banking in residential mortgage origination. Documenting that market share of shadow banks nearly doubled from 2007 to 2015, they find that regulation accounts for around 60% of shadow bank growth. Our paper shares their interest in the role role that shadow banks play in loan origination, but we focus on corporate credit extended to the largest firms in South Korea. More generally, our empirical methodology draws from an extensive literature estimating the bank lending channel, starting with Khwaja and Mian (2008), Amiti and Weinstein (2018), and Morais et al. (2019) more recently.

Our work is also closely related to an emerging literature that builds theoretical and quantitative models to analyze the consequences of bank regulations. Farhi and Tirole (2018) define four pillars of traditional banking and describe how the emergence of shadow banking calls for adjustment in prudential regulation. Begenau and Landvoigt (2018) propose a framework in which households value liquidity services provided by banks. Shadow banks are different from regulated banks in that they lack the government provided deposit insurance. Optimal level of regulation in the economy trades off the motive for maximizing liquidity provision and reducing safety of the financial system. Dempsey (2017) assumes banks and non-banks differ in terms of the technology for monitoring risky borrowers. Tighter capital regulations then lead initially to higher monitoring effort of regulated banks and a moderate effect on the equilibrium quantity of loans. Only at higher levels of the requirement do borrowers begin to substitute such loans with non-bank borrowing. Luck and Schempp (2019) analyze the role of shadow banks in creating a maturity mismatch in the economy and argue that as such, it does not pose an aggregate risk to the economy as long as the shadow banking sector is small and can be bailed out by the regulated banks. Hachem and Song (2017) argue that stricter liquidity rules led to a rise in shadow banking in China since the early 2000s and propose a simple model illustrating the channel. Corbae and D'Erasmo (2018) propose a quantitative model of the banking industry where big and small banks interact. They show that various capital requirement reforms have important effect on the equilibrium distribution of bank sizes. As Section 4.7 explains in more detail, relative to most of these papers we abstract from the risk posed by financial institutions and focus on modeling their choices in normal times rather than financial crises. We do so in order to be able to match our data and exploit its benefits at the micro level.

The remainder of this paper is structured as follows. Section 2 provides some background information about the Basel III reforms worldwide and their Korean implementation. Section 3 introduces our econometric methodology and discusses the results. Section 4 describes the quantitative model of heterogeneous banks, quantifies it and summarizes the results. Section 6 concludes.

2 Background

2.1 The Global Basel 3 Accord

The Basel Committee on Banking Supervision agreed in 2011 on a new global regime on capital adequacy, stress testing and liquidity risk for banks, the so-called Basel III. The accord was supposed be to introduced in years 2013-2015 and consisted of the following key pillars:

1. New capital standards:

   - The minimum fraction of **common equity to risk-weighted assets (RWA)** to increase from 2% to 4.5%.
   - A **conservation buffer** of 2.5% of common equity to RWA to be maintained at all times, bringing the total requirement to 7%. Banks that fall below this threshold will be constrained in their ability to distribute earnings.
   - A **counter-cyclical buffer** of $0\% - 2.5\%$ (set by national authorities) of common equity to RWA to be created in the times of high credit growth, to prevent the build-up of systemic risk.
   - A special buffer for **Systemically Important Banks** (SIB), mandated individually by national authorities of each country.

2. New leverage standards:

   - A minimum leverage ratio, defined as share of Tier 1 capital in bank's total exposure (which includes all assets and non-balance sheet items) to be maintained above 3% at all times.

3. New liquidity standards:

   - The Liquidity Coverage Ratio (LCR), defined as share high quality liquid assets in total net liquidity outflows over 30 days, to be above 100%.
   - Net Stable Funding Ratio (NSFR), which is defined as a share of available stable funding relative to the amount of required stable funding, must be above 100%. According to Basel III accord, "available stable funding" is defined as the portion of capital and liabilities expected to be reliable over the time horizon considered by the NSFR, which extends to one year.

In the present version of the paper, we focus on the effects of the elevated capital capital ratios on corporate lending.

2.2 Basel 3 implementation in Korea

In South Korea, the Basel 3 was formally introduced on December 1st 2013 but the factual implementation was gradual. In particular, only starting from January 1st 2016 were the formal penalties for not meeting the minimum capital ratios applied to commercial banks. Table 1 presents the development of minimum capital requirements over time. Regulated banks had to increase their minimum capital ratios from 5.125 to 7 for Common Equity Tier 1 capital, and from 6.625 to 8.5 for Tier 1 capital. In addition to these baseline levels, a separate requirement mandated the holdings of a Countercyclical Capital Buffer as well as a D buffer designed for Systemically Important Banks (the two buffers are jointly described by variable K_{it}). Introduction of these buffers was also designed to be gradual and stretched over four years.

Table 1: Minimum capital ratio requirements

Capital Ratio (%)	CET1		Tier1		Total	
Until 2015	None					
From 2016 Jan 1st	5.125	$+ K_{it} \times 1/4$	6.625	$+ K_{it} \times 1/4$	8.625	$+ K_{it} \times 1/4$
From 2017 Jan 1st	5.75	$+ K_{it} \times 1/2$	7.25	$+ K_{it} \times 1/2$	9.25	$+ K_{it} \times 1/2$
From 2018 Jan 1st	6.375	$+ K_{it} \times 3/4$	7.875	$+ K_{it} \times 3/4$	9.875	$+ K_{it} \times 3/4$
From 2019 Jan 1st	7	$+ K_{it}$	8.5	$+ K_{it}$	10.5	$+ K_{it}$

Note: CET1 denotes Common Equity Tier1. CET1 $\subseteq$ Tier1 $\subseteq$ Total. K_{it} is the sum of Countercyclical Capital Buffer and Domestic Systematically Important Banks (D-SIB) capital.

Table 2 presents a summary of penalties that apply to regulated banks in Korea for violating the capital requirements, starting from January 1st 2019. Should the capital ratio fall below the thresholds specified in the table, a corresponding minimum conservancy ratio will be applied. This means that banks are forced to buy back stocks, withhold dividend payments or limit the distribution of profit in another way.

Table 2: Minimum capital conservation ratio (From 2019 Jan 1st)

CET1 capital ratio or Tier1 capital ratio or Total capital ratio	$< 5.125 + K_{it}$ $< 6.625 + K_{it}$ $< 8.625 + K_{it}$	$< 5.75 + K_{it}$ $< 7.25 + K_{it}$ $< 9.25 + K_{it}$	$< 6.375 + K_{it}$ $< 7.875 + K_{it}$ $< 9.875 + K_{it}$	$< 7 + \mathrm{K}$ $< 8.5 + \mathrm{K}$ $< 10.5 + \mathrm{K}$	$\geq 7{+}K_{it}$ $\geq 8.5{+}K_{it}$ $\geq 10.5{+}K_{it}$
Min. conserv. ratio	100%	80%	60%	40%	0%

Note: CET1 denotes Common Equity Tier1. CET1 $\subseteq$ Tier1 $\subseteq$ Total. K_{it} is the sum of Countercyclical Capital Buffer and Domestic Systematically Important Banks (D-SIB) capital.

2.3 Aggregate credit in years 2013-2018

We use the data on the credit extended by regulated and shadow banks to the largest 2000 firms in South Korea in the period of 2013Q2-2019Q1. More details about our data are provided in Section 3.1. Here we present some general trends for aggregate variables that coincide with the implementation of Basel 3.

