Capital Regulation and Shadow Finance: A Quantitative Analysis

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Abstract

This paper studies the effects of higher bank capital requirements. Using new firm-lender matched credit data from South Korea, we document that Basel III reform coincided with a 25% decline in credit from regulated banks, and an increase of similar magnitude from non-bank (shadow) lenders. We use our data to provide robust estimates for the elasticity of bank credit with respect to capital requirements, and the spillover effect of the reform on non-bank lending. We then build a general equilibrium model with heterogeneous banks that accumulate equity and invest in corporate loans. In addition, wealthy firms may endogenously choose to become a shadow lender. The model replicates the micro estimates and suggests that Basel III can account for most of the observed decrease in regulated bank lending, and about three quarters of the increase in shadow lending. The latter is driven exclusively by general equilibrium effects of the reform.

Keywords: Bank regulation, shadow banks, heterogeneous agents, general equilibrium

JEL Classification Numbers: E44, E50, G21

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"A banker uses the money of others; as long as he uses his own money he is only a capitalist."

— David Ricardo

1 Introduction

The near-collapse of the financial sector in 2008 led to widespread calls for a global tightening of bank regulation. The resulting Basel III standards have significantly increased the required level of equity that banks must hold to back their risky assets. As of 2020, the reform implementation has just been completed in most countries or is still ongoing. This opens new opportunities to answer questions about the macroeconomic effects of such changes, theoretically and empirically. One implication of higher capital requirement is that it may lead to a contraction in the regulated credit market as banks must reduce risky assets on their balance sheets. But how big is this effect and how exactly does that occur? Another potential consequence is that the unmatched demand for risky loans may be channeled through unregulated non-bank (shadow) lenders. Indeed, non-bank financial intermediation has recently been on the rise around the world.[1] To what extent does bank regulation contribute to this trend, and what is the underlying mechanism?

This paper presents a quantitative analysis of the effects of higher capital requirements on lending by regulated banks and by non-bank (shadow) creditors. Using a novel dataset of matched firm-lender credit accounts from South Korea, we document that the Basel III implementation coincided with a 25% decline in lending from regulated banks, and an increase of similar size from shadow lenders.[2] While the former mostly occurred on the *intensive margin*, i.e. within existing bank-firm pairs, the latter was driven by growth on the *extensive margin*, i.e. formation of new lending relationships (partly due to the entry of new shadow lenders). We use the micro-structure of our data to robustly estimate the elasticity of bank credit growth with respect to capital requirement. We also estimate the spillover effect of capital requirement on the growth of shadow lending, both on the intensive and extensive margin. Based on these results, we then build a quantitative general equilibrium model that features heterogeneous banks and firms. An increase in capital requirement affects banks directly by inducing them to reduce risky loans and build a larger equity buffer. But it also indirectly affects potential shadow lenders by widening the general equilibrium interest rate spread and attracting new entrants into the business. Calibrating the model to match the structure of the financial sector in Korean economy, we calculate the transitional dynamics set off by the reform, and redo our econometric

[1] See Financial Stability Board: "Global Monitoring Report on Non-Bank Financial Intermediation 2018".

[2] We define a shadow lender as any institution that lends to corporations and is not a regulated bank. In our dataset, most of these are insurance companies, investment funds, etc.

analysis on a panel of simulated agents. The model reinforces our empirical findings by yielding statistically equivalent estimates for the effects of capital regulation on both bank and non-bank lending. On the aggregate level, we find that Basel III accounts for most of the observed decrease in regulated bank lending, and for about three quarters of the increase in shadow lending. This result shows that, at least in the case of Korea, the recent rise of shadow finance can be viewed primarily as an unintended consequence of bank regulation tightening, as opposed to alternative forces e.g. the development of "fintech".