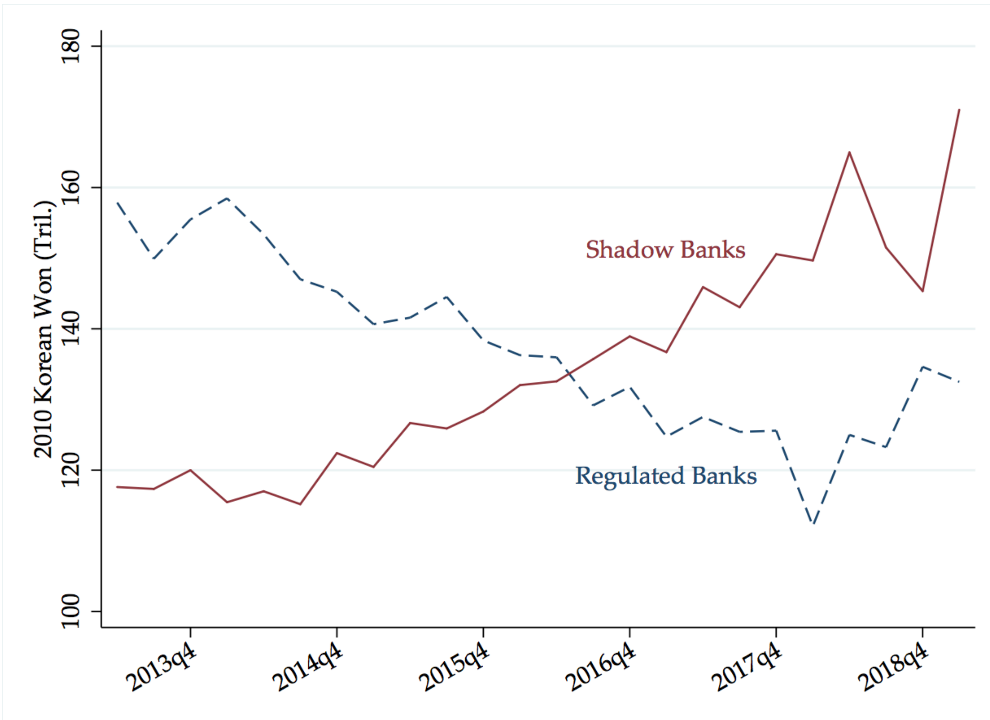


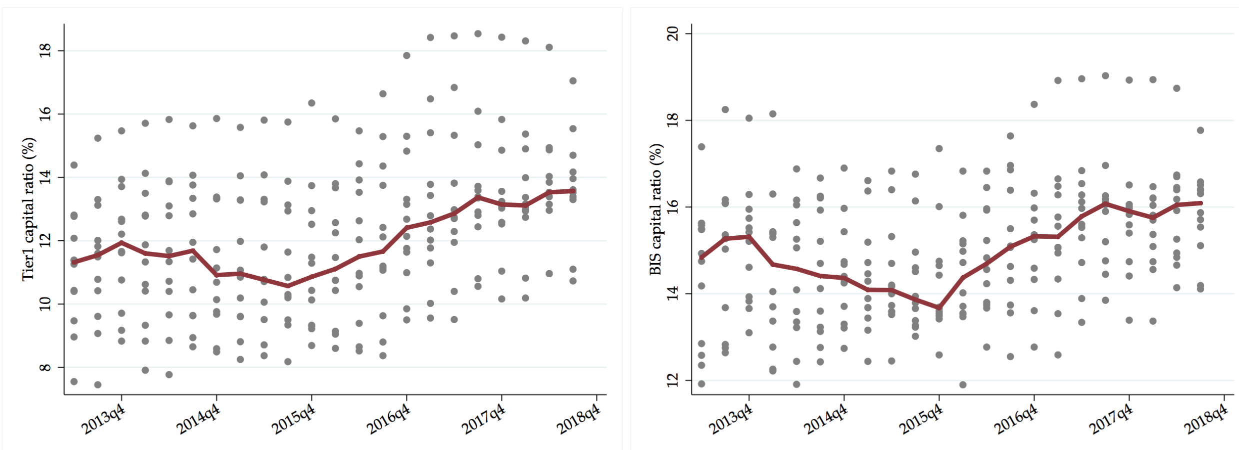
Figure 1: Total credits by commercial and shadow banks

Figure 1 presents the evolution of total credit extended to corporations by commercial and shadow banks. During the time period covered by our dataset, the credit from regulated institutions dropped from 160 to 120 trillion KRW, which constitutes a 25% decline in five years. At the same time, the total credit originating from shadow banks, which we define as non-regulated financial institutions with lending capacity[1], moved in the opposite direction, rising from just below 120 trillion KRW to 165 trillion at its peak, before falling back to 140 trillion. A dip in total credit by shadow banks at the end of sample period, which accompanied with an increase in regulated bank loans, can be explained by an adjustment of risk weights. Concerned about sharp increase in safer household loans, regulators shifted risk loadings from corporate to household loans in January 2018.

[1]In Korea, the majority of shadow banks are institutions such as insurance firms or industry coops.

2.4 Bank capital ratios over time

We now turn to the analysis of bank balance sheets over the time period of interest. Figure 2 presents the evolution of two concepts of bank capital ratios, with the median marked by solid red line. Notice that the distribution of capital ratios is generally stable in years 2013-2015, and then goes on an upward trend starting from year 2016. This is consistent with the background facts we describe in Section 2.2, which shows that the enforcement of new capital regulations only started in Korean at the beginning of 2016. In the remainder of this paper, we will show that the tightening capital regulations exhibit a strong relationship, both empirically and theoretically, with the credit decline among the traditional bank and the rise of the shadow banking sector.



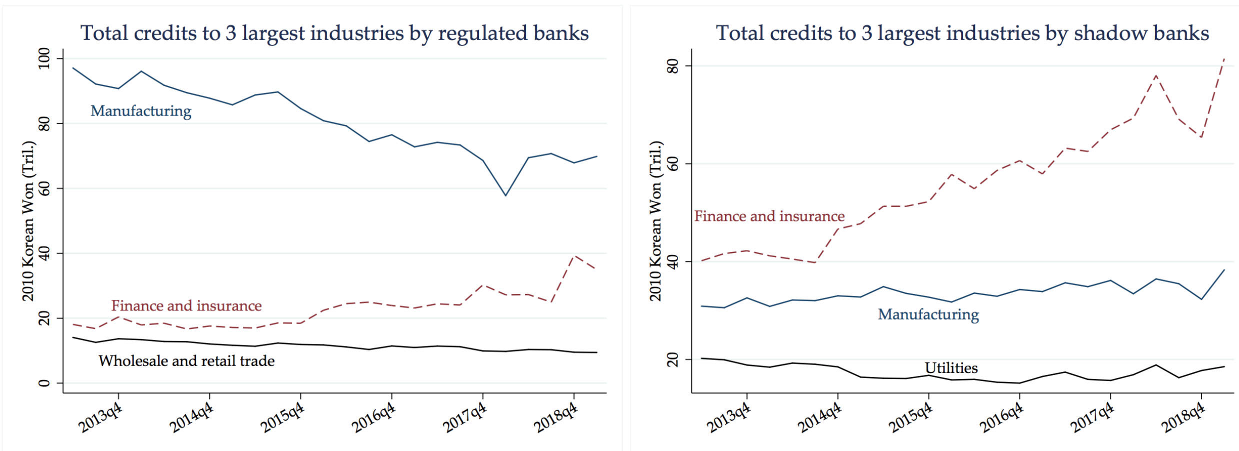
(a) Tier 1 capital ratios (b) BIS capital ratios

Figure 2: Realized bank capital ratios over time

2.5 Industry decomposition

We characterize credits by classifying borrowers into industries. In Figure 3, we depict three largest industries to which regulated and shadow banks extend their credits, following Korean Standard Industrial Classification (KSIC). Regulated banks shed credits to manufacturing sector over the sample period, by nearly 40% from 2013Q2 to 2018Q1. This explains most of the decrease in total credits by regulated banks. At the same time, credits to Finance and insurance sector increased, especially since 2016Q1. This coincides with the onset of Basel 3 implementation with penalties.

Shadow banks increased their credits mostly to Finance and insurance sector from 2013 to 2019, doubling the amount in 2019Q1 compared to 2013Q2. Credits to manufacturing sector increased as well, by 8 trillion KRW at the end of sample period.



(a) Regulated banks

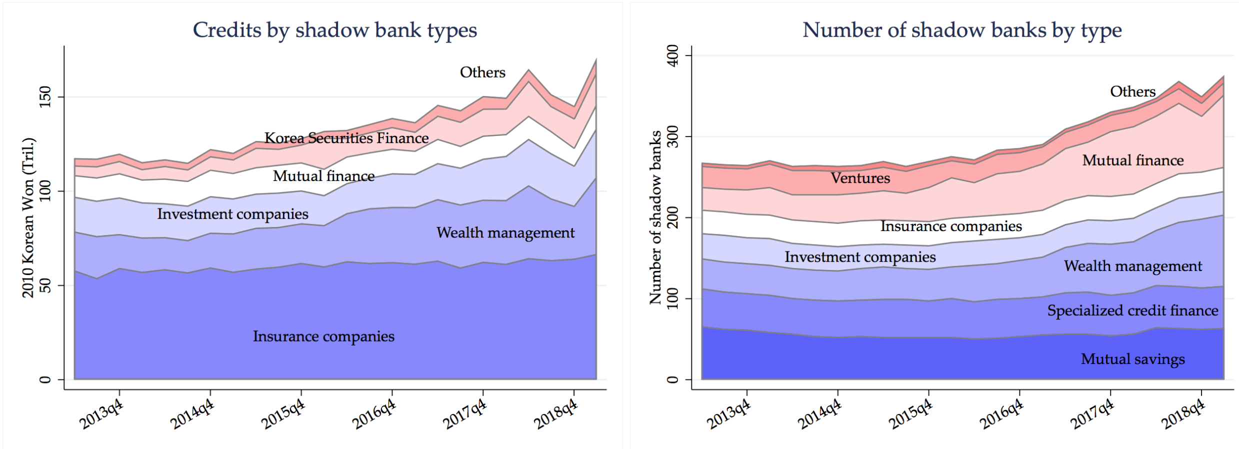
(b) Shadow banks

Figure 3: Total credit to the three largest industries, by regulated and shadow banks

2.6 Evolution of shadow bank types over time

Turning our attention entirely to shadow banks, Figure 4 provides a decomposition of these institutions by type and over time in terms of their number and total extended credit. We define a shadow bank as any non-regulated institution that provides loans to corporations. As such, the shadow banks that we observe in our data[2] span various financial institutions such as mutual savings or finance firms, wealth managements funds and insurance companies. Panel 4(a) shows that roughly half of the loans extended by shadow bank come from insurance companies, although the largest growth in the amount of extended credit comes from wealth management funds and various investment firms. Panel 4(b) on the other hand presents the number of firms who operate as shadow banks in our data. This number is roughly constant, at just under 300, until 2015 and then starts to increase in coincidence with the introduction of penalties for the banks for violating the capital constraints. The number of shadow banks climbs up to almost 400 by 2019Q1, and the types with most new entrants are once again mostly financial and wealth management funds.

[2]The data comes from a major corporate credit bureau in Korea and, as a result, contains any lender who is willing to screen a potential borrower.