Our micro data is a quarterly panel obtained from a major credit bureau in South Korea and covers all credit accounts of public firms in that country, matched with banks and non-bank lenders. To estimate the direct effect of capital regulation on traditional bank lending, we regress credit growth within a bank-firm pair on the log of capital ratio requirement, which varies across time and banks. Our econometric analysis exploits the nature of Basel III implementation in Korea, which was pre-announced and designed to be gradual over time and non-uniform across banks.[3] This allows us to cast the reform effectively as a sequence of exogenous treatments on regulated banks with heterogeneous treatment intensity (where a treatment means being subjected to higher capital requirement). To control for potential confounding factors, we adopt an identification strategy in the spirit of Khwaja and Mian (2008). Given that borrowers in our data tend to be connected with multiple lenders simultaneously (and vice-versa), we use firm and bank fixed effects to control for any shocks to firms' demand or banks' supply. We find that capital requirement has a strong and negative effect on bank lending where a one percent increase in capital requirement reduces the credit growth rate by 0.14 percentage points.[4] We show this estimate is robust to various alternative specifications and measurements.

Because the regulation does not directly affect shadow lenders, we design a separate specification to estimate the spillover effect of capital requirement on credit growth in that sector. Concretely, we pool the credit growth data of both regulated banks and non-banks and regress them against an interaction of time dummies and a non-bank dummy. In this way, we measure the extra credit growth coming from shadow lenders over time. We find that credit growth from shadow lenders is up to ten percentage points higher than that from regulated banks starting from 2016, precisely the time when Basel III comes into effect in Korea. To further uncover the role of the extensive margin in the rise of shadow

[3]This stems from the special treatment of Domestic Systemically Important Banks (D-SIB) as proposed by the Basel committee.

[4]To get a sense of the magnitude of this number, note that between 2013 and 2019 the Tier 1 capital ratio requirement was raised from 4% to 8.5%, a total increase of 112.5%.

lending, we restrict our sample to non-banks only and run a logistic regression on time fixed effects to estimate the formation of lending relationships. Once again, we find that the probability of an active firm-lender match increases sharply starting from 2016.

To understand the channels through which higher capital requirement leads to a credit crunch in the regulated bank sector, and a boom in non-bank lending, we build a dynamic general equilibrium model with multiple groups of heterogeneous agents. First, heterogeneous banks seek to smooth out dividend payouts over time 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 asset value is hit with an idiosyncratic shock (such as a realization of default rate) which puts them at risk of violating the capital regulation. Our main innovation in this part is that we introduce the capital requirement in a soft form and model the penalty that financial authorities impose on a bank in case its capital ratio comes close to violating the requirement. In equilibrium, banks build an endogenous capital ratio buffer above the required minimum, which depends on the equilibrium spread between the interest rates paid on risky loans and riskless deposits. This result explains the reality of most modern financial intermediation systems where banks post capital ratios much in excess of the required minimum, and nevertheless violate it occasionally in stress-testing exercises. We show that our model quantitatively replicates the pre-reform distribution of posted capital ratios, and correctly predicts its evolution in response to a higher capital requirement.

Second, the model features heterogeneous entrepreneurs who hire labor and invest in physical capital to fulfill their business ideas. Entrepreneurs with high productivity but low wealth demand loans (and tend to default on them non-strategically), while entrepreneurs with extra funds may deposit them in checking accounts. Our main innovation in this part is that we endow such entrepreneurs with an additional choice, namely an option to become a *shadow lender*. This entails incurring a fixed cost and facing the same loan default risk as regular banks do. In exchange, such firms can earn a higher interest rate on the part of their wealth that is not being used in their core business operations. In equilibrium, firms that are not very productive, but own a large stock of wealth, endogenously choose to become a shadow lender. Such firms can be naturally interpreted as the non-bank financial sector of the economy, lending surplus funds to highly productive but not so wealthy firms (e.g. from the manufacturing or technology sectors). Crucially, shadow lenders are not bound by any regulations and can expand in the situation where the reform causes traditional banks to reduce lending.

To close the model, we add heterogeneous workers who accumulate precautionary savings and deposit them with banks. We compute a stationary equilibrium of the model in which all aggregate variables are invariant and the interest rates and wages clear all markets. We use the model to conduct a Basel III reform experiment. We increase the capital requirement by 4.5 percentage points and calculate the new stationary equilibrium. We find that the overall amount of loans extended by regulated banks falls by about 14% (steady-state to steady-state), while total credit from shadow lenders increases by 17%. In response to the new regulation, traditional banks post higher capital ratios over the required minimum by reducing the amounts of loans and deposits. This causes the spread between interest rates on loans and deposits to widen in the new general equilibrium. As a result of this change, shadow lenders grow on both the *intensive* and *extensive* margins. A higher loans rate encourages more entrepreneurs to incur the costs of entry and lend more of their funds to other firms, while a lower deposit rate discourages firms from storing their financial assets with the banks. That is, the increase in shadow lending is driven exclusively by the general equilibrium effects of higher capital requirement. We validate this channel by showing that the average spread has indeed increased in the data since the reform became binding, by a similar magnitude.

To tie our theoretical framework to the econometric findings, we calculate the transitional dynamics induced by the reform in our model. We pose a reform schedule that mimics the Korean implementation of Basel III and obtain the paths of general equilibrium prices and quantities that correspond to our data sample. Using simulated panels of banks and non-bank lenders, we then run the analogous set of regressions as with our micro data. We find that the model generates both the elasticity of regulated bank credit with respect to capital requirement, and the spillover effect on shadow lending, that fall well within the confidence intervals of the original data estimates. As such, we show that our empirical results are supported by a fully independent economic model, and our theoretical analysis is consistent with the micro estimates. On the aggregate level, over the transition, the model explains most of the observed decline in regulated bank credit, and about three quarters of the increase in shadow lending.

While this paper does not directly address the question of optimal capital regulation,[5] our results quantify the crucial channel for this debate. Higher capital requirements presum-

[5]This is because our micro data does not cover episodes of financial crises or bank failures that would rationalize the very existence of bank regulation. For this reason, throughout the paper we assume that capital requirements are put in place (and then changed) exogenously.

ably make the banking sector safer in the event of a systemic financial crisis, but they also cause bank lending to contract and be replaced by shadow credit. To highlight the role of this alternative lending source, we conduct a counterfactual experiment where, along with imposing higher capital requirements, regulators also prevent the rise of shadow lending (by increasing the fixed cost for such lenders appropriately so that the share of shadow credit remains constant on transition). In this counterfactual scenario, we find that the output and wages drop by more than twice as much on transition, compared to the baseline reform, and the loans-deposits interest rate spread is almost 30% higher. This result illustrates the trade-off that financial regulators face when deciding on the level of capital requirement and on their tolerance for the rise in non-bank finance.

1.1 Literature review

This paper is related to a growing quantitative literature on the effects of capital regulation on financial intermediation markets. Our model of banking shares many similarities with Bianchi and Bigio (2018). In contrast to their framework, we do not consider the inter-bank market but instead focus on modeling the formation of an endogenous capital buffer over the required minimum. Aliaga-Díaz, Olivero, and Powell (2018) present a model in which banks also post an endogenous buffer over the constraint, although their focus is on counter-cyclicity of the regulation rather than its level. Ríos-Rull, Takamura and Terajima (2020) find rather small quantitative effects of counter-cyclical buffers in a model with heterogeneous banks. Corbae and D'Erasmo (2018) propose a quantitative model of the banking industry where big and small banks interact. They show that many of the proposals of Basel III can have important effects on the equilibrium distribution of bank sizes and on the allocation of resources. De Nicolò, Gamba, and Lucchetta (2017), Mankart, Michaelides, and Pagratis (2020), and Goel (2019) further analyze various aspects of optimal regulation using dynamic models with heterogeneous banks. Van den Heuvel (2008), Davydiuk (2019), and Nguyen (2014) all focus on the welfare implications of bank capital regulation. Dempsey (2020) develops a model in which, similarly to our framework, firms may substitute traditional bank loans with non-bank finance. In contrast to our results, he finds this effect to be quantitatively small. Begenau and Landvoigt (2018) propose a model with the possibility of a rise in shadow banking activities in response to a higher capital requirement. They find that this does not necessarily make the financial system more fragile, which warrants a relatively high capital requirement. Our paper contributes to this literature by using micro-evidence from the latest major reform in capital regulation (Basel III) to quantify its intended and unintended consequences.