(a) Total credit extended (b) Number of institutions

Figure 4: Decomposition of shadow bank types over time

3 Econometric analysis

In this section, we employ the econometric tools to estimate the empirical relationship between the changes in minimum capital ratios and the growth of corporate credit. In doing so, we use our micro data to control for both the shocks to demand for loans, as well as shocks to supply of deposits, both of which could also be important drivers of the decline in lending. We achieve variation in the data by exploiting the gradual implementation of the Basel III reform in Korea, as described in Section 2.2.

3.1 Data description

The main dataset we use in this paper is a panel of bank-firm lending relationships for the largest companies in South Korea. The data is proprietary and acquired from a major credit bureau in Korea. It comes at quarterly frequency and covers the time period of 2013Q2-2019Q1. In total, we observe 578 financial institutions matched to 2204 firms, which yields a total of 402,098 active observations at the bank-firm-time level.[3] We adjust all loan amounts for inflation with GDP deflator and express all monetary variables in 2010 Korean won. A non-negligible fraction of the corporate loans market in Korea operates through state-owned banks and financial institutions sponsored by the government. Because such relationships are beyond the scope of our analysis, we exclude them from our analysis. A major advantage of our data lies in its extensive coverage of lending by

[3]In reality, we have many more observations due to the fact that most bank-firm pairs have multiple non-zero accounts.

Korean shadow banks, such as the insurance companies, investment or wealth management funds. For the sake of preciseness, we will define as shadow bank any institution that engages in legal forms of lending to corporations and is not regulated by the bank supervising authority. Table 3 shows summary statistics of data used in the main analysis.

Table 3: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Loan level					
total credits	24,557	149516	0.88	12,246,918	383,708
Δ ln total credits	-0.10	1.14	-11.29	11.46	249,998
Bank level: Regulated					
deposits	26,408,149	57,030,329	0	230,682,416	777
Δ ln deposit	0.28	1.51	-8.39	12.73	583
total capital ratios	14.96	1.47	11.90	19.03	273
Δ total capital ratios	0.24	1.01	-2.87	2.51	221
Bank level: Shadow					
total liabilities	5,475,671	16,756,303	17.53	211,505,808	4,540
Δ ln total liabilities	0.11	0.48	-2.84	4.69	3,272
Firm level					
net sales	200,389	1,150,412	-3,392,815	41,815,064	35,624
employment	870	3,913	1	102,590	32,503

Note: Total credits, deposits, and net sales are in millions of 2010 Korean Won. Differences are between times t and $t-4$.

In our data, we observe all types of credit accounts separately, while loans from each single category are pooled. In our baseline analysis we use the total credit, i.e. a sum of all credit accounts that we observe.

Our secondary dataset comes from the Financial Supervisory Service in Korea covers the balance sheets of Korean banks for the same time period. The data allows us control for the changes in liabilities of the lending institutions. In the case of regulated banks, we can also see the capital ratios measured according to three definitions, which will be useful in a part of our analysis.

3.2 Methodology

To identify the relationship between effect of bank capital regulations and corporate credit growth, we employ a strategy in the spirit of Khwaja and Mian (2008). The main confounding factors which could also drive the observed quantities in the credit market are unobserved shocks to firm demand for loans, as well as deposit withdrawal shocks on the banks side. To deal with this problem, we include firm fixed effects in our specification and exploit the observation that a typical firm in the data borrows from multiple banks. Intuitively, a decline in credit will be attributed to a firm's demand shock if that firm reduces its borrowing from many banks at the same time, while it would be considered a loan supply shock coming from the bank if it is specific to this relationship. To deal with the effect of potential deposit withdrawal shocks on the banks' supply of credit, we control for the changes in bank deposits in some of our specifications, and show that the main results are not significantly altered.

3.3 Results

In our baseline specification, we regress the change in total log credit extended by bank i to firm j in quarter t on the intercept, firm fixed effects, change in the minimum capital ratio required of bank j in quarter t and change in banks' log deposits.

$$\Delta \ln total\_credit_{ijt} = \alpha + f_i + \beta \Delta \ln min\_cap\_ratio_{jt} + \gamma \Delta \ln deposits_{jt} + \varepsilon_{ijt} \tag{1}$$

In a typical analysis of the effects of a policy reform, a typical concern would be that the error term contains aggregate shocks that coincided with the reform. In regression (1) we attenuate this concern by exploiting the fact that implementation of Basel III was very gradual in Korea. Notice that the minimum capital ratio requirement[4] is indexed by time and by bank. This is because, as Table 1 explains, the capital requirements were increasing linearly in years 2016-2019. In addition, the selected group of Systemically Important Banks were obliged to set aside additional 0.25pp of capital in each of those years. While potential unobserved aggregate shocks may still bias our results in this specification, their path would have to align perfectly with the Korean implementation schedule to invalidate our findings.

Table 4 presents the results of estimating equation (1) with and without controlling for

[4] We use Common Equity Tier1 Capital Ratio in this regression, but results are robust to other types of capital ratios such as Tier1 or Total capital ratio.

changes in bank deposits, as well as including or not the foreign banks. Foreign banks are technically subject to the Basel III requirements in their own country of origin, which may not be exactly the same (or may not be implemented at the same time) as in Korea. Nonetheless, it turns out that our estimation results do not change much if we include them, just as they are not greatly affected by omission of the deposits control. Table 4 then indicates that one percent increase in the minimum capital ratio requirement leads to a reduction in credit growth at the firm level of around 0.8%. The coefficient on the change in bank deposits is positive and significant in the regression with domestic banks only, similarly to what Khwaja and Mian (2008) find, but it loses significance in the regression with foreign banks included.

To shed more light on how banks actions are linked to the decline in credit, we also run a regression of the change in firm credit on *realized* bank capital ratios, of the form

$$\Delta \ln total\_credit_{ijt} = \alpha + f_i + \beta \Delta \ln real\_cap\_ratio_{jt} + \gamma \Delta \ln deposits_{jt} + \varepsilon_{ijt} \qquad (2)$$

Table 5 shows the results of estimating equation (2). We control for changes in bank deposits and we use three possible measures of bank capital ratios: Tier 1 capital ratio, Common Equity Tier 1 capital ratio and the ratio calculated by the BIS. In each case bank capital ratios are strongly and negatively related to the corporate credit growth at the firm level. Roughly speaking, one percent increase in the bank capital ratio can be asso-

Table 4: Effects of minimum capital requirements on credit growth

VARIABLES	(1) d_ln_tot_credit	(2) d_ln_tot_credit	(3) d_ln_tot_credit	(4) d_ln_tot_credit
d_ln_min_cap_ratio	-0.771***	-0.798***	-0.804***	-0.818***
	(0.242)	(0.253)	(0.252)	(0.253)
d_ln_deposits			-0.0184	0.435*
			(0.0130)	(0.236)
Constant	-0.0415*	-0.0482*	-0.0381	-0.0622**
	(0.0220)	(0.0241)	(0.0252)	(0.0255)
Observations	77,913	69,007	69,366	65,131
Firm FE	Yes	Yes	Yes	Yes
Sample	Domestic +Foreign	Domestic	Domestic +Foreign	Domestic
R2	0.0699	0.0796	0.0780	0.0828

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

ciated with around 0.8-1.2% reduction in credit growth. The results in Table 5 should be interpreted with caution. The capital ratios which we use as regressors here are highly endogenous themselves, as banks optimally choose an equity buffer over the required minimum imposed by regulators. Nonetheless, the firm-level correlations between credit growth and capital ratios are going to be useful in Section 4 where we build a model to understand the theoretical determinants of such buffers.

As a robustness check on the effects of capital ratio requirements on credit growth, we design a placebo test. We regress log differences of total credits on *hypothetical* changes in minimum capital ratio, for the sample periods before 2016.

$$\Delta \ln total\_credit_{ijt} = \alpha + f_i + \beta \Delta \ln placebo\_cap\_ratio_{jt} + \gamma \Delta \ln deposits_{jt} + \varepsilon_{ijt} \quad (3)$$

As explained in Section 2.2, Basel III regulations were introduced in Korea since 2013 but legal penalties for violating capital requirements were applied only from 2016. Therefore, from 2013 to 2015, there were only soft guidelines for minimum capital ratio, which gradually increased from 3.5% to 4.5%. We use these guideline minimum capital ratios in our placebo test, and see whether there are any similar effects in our baseline specification.

Table 5: Relationship between credit growth and realized bank capital ratios

	(1)	(2)	(3)
VARIABLES	d_ln_tot_credit	d_ln_tot_credit	d_ln_tot_credit
d_ln_BIS	-1.272***		
	(0.236)		
d_ln_Tier1		-0.865***	
		(0.180)	
d_ln_CET1			-0.843***
			(0.165)
d_ln_deposits	-0.0227	-0.0234	-0.0243
	(0.0308)	(0.0313)	(0.0314)
Constant	-0.0917***	-0.0857***	-0.0846***
	(0.0214)	(0.0191)	(0.0200)
Observations	66,709	66,709	66,709
Firm FE	Yes	Yes	Yes
R2	0.0802	0.0803	0.0803

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6 shows that before 2016, we cannot find any statistically significant relationship between credit growth and capital requirements under various samples and controls. These results contrast to the baseline coefficients in Table 4, which show strongly negative effects of capital requirements on credit growth.