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 Basel III on the increased shadow banking 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. In the context of residential mortgage loans, Buchak et al.(2018a, 2018b) document that the market share of shadow banks nearly doubled from 2007 to 2015, and they find that regulation accounts for around 60% of it. Our paper shares their interest in the role of shadow banks in loan origination, but we focus on corporate credit extended to all public 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), and more recently Amiti and Weinstein (2018), or Morais et al. (2019).

The remainder of this paper is structured as follows. Section 2 provides 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 and firms. Sections 5 quantifies the model and presents the main model exercise. Section 6 shows the transition induced by the reform and ties the model's micro-estimation results to our econometric analysis. Section 7 discusses the macroeconomic effects of higher capital requirements. Section 8 concludes.

2 Background

This section describes the data and introduces the motivating observations. First, we show the aggregate trends in corporate credit markets in Korea (subsection 2.2) and discuss various underlying details (subsections 2.3-2.6). Second, we describe the Basel III reform (subsections 2.7-2.8), and the banks' behavior upon its introduction (subsection 2.9). This establishes a strong correlation between the two at an aggregate level. In the rest of the paper, we formally quantify the extent to which capital regulation explains the trends in corporate credit, both empirically (Section 3) and theoretically (Section 4).

2.1 Data description

The main dataset we use in this paper is a panel of firm-lender matched credit accounts for all public companies in South Korea. The data is proprietary and acquired from eCredible Co., Ltd., a major credit bureau in Korea. It comes at quarterly frequency and covers the time period of 2013Q2-2019Q1. Overall, we observe 578 financial institutions matched to

2204 firms, which yields a total of 402,098 active observations at the bank-firm-time level. It is an unbalanced panel consisting only of observations with positive amount of credit. All firms included in the data are public and listed in one of the three trading boards in Korea (KOSDAQ, KOSPI, KONEX) at least for one quarter during the sample period. We adjust all credit amounts for inflation using the 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 often based on political decisions rather than market factors, we exclude them from our analysis.

A major advantage of our data lies in its extensive coverage of credit provided by Korean non-bank lenders such as the insurance companies, investment or wealth management funds. Throughout this paper, we define a shadow lender as any institution that engages in legal forms of lending to corporations and is not a regulated bank.[6] In the following subsections, as well as in Appendix A, we provide more details on the nature of our data.

It should be emphasized that our main dataset contains information on realized quantities of credit only, and not on the corresponding interest rates or loan applications. Throughout the paper, we therefore supplement our analysis using data on average interest rates for corporate loans obtained from the Bank of Korea.

Our secondary dataset comes from the Financial Supervisory Service in Korea, which publishes the balance sheets of financial institutions. For regulated banks in particular, we observe the capital ratios measured according to the latest regulatory guidelines (which we describe in subsection 2.9), along with standard balance sheet items such as loans, deposits and equity. For shadow lenders, the coverage of their balance sheets in this dataset is incomplete because not all such institutions are monitored by the Financial Supervisory Service. In particular, shadow lenders do not have their capital ratios measured.

A final remark about the data is in order. In contrast to lenders, the firms in our dataset show up in a de-identified form. This means that, in our empirical work, we can use fixed effects to control for any intrinsic firm characteristics. However, we are unable to match our records with an external database on firm financial statements.

[6] We view this definition as more general than the concept of a shadow bank. As Section 2.4 shows, the non-bank lenders in our data are a collection of heterogeneous institutions, many of which are non-deposit-takers and hence should not be referred to as banks.

2.2 Aggregate credit in years 2013-2019

Using our main credit data, we now describe the aggregate trends in total credit provided by regulated banks and shadow lenders over the sample period.