The results presented so far are based on the sample limited to regulated bank loans. This is due to the fact that only these banks are formally subject to the Basel III regulations, and only they have the capital ratio formally measured. We now turn our attention to the analysis of different is credit growth from regulated banks relative to the shadow banks at different points in time. Compared to equations (1)-(2) we replace the capital ratio variables on the explanatory side with time fixed effects, and we interact them with a dummy variable for whether institution j is a shadow bank. Specifically, we run a regression of the form

$$\Delta \ln total\_credit_{ijt} = \alpha + f_i + f_t + \beta I.shadow_j + \tilde{f}_t \times I.shadow_j + \gamma \Delta \ln deposits_{jt} + \varepsilon_{ijt} \quad (4)$$

where f_i and f_t are firm and time fixed effects, respectively. $I.shadow_j$ is an indicator which takes the value of one if the lending institution j is a shadow bank, while $\tilde{f}_t$ are the time fixed effects interacted with this dummy. Figure 5 depicts the evolution of $\beta + \tilde{f}_t$ over time, along with 95% confidence intervals. Prior to 2016, when the penalties for noncompliance with Basel III came into force in Korea, credit growth from shadow banks

Table 6: Effects of placebo capital requirements on credit growth

VARIABLES	(1) d_ln_tot_credit	(2) d_ln_tot_credit	(3) d_ln_tot_credit	(4) d_ln_tot_credit
d_ln_placebo_cap_ratio	-0.111	-0.395	-0.642	-1.197
	(1.582)	(1.732)	(1.559)	(1.590)
d_ln_liab_dep			-0.0215	0.661**
			(0.0305)	(0.242)
Constant	-0.0592	-0.0281	0.0109	0.0457
	(0.210)	(0.231)	(0.206)	(0.209)
Observations	31,536	29,598	27,300	25,722
Firm FE	Yes	Yes	Yes	Yes
Sample	Domestic +Foreign	Domestic	Domestic +Foreign	Domestic
R2	0.177	0.185	0.191	0.199

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

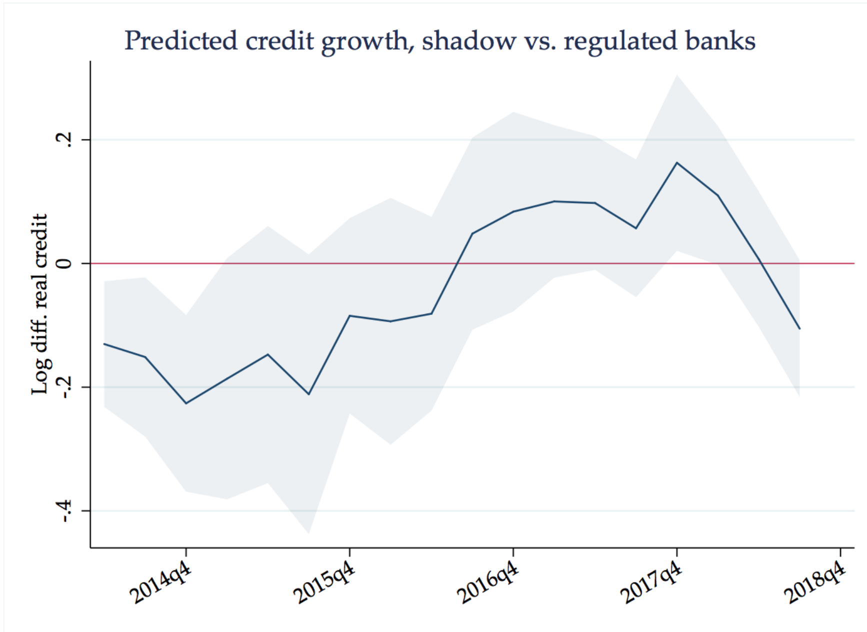


Figure 5: Shadow vs. regulated banks, predicted credit growth

was on average lower by up to 2% at the firm level. This result changes dramatically around 2016, when credit growth from shadow banks becomes higher on average and in statistically significant way.

4 Model

In this section we propose a dynamic equilibrium model with a banking sector to analyze the impact of capital requirements. Time is discrete, indexed by t, and goes until infinity. Heterogeneous banks can issue deposits and invest in both risky assets (such as loans to firms), and riskless ones (such as central bank deposits). Banks are also subject to idiosyncratic shocks to their risky assets (representing loan defaults or fluctuations in investment value). There is no aggregate uncertainty and banks' objective is to smooth out the stream of dividends. The key feature of the model is that due to stochastic fluctuations in the value of risky assets, banks have incentive to maintain a precautionary buffer of common equity over the minimum level required by the regulator.

On the other side of the economy, a mass of entrepreneurs have ideas whose productivities follow an idiosyncratic stochastic process and accumulate assets. Entrepreneurs spend their assets to install physical capital which, in combination with hired labor, yields an output. Entrepreneurs can borrow funds up to a certain limit, or deposit their savings with the banks. They may also decide to pay a fixed cost and become shadow banks. In such case, their savings become risky investment with a higher expected rate of return.

Finally, there are also heterogeneous households who face uninsured idiosyncratic labor risk and accumulate precautionary savings. These savings are deposited in bank accounts.

4.1 Banks

Preferences The model comprises a continuum of heterogeneous banks with mass λ_b which are indexed by i. Banks have preferences over a stream of dividend payments $\{c_t^i\}$ given by

$$\mathbb{E}_0 \sum_{t \geq 0} \beta_b^t u(c_t^i) \tag{5}$$

where we assume the function $u(\cdot)$ is strictly increasing, concave and twice continuously differentiable. The discount factor is given by $\beta \in (0, 1)$. The concavity in the utility function gives banks a dividend-smoothing motive. This assumption is made for convenience of aggregation, but is also empirically relevant as it can represent various frictions in firm financing.

Budget constraint Banks arrive in each period with a single state variable, equity. The budget constraint states that they can spend it on dividend payout, investment or risk-free reserves. Banks can also supplement their equity with deposits from other agents in the economy. Formally, the budget constraint is

$$c_t^i + b_{t+1}^i + m_{t+1}^i - d_{t+1}^i = e_t^i \tag{6}$$

Uncertainty Banks are subject to an idiosyncratic shock to the value of their assets, ω_{t+1}^i. This shock can be though of as realization of loans default rate or fluctuations in the market value of assets. Banks take as given the current market interest rate on risky loans, risk-free reserves and deposits. As a result, the next period realized equity of a bank is given by

$$e_{t+1}^i = (1 + r_t^b)(1 + \omega_{t+1}^i)b_{t+1}^i + (1 + r_{t+1}^m)m_{t+1}^i - (1 + r_{t+1}^d)d_{t+1}^i \tag{7}$$

Regulatory environment In making their decisions, banks are subject to regulations imposed on them by the authorities. In particular, the minimum capital requirement states that

$$\frac{(1 + \omega_{t+1})b_{t+1}^i + m_{t+1}^i - d_{t+1}^i}{(1 + \omega_{t+1})b_{t+1}^i + \chi m_{t+1}^i} \geq \kappa \tag{8}$$

The numerator in equation (8) represents bank i's realized equity in next period, while denominator are the risk-weighted assets. The constraint states that this ratio must be greater than an exogenously imposed parameter κ. In our actual application in Section 4.5, we impose a soft form of this constraint, allowing banks to violate it while incurring a utility cost.

The second regulatory constraint is the minimum reserve requirement which states that banks must hold at least a fraction ρ of their deposits in the form of risk-free assets.

$$m_{t+1}^i \geq \rho d_{t+1}^i \tag{9}$$

where $\rho \in [0, 1]$ is a parameter.

4.2 Entrepreneurs

Preferences There is a continuum of heterogeneous entrepreneurss with mass λ_e in the economy indexed by j. They have preferences over consumption and leisure given by

$$\mathbb{E}_0 \sum_{t\geq 0} \beta_e^t u(c_t^j, 1 - \ell_t^j) \tag{10}$$

where we assume the function $u(\cdot)$ is strictly increasing, concave and twice continuously differentiable. The discount factor is given by $\beta_e \in (0,1)$.

Production technology Following the span of control literature, we assume that every entrepreneur has access to a decreasing returns to scale production function $f(z,k,n)$. This technology transforms k units of physical capital and n units of hired labor into the consumption good. An entrepreneur's own productivity z is a random variable that follows a Markov process with transition matrix Γ_z. We assume that the production function is of the form

$$f(z,k,n) = z^{1-\nu}(k^\alpha n^{1-\alpha})^\nu$$

Notice that it is the presence of the entrepreneur-specific fixed factor z that introduces decreasing returns to scale. Then, given z and an installed level of capital k, each firm hires labor to maximize profit

$$\pi(k,z) = \max_n \Big\{ f(z,k,n) - wn \Big\}$$

As it is standard, given our specific assumptions, the total profit can be expressed as a sum of the return to capital and a return to productivity, i.e.

$$\pi(k,z) = f_k k + f_z z$$

4.3 Workers

Preferences There is a continuum of workers in the economy indexed by s. They have preferences over consumption and leisure given by

$$\mathbb{E}_0 \sum_{t\geq 0} \beta_w^t u(c_t^s, 1 - \ell_t^n) \tag{11}$$

where we assume the function $u(\cdot)$ is strictly increasing, concave and twice continuously differentiable. The discount factor is given by $\beta_w \in (0,1)$.

4.4 Timeline and summary

Every period begins with the realization of idiosyncratic shocks: to productivity of the entrepreneur z_t^j, to labor efficiency of the worker ε_t^s, and to the asset value of a lending institution ω_t^i. Afterwards, agents make their intertemporal decisions.

Figure 6 presents a graphic summary of the linkages between the different groups of agents in the model economy. Workers accumulate savings to insure against idiosyncratic labor income shocks. These assets are deposited in bank accounts and earn a deposit interest rate r^d. Banks then use these funds to make loans to businesses, earning an interest rate of r^b. Some entrepreneurs may also find it optimal to save, rather than borrow, in which case they may also add to the stock of deposits in the economy. Finally, some entrepreneurs may choose to become shadow banks. In that case, they use their own funds make loans to other entrepreneurs and earn the interest rate r^b which is (potentially) higher than r^d. Such entrepreneurs then face the idiosyncratic investment risk (just as banks do). Crucially though, shadow banks are not subject to capital regulation.

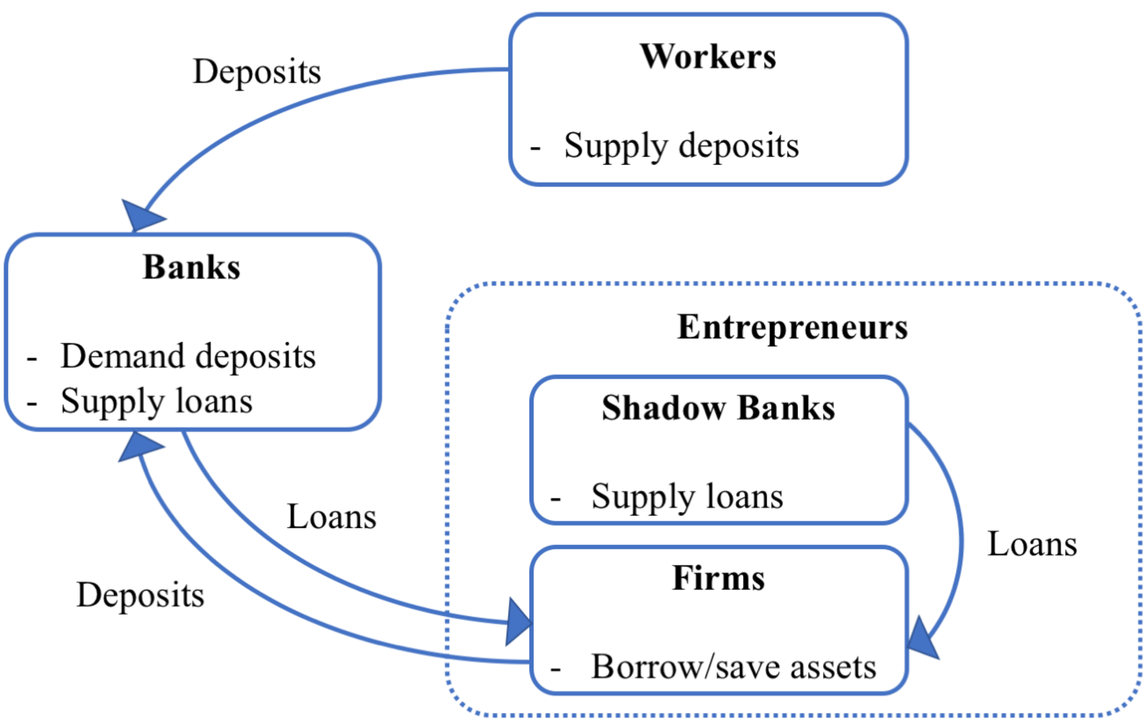


Figure 6: Diagram of the economy

4.5 Recursive Formulation

In this section, we express the model in recursive formulation that we will use directly to compute the solution. For notational convenience, we suppress the bank, entrepreneur, and worker superscripts, as well as time subscripts.

Bank's problem In what follows, we convert the bank's problem into one where equity e is a single state variable (Bianchi and Bigio (2018)). The recursive problem of the bank is

$$V^B(e) = \max_{c,\tilde{b},m',d'} u(c) - h(p) + \beta E_{\omega'} V^B(e') \tag{12}$$

$$s.t.\ \ c + \tilde{b} + m' - d' = e \tag{13}$$

$$e' = (1+r^b)(1+\omega')\tilde{b} + (1+r^m)m' - (1+r^d)d' \tag{14}$$

$$p' = \kappa\Big((1+\omega')\tilde{b} + \chi m'\Big) - \Big((1+\omega')\tilde{b} + m' - d'\Big) \tag{15}$$

$$m' \geq \rho d' \tag{16}$$

In the problem above, formula (13) represents the bank's budget constraint which implies that current equity can be spent on dividend payouts, risky loans to firms, central bank reserves, as well as it can be supplemented with raising deposits. Equation (14) shows that the equity next period will depend on the interest rates on the three portfolio components, as well as a realization of the investment value shock ω'. The bank is punished for violating the minimum capital requirement. Variable p' in formula (15) captures the deviation of the bank's equity next period from the κ-fraction of its risk-weighted assets. A positive value of p' implies that the bank's capital ratio has fallen below the required minimum. The penalty operates through a functional form $h(p)$ in the bank's utility, to be specified in the next section.[5] Finally, expression (16) contains the reserve requirement of the bank, i.e. banks must invest at least a fraction ρ of their deposits in risk-free assets.

Banks are heterogeneous with respect to accumulated equity due to each having experienced a different path of shocks over time. The main result from the model of Bianchi and Bigio (2018) is that banks' policy functions are linear in equity. As we will next show, this is not necessarily the case in our setup, which has the features of Aiyagari (1994). This is due to the fact that capital constraints inhibit the ability of some banks to use deposits and reduce curvature of their policy functions.

[5] In reality, when a bank finds its capital ratio drop below the required minimum, it may be prohibited from paying further dividends or investing in assets.

Entrepreneurs An entrepreneur in our model enters each period with two state variables: the level of cash-on-hand x, and an idiosyncratic productivity of his business idea z. Using physical capital in place, production takes place in which the entrepreneur hires workers. The entrepreneur's income consist of the sum of his own labor income, profit from running business, undepreciated capital and gross return on the financial assets. The entrepreneur decides how much to consume now and how much to save, which in turn entails a portfolio choice between selecting financial assets and installed capital for next period. The entrepreneur must also decide whether to become a shadow bank in the following period.

Problem of a regular firm An entrepreneur chooses to be a regular firm solves

$$V^R(x,z) = \max_{c,a',k'} u(c, 1-\bar{\ell}) + \beta_e \mathbb{E}_{z'} \Big[V(x',z') | z \Big] \tag{17}$$

$$s.t.\;\; c + a' + k' = x \tag{18}$$

$$x' = w\bar{\ell} + \pi(k',z') + (1-\delta)k' + \big(1 + r(a')\big)\, a' \tag{19}$$

$$r(a') = r^d \mathbb{1}\{a' \geq 0\} + r^b \mathbb{1}\{a' < 0\} \tag{20}$$

$$a' \geq \underline{a} \tag{21}$$

where V is the continuation value of a generic entrepreneur who then decides again whether to become a shadow bank or not. Current cash-on-hand x can be spent on consumption, or investment in financial assets a' or physical capital k'. Then, next period cash-on-hand will consist of the entrepreneur's labor income, as well as gross returns on the two types of assets. Equation (20) shows that entrepreneurs face different interest rates on their financial assets, depending on whether they have savings or loans. A firm who decides to take a loan may do so up to an exogenous borrowing limit of $\underline{a}$.

Problem of a shadow bank An entrepreneur chooses to be a shadow bank solves

$$V^S(x,z) = \max_{c,a',k'} u(c, 1-\bar{\ell}) + \beta_e \mathbb{E}_{z',\omega'} \Big[V(x',z') | z \Big] \tag{22}$$

$$s.t.\;\; c + a' + k' + f_S = x \tag{23}$$

$$x' = w\bar{\ell} + \pi(k',z') + (1-\delta)k' + (1+r^b)(1+\omega')a' \tag{24}$$

$$a' \geq \underline{a} \tag{25}$$

where V is the continuation value of a generic entrepreneur who then decides again whether to become a shadow bank or not. Current cash-on-hand x can be spent on consumption, or investment in financial assets a' or physical capital k'. In addition, to operate a shadow bank, an entrepreneur must incur a fixed cost of f_S. Next period cash-on-hand will consist of the entrepreneur's labor income, as well as gross returns on the two types of assets. The key difference relative to a regular firm who saves ($a' \geq 0$) is that the shadow bank can earn interest rate r^b on their financial assets, as opposed to a (potentially lower) rate r^d. On the other hand, in addition to the fixed cost, shadow banks bear an idiosyncratic risk on their financial investment ω'.

Choice to become a shadow bank A generic entrepreneur chooses whether to become a shadow bank or not by comparing the two value functions

$$V(x,z) = \max\Big\{V^R(x,z), V^S(x,z)\Big\} \tag{26}$$

Worker's problem The recursive problem of a worker is

$$V^W(a,\varepsilon) = \max_{c,a'} u(c, 1-\bar{\ell}) + \beta_w E_{\varepsilon'}\Big[V^W(a',\varepsilon')|\varepsilon\Big] \tag{27}$$

$$s.t.\ \ c + a' = w\bar{\ell}\varepsilon + (1+r^d)a + c_b \tag{28}$$

$$a' \geq 0 \tag{29}$$

Workers in this economy are standard and modeled as in Aiyagari (1994). Uninsurable idiosyncratic labor risk generates a motive for workers to accumulate assets, which are then deposited with the banking sector. Each workers' labor productivity follows an autoregressive process. Because we do not model consumer credit in this paper, for simplicity we assume that workers cannot borrow. However, because workers are ultimately the owners of all banks, they receive a lump-sum transfer of the banks' dividend c_b.