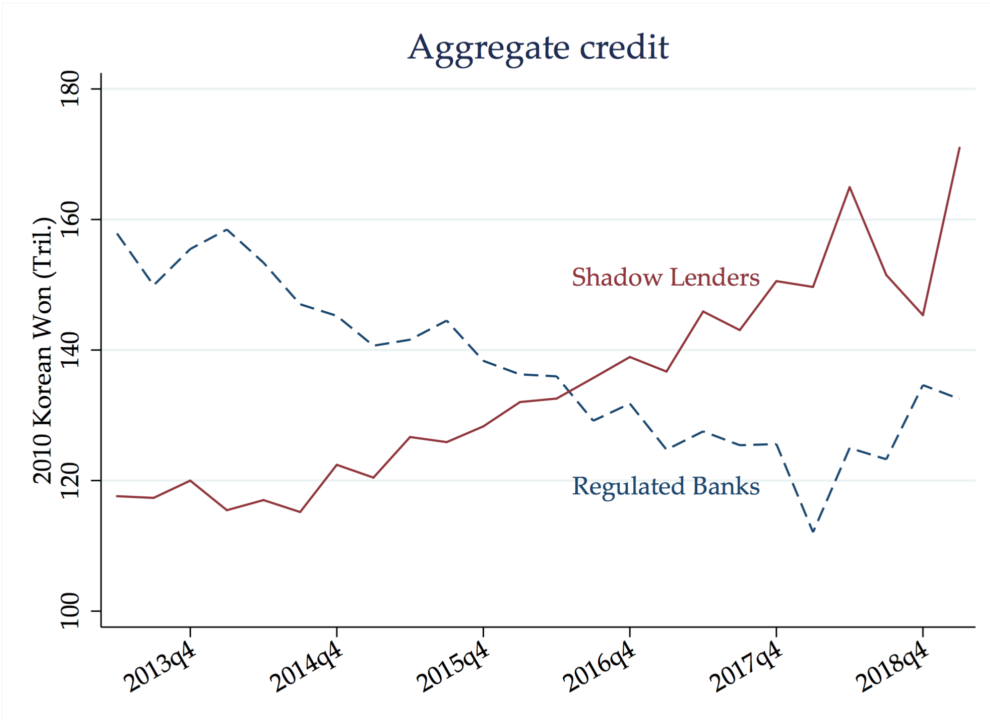


Figure 1: Total credit by regulated banks and shadow lenders

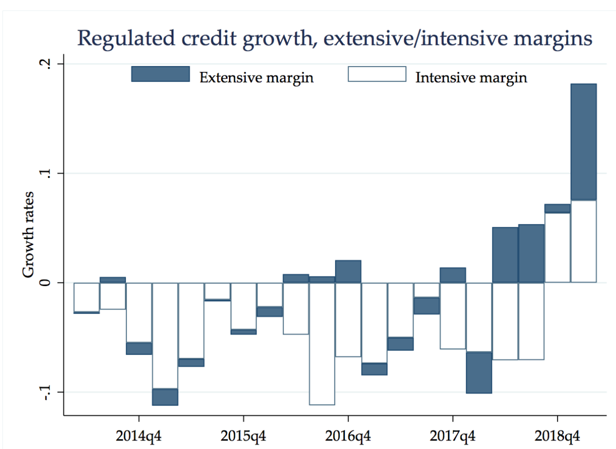
Figure 1 presents the evolution of credit extended to corporations by regulated banks and shadow lenders. During the time period covered by our data, the total credit from regulated banks dropped from 160 to 120 trillion Korean Won (KRW), which constitutes a 25% decline in five years. At the same time, the total credit originating from shadow lenders moved in the opposite direction, rising from just under 120 trillion KRW to 170 trillion at its peak. The noticeable dip in shadow credit at the end of the sample period, accompanied by a rebound in regulated bank lending, is attributed to the concurrent adjustment in risk weights by the Korean financial supervisors. Concerned about the sharp decline in bank provision of corporate credit, the authorities announced sweeping changes in regulatory measures in January 2018. The new measures included a shift in risk loadings from corporate to household loans[7], introduction of household sectoral countercyclical capital

[7]There is a loan-to-deposit ratio regulation in Korea, applicable to commercial banks since 2012, which mandates that KRW loans to deposit ratio be less than 1. Under the new regulation announced in 2018, 1 KRW of household loans is weighted as 1.15 KRW, while 1 KRW of corporate loans counts as 0.85 KRW.