4.6 Competitive Equilibrium

We finish describing the model by introducing the definition of a competitive equilibrium.

Definition 1 *A recursive competitive equilibrium consists of allocation and asset holdings of banks* $\{c_b, \tilde{b}, m', d'\}$, *regular firm entrepreneurs* $\{c_r, a'_r, k'_r\}$, *shadow bank entrepreneurs* $\{c_s, a'_s, k'_s\}$, *and workers* $\{c_w, a'_w\}$, *labor allocations in regular firms and shadow banks* $\{n_r, n_s\}$, *and prices* $\{r^b, r^d, r^m, w\}$, *measures* $\{\mu_b, \mu_r, \mu_s, \mu_w\}$, *and value functions* $\{V^B, V^R, V^S, V^W\}$ *such that:*

1. *Given prices, allocations, asset holdings, and value functions solve the bank, regular firm, shadow bank, and worker's maximization problem.*

2. *Asset and labor markets clear.*

$$\begin{aligned}
&\int_E \tilde{b}(e)d\mu_b(e) + \int_{X\times Z} a'_s(x,z)\mathbb{1}_{\{a'_s>0\}}d\mu_s(x,z) \\
&\qquad = \int_{X\times Z} a'_r(x,z)\mathbb{1}_{\{a'_r<0\}}d\mu_r(x,z) + \int_{X\times Z} a'_s(x,z)\mathbb{1}_{\{a'_s<0\}}d\mu_s(x,z) && (loans)\\
&\int_E d'(e)d\mu_b(e) = \int_{A\times\varepsilon} a'_w(a,\varepsilon)d\mu_w(a,\varepsilon) + \int_{X\times Z} a'_r(x,z)\mathbb{1}_{\{a'_r>0\}}d\mu_r(x,z) && (deposits)\\
&\int_E m'(e)d\mu_b(e) = \overline{M} && (reserves)\\
&\int_{X\times Z} n_r(x,z)d\mu_r(x,z) + \int_{X\times Z} n_s(x,z)d\mu_s(x,z) \\
&\qquad = \int_{X\times Z} \bar{\ell}_r(x,z)d\mu_r(x,z) + \int_{X\times Z} \bar{\ell}_s(x,z)d\mu_s(x,z) + \int_{A\times\varepsilon} \bar{\ell}_w(a,\varepsilon)d\mu_w(a,\varepsilon) && (labor)
\end{aligned}$$

4.7 Discussion of the model

This section provides a more general discussion of our modeling framework and explains several important assumption.

In this paper we abstract from any notion of risk that financial institutions such as banks or shadow banks pose to individual depositors or the aggregate economy. Each of these institutions faces an idiosyncratic risk related to the uncertain return on their assets, but they do not have the option of defaulting or exiting the market. We take this approach because we are primarily interested in explaining the patterns observed in our micro-level data from Korea during the times that do not involve any observable stress or financial crises. Instead, the goal is to provide theoretical insights that the previous literature did not focus on, such as what firms decide to engage in shadow lending or how regulated banks optimally choose the size of their capital buffer over the minimum requirement.

A direct consequence of this modeling approach is that we abstract of several features of shadow banks that are common in the literature. We assume that shadow banks are independent entities of regulated banks and thus do not allow for the formation of banks' off-balance sheet investment vehicles. We also abstract from any potential maturity mismatch, primarily due to the fact that our data does not provide us with information about the maturity structure of firms' debt. As a result, our model also ignores the issues related to depositors' beliefs and possible self-fulfilling bank runs.

Our frameworks also does not allow us to answer any questions related to the optimal level of bank regulations or welfare consequences of changing the capital requirements. In the model, a reform occurs for exogenous reasons and agents must optimally respond to it, while aggregate prices adjust to clear the markets.

Taking our model to the data in Section 5, we ignore household debt and focus entirely on the corporate credit market. In particular, we set the workers' financial constraint to zero (no borrowing) and calibrated the size of aggregate debt in the economy to the corporate loans sector only. These assumptions could be relaxed, at the cost of complicating the analysis and with no apparent benefit as our data does not contain the household debt.

Finally, the idiosyncratic asset volatility that financial institutions face in our model is a reduced-form way of pooling various sources of balance sheet risk, for example deriving from loan defaults or fluctuating prices in secondary markets.

5 Quantitative Analysis

In this section, we describe the calibration of our model and discuss the mechanics of its stationary distribution. We then conduct an experiment where we increase the capital requirement by a magnitude similar to that of Basel III.

5.1 Functional forms

For the banks, similar to Bianchi and Bigio (2018), we select a standard CRRA utility function of the form $u(c) = \frac{c^{1-\gamma_b}}{1-\gamma_b}$. While banks are typically thought to be risk neutral, their owners plausibly have a consumption-smoothing motive. The consumption in this case can therefore be thought of as dividend paid out to stockholders. The penalty for violating the capital requirement is

$$h(p) = \varphi_0 \exp(p)^{\varphi_1}$$

This non-linear specification takes very small values for negative p, and increases smoothly once p becomes positive. This has an advantage of producing a highly asymmetric punishment while the function itself is differentiable and can be used in first-order conditions.

We assume that both workers and entrepreneurs have the same preferences given by

$$u(c, \ell) = \frac{c^{1-\gamma}}{1-\gamma} + \frac{\ell^{1+\frac{1}{\psi}}}{1+\frac{1}{\psi}}$$

The stochastic process for entrepreneurs' productivity is

$$log(z_{t+1}) = \mu_z + \rho_z log(z_t) + \sigma_z \epsilon_{z,t+1}$$

Similarly, the workers' labor efficiency follows the process

$$log(\varepsilon_{t+1}) = \mu_\varepsilon + \rho_\varepsilon log(\varepsilon_t) + \sigma_\varepsilon \epsilon_{\varepsilon,t+1}$$

where both $\epsilon_{z,t+1}$ and $\epsilon_{\varepsilon,t+1}$ are i.i.d. standard normal innovations.

5.2 Calibration

Table 7 summarizes the parameter values assumed in the model. The discount factor β and risk aversion γ are set to standard values of 0.9 and 2, respectively. The weight on central bank reserves χ is 0.9 implying that investing in reserves contributes less to the measure of risk-weighted assets than investing in corporate loans. The shock $(1 + \omega')$ is assumed to follow a reverse lognormal distribution which implies that assets value usually undergoes large and infrequent drops or common and small increases. The standard deviation of this shock is set to 0.01 which implies fluctuations of in the value of risky assets within the bounds of roughly $(-3\%, +3\%)$. The initial capital requirement is 5%, marginally higher than the pre-Basel III regime, while the reserve requirement is set to a standard value of 10%. Rather than modeling the quantities of the Fed balance sheet, we specify the reserve interest rate r^m directly and set it to 0.0%. We set the parameters of the penalty function φ_0 and φ_1 to 0.0005 and 1.1, respectively, to target the empirically plausible buffers of realized capital ratios over the posted requirements.

The parameters of entrepreneurs and workers are fairly standard and consistent with existing literature. Discount factors are set to 0.96, risk aversion is 2, while the persistence of idiosyncratic productivity and labor efficiency is 0.9. We assume standard values for the entrepreneurs' problem, including the span of control parameter ν of 0.8, capital depreciation rate of 5%, and capital share in production function of 0.3. We furthermore impose a borrowing limit of -0.5 and a fixed cost of running a shadow bank of 0.1 in every period.

The parameters are selected jointly such that aggregate bank equity in the baseline stationary equilibrium is normalized to 100. Then, in Section 5.4 we conduct an experiment in which we increase the minimum capital requirement, while holding all other parameters fixed, and we investigate the effect that it has on the stationary equilibrium.

5.3 Model mechanics

Banks decisions Before showing the equilibrium stationary distribution, we first analyze the mechanics of a bank's decision making in the model. Figure 7 depicts the policy functions for loans and deposits at different levels of bank equity. Notice that for most values of equity, policy functions are essentially linear which mimics the model of Bianchi and Bigio (2018). However, in contrast to their setup, here it is not the case globally. The policy functions exhibit considerable curvature at low levels of equity, i.e. for small banks. This is due to the fact that banks in this region are constrained in their decisions by min-

Parameter	Value	Description
Bank parameters		
β	0.9	Discount factor
γ_b	2	Risk aversion
χ	0.9	Asset risk weight on reserves
κ	0.05	Capital requirement
ρ	0.1	Reserve requirement
σ	0.01	Variance of $(1+\omega')$
φ_0	0.0005	Penalty function parameter
φ_1	1.1	Penalty function parameter
r_m	0.0%	Interest rate on reserves
Entrepreneur parameters		
β_e	0.96	Discount factor
γ_e	2	Risk aversion
μ_z	1.0	Mean productivity
ρ_z	0.9	Persistence of productivity
σ_z	0.17	Variance of productivity
ν	0.8	Span of control
α	0.3	Capital share
δ	0.05	Capital depreciation
$\underline{a}$	-0.5	Borrowing limit
f_S	0.1	Fixed cost of running a shadow bank
Worker parameters		
β_w	0.96	Discount factor
γ_w	2	Risk aversion
μ_ε	1.0	Mean labor efficiency
ρ_ε	0.9	Persistence of labor efficiency
σ_ε	0.37	Variance of labor efficiency

Table 7: Calibrated parameters

imum capital requirements. As a results, they are unable (or, more precisely, unwilling) to leverage their desired level of asset investment with deposit taking, and consequently they must invest less. In that sense, capital requirements provide a motive for small banks to engage in precautionary savings and build up a desired level of buffer stock of equity.

The effect of binding capital requirements can be further appreciated by inspecting Figure 8 which presents realized capital ratios as function of current equity and for different realizations of the idiosyncratic shock (mean value, as well as ± 3 sigma). With the benchmark capital requirement of 5%, small banks tend to violate it even when the value of under-

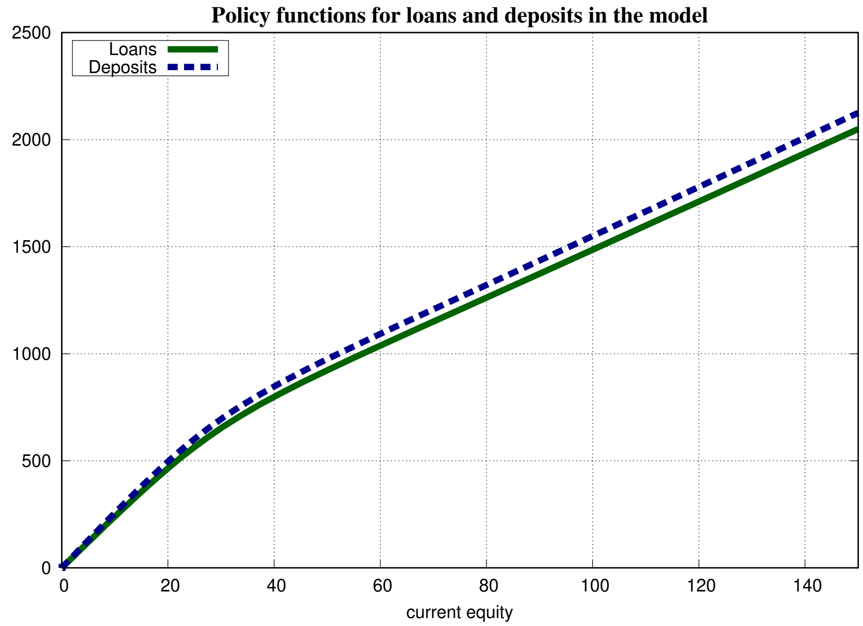


Figure 7: Policy functions in the model

lying assets does not change. For extreme realizations of the shocks we obtain extreme outcomes. A +3 sigma shocks implies that no bank violates the capital requirement, while a -3 sigma shocks implies that all banks will breach it, no matter the size. This general motive to avoid violating the capital requirements is then a main driver of the non-linearity in policy functions evident in Figure 7, a result not present in Bianchi and Bigio (2018) where banks' capital ratios are determined with certainty already at the lending stage.

Formation of shadow banks We next consider the behavior of firms in our model, with a focus on the determinants of shadow bank formation in the economy. Figure 9 presents the decision rule of entrepreneurs as function of the two state variables, wealth and productivity. Intuitively, the firms who have high productivity but do not own enough wealth tend to be borrowers. Holding a productivity level fixed, as wealth of an entrepreneur increases he borrows less and less, until he finally decides to deposit some of the financial assets on a checking account. On the other extreme, the firms who are not very productive but have high wealth tend to become shadow banks, lending out excess cash that cannot be used productively in their core business. The dotted red lines in the figure illustrate how the two decision threshold change in the aftermath of a reform that

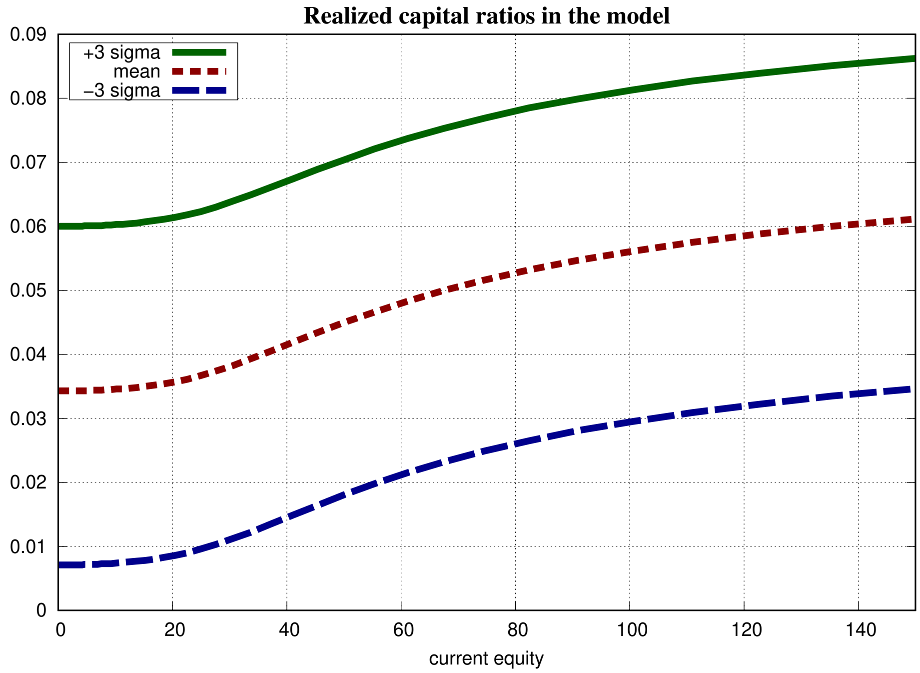


Figure 8: Realized capital ratios in the model

raises capital requirements for banks. Both thresholds move leftwards, implying fewer borrowers and more shadow banks, even though firms in our model are not directly connected to the banking sector in any way. As the next section will show, these shifts occur due to the changes in general equilibrium interest rates.

5.4 General equilibrium and the effects of higher capital requirements

The first column of Table 8 shows the general equilibrium of our model under a baseline capital requirement of 5%. All quantities are expressed relative to average bank equity which is normalized to 100. In this benchmark economy, banks' deposits and loans are roughly 17 times the equity level, which bank dividend is just below 9% of equity. On the other hand, loans from shadow banks make up for one quarter of all lending and 1.5% of all entrepreneurs choose to engage in this activity. The loan and deposit interest rates which clear the capital flows are 1.5% and 1.0%, respectively. The spread of 0.5 percentage points between them reflects the banks' investment risk, as well as the requirement to hold a fraction of all deposits in the form of reserves.

We now use our model to analyze the effects of a capital requirement reform. For now, we abstract from any effects along a transition path and instead calculate the new station-

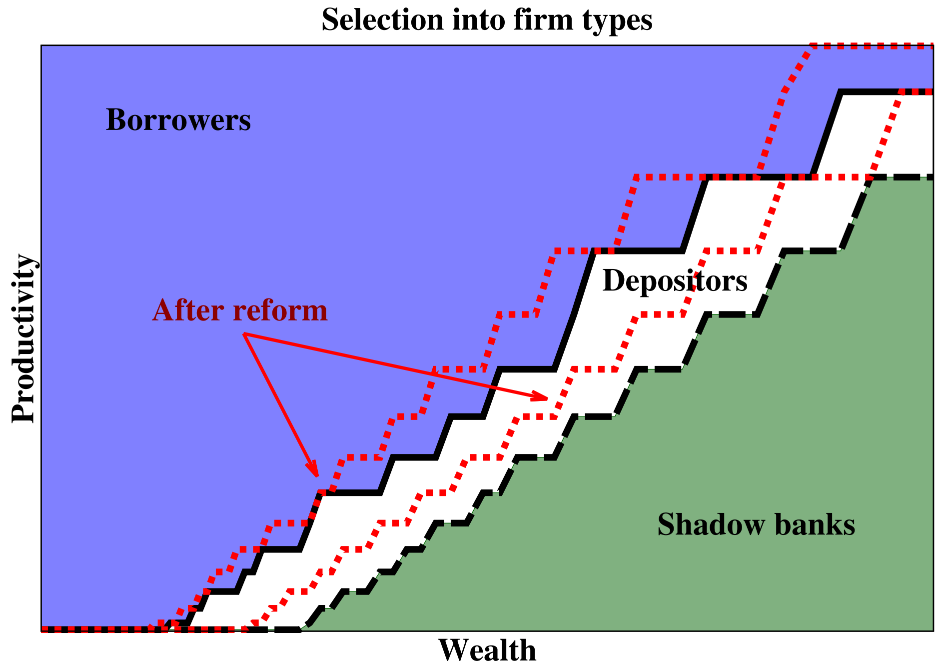


Figure 9: Endogenous selection into borrowers and shadow banks in the model

ary distribution under the elevated requirement. We assume that the minimum capital ratio goes up by 5 percentage points, to 10% altogether, mimicking the size of the increase mandated by Basel III. As a first step, the second column of Table 8 presents the partial equilibrium results, i.e. the invariant distribution under fixed prices. It is immediate to notice that doubling the capital requirement roughly halves the banking sector activity, while lending from shadow banks remains unchanged. The last column of Table 8 summarizes the new general equilibrium in which a new price vector is found such that assets markets clear. In this equilibrium, average bank equity is about 16% lower than in the benchmark while loans and deposits fall by just over 35%. As a result, banks on average hold higher equity relative to the size of their investment and thus enjoy an overall higher level of dividend. Naturally, the price vector that supports this equilibrium includes a higher interest rate for loans and a lower interest rate on deposits. But these new interest rates change the incentives of entrepreneurs who are now discouraged from borrowing or saving in checking accounts, while they find it more attractive to incur the cost and engage in shadow lending. In our calibration, the shadow banking sector is very responsive to this change, leading the total shadow loans quantity to increase by a factor of three, while the fraction of credit extends by such lenders rises to 65% of total, similarly to what we find in the data for South Korea (Figure 1). At the same time, the fraction of entrepreneurs who decide to run a shadow bank increases from 1.5% to 5.3%.

	Before reform	After (PE)	After (GE)
Capital requirement	5%	10%	10%
Banks			
Equity	100	51.9	83.7
Deposits	1767.2	707.6	1127.4
Loans	1681.9	684.2	1088.6
Reserves	176.7	70.8	112.7
Dividend	8.6	4.56	9.7
Shadow banks			
Loans	635.4	635.4	2000.6
Share in all loans	27.4%	48.2%	64.8%
Share in all firms	1.5%	1.5%	5.3%
r_b	1.50%	1.50%	1.74%
r_d	1.00%	1.00%	0.89%
w	0.3	0.3	0.30002

Table 8: Comparison of stationary equilibria before and after the reform

Table 9 presents further information about the behavior of firms in the model equilibria before and after the reform. With the capital requirement of 5%, 89% of firms choose to borrow, while just under 10% are depositors. In line with basic intuition, borrowers tend to have lower wealth and physical capital, but they hire more labor and are more profitable. On the other side, shadow bankers have the highest wealth and because they can achieve a higher return on their financial assets than regular depositors, they install less physical capital. With the capital requirement of 10%, the fraction of entrepreneurs who borrow drops to 83% and their average debt level is reduced, while we observe an expansion of depositors and shadow bankers. Interestingly, because loans are more expensive, the average profit of borrowers is lower than that of depositors who now install more physical capital and higher more labor due to the fact that depositing assets with banks becomes less attractive.

5.5 Interest rates in the data

As Table 8 makes it clear, the rise of shadow banks in our model is driven through the change in general equilibrium interest rates as resulting from the new capital requirements. In this section, we provide empirical validation for this channel by examining interest rate movements in Korea over the time period of interest. Figure 10(a) plots the evolution of loan, deposit and reference risk-free interest rate in years 2013-2019, while

Before reform (capital requirement 5%)			
Aggregates:	Borrowers	Depositors	Shadow banks
Share	0.8884	0.0964	0.0152
Assets	-4.4838	2.4167	22.9632
Capital	27.8595	32.7358	30.8743
Labor	16.2722	15.6217	15.6663
Profits	4.4167	4.2402	4.2523
Wealth	26.6323	38.0801	57.2000

After reform (capital requirement 10%)			
Aggregates:	Borrowers	Depositors	Shadow banks
Share	0.8295	0.1180	0.0525
Assets	-4.2872	0.4645	20.9208
Capital	27.5344	33.5355	29.1946
Labor	16.2318	16.3510	15.3400
Profits	4.4061	4.4384	4.1640
Wealth	26.5020	37.0659	53.4896

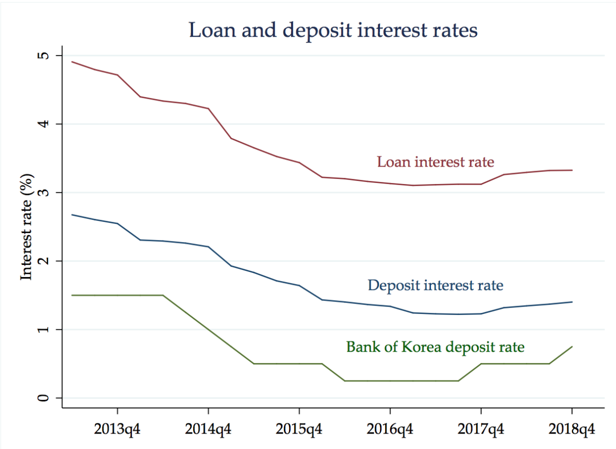
Table 9: Stationary distribution of firms before the reform and after

Figure 10(b) calculates the loan-deposit interest spread. The rates are averages across regulated banks and weighted by their share in total credit.[6] As can be noticed, interest rates used to follow a decreasing trend until the end of 2015, which coincides with the introduction of binding Basel III constraints. Since then, interest rates started to rise modestly, with the average loan rate increasing faster than the average deposit rate, resulting in a loan-deposit spread higher by roughly 0.2%, in line with the main prediction of our general equilibrium model.

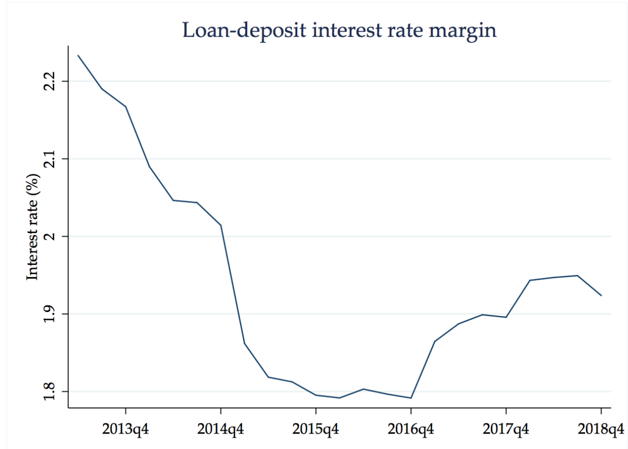
5.6 Distributional effects of higher capital requirements

Figure 11 presents the effects of increased capital requirements on the distribution of bank equity in a stationary equilibrium. Under a lower capital requirement the distribution is highly left-skewed meaning that there are many small banks in equilibrium. As a result of increasing the capital requirement by five percentage points, banks are forced to accumulate equity and the entire mass shifts to the right. The consequence of Basel III therefore, through the lens of our model, is the disappearance of small banks and a further growth of large banks, producing a fatter upper right tail.

[6] Due to data limitations, these interest rates are only available for regulated banks, and not the shadow banks. Given our model assumption that loans from shadow banks are perfect substitutes to loans from regulated banks, this should not be an issue.



(a) Interest rate levels



(b) Difference

Note: Data of interest rates from Financial Supervisory Service (fisis.fss.or.kr). All interest rates are weighted by the total credits in data. Sample includes regulated banks, excluding special banks. Bank of Korea deposit rate is Base rate - 100bp, sourced from Bank of Korea.

Figure 10: Interest rates for regulated banks in the data

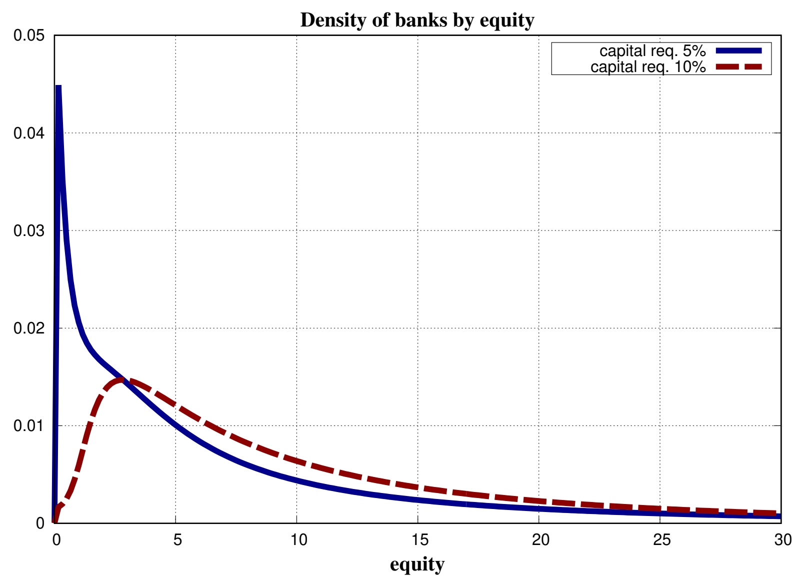


Figure 11: Effects of capital regulations on the distribution of bank equity

6 Conclusion

In this paper we document that the implementation of Basel III reforms in South Korea coincided with a 25% decline in lending to corporations by regulated banks, and a similar increase in lending from the shadow sector. We use a new micro-level dataset to estimate the effect of minimum capital ratio requirements on corporate credit at the firm level, while controlling for a number of confounding factors. We find that this effect is strong and negative, as is the overall relationship between bank capital ratios and credit growth when the reform becomes binding in Korea.

We then build a general equilibrium model with heterogenous banks who allocate their portfolios of assets and decide on the optimal amount of equity buffer over the required minimum capital. We find that in response to a tightening of the capital constraint, banks optimally increase their holdings of own capital and do so by reducing the loans to corporations.

In the ongoing work, we use our model with shadow banks to analyze the extent to which the rise in shadow banking recently observed in Korea can be attributed to the Basel III reforms. We then conduct a series of quantitative experiments, in particular to evaluate the counterfactual effects on the loans market if shadow banks operations were to become illegal.

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