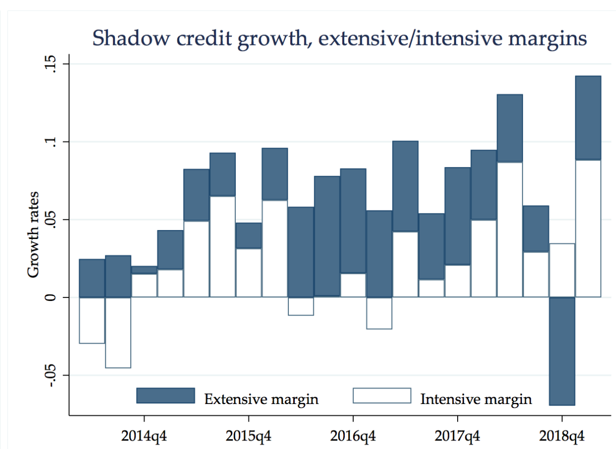
buffer, and further increasing of the risk weights on high-LTV (loan-to-value) mortgages.

2.3 Intensive and extensive margin decomposition

To shed more light on these trends, we now decompose credit growth into intensive and extensive margins for both bank credit and for shadow credit. The intensive margin includes year-on-year log differences in credit arising within existing firm-lender relationships. The extensive margin on the other hand consists of changes in credit due to entry or exit of firm-lender relationships. The sum of changes on the intensive and extensive margin is equal to aggregate credit growth in each time period. Figure 2 shows this decomposition separately for regulated (left) and shadow (right) credit markets. The dark and white bars depict changes on extensive and intensive margins, respectively. Two observations stand out immediately. First, most of the decline in regulated bank credit occurred on the intensive margin, i.e. within existing relationships. Second, most of the growth in shadow credit occurred on the extensive margin, especially starting from 2016Q1 which is when Basel III was enforced with penalties in Korea (see Section 2.8). This means that the formation of new firm-lender relationships mostly drove the observed increase in shadow lending. While some of these are literally new relationships between two entities that are already present in the data, the next section shows that many of them are actually due to new shadow lenders entering the business and adding to our sample.



(a) Regulated banks



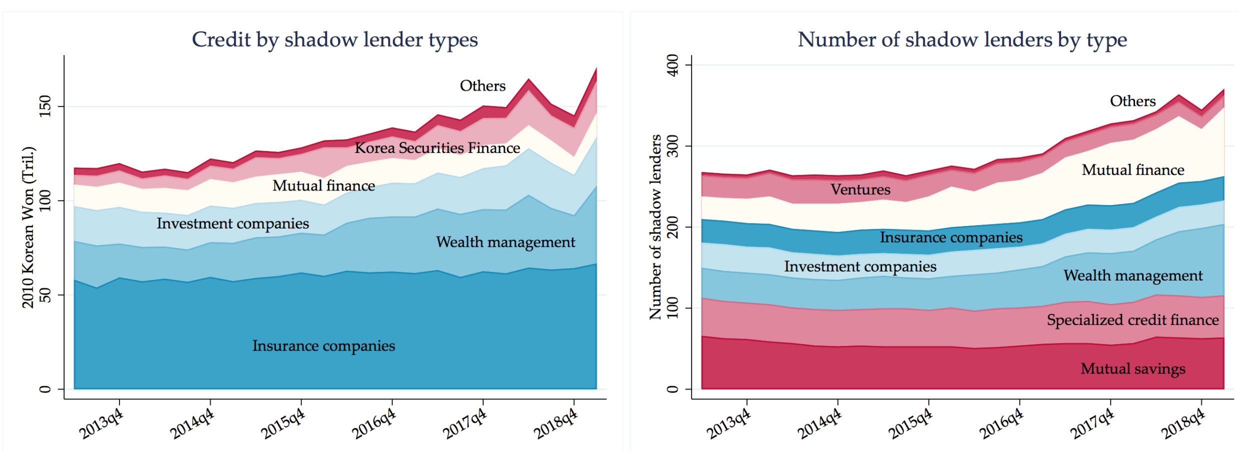
(b) Shadow lenders

Figure 2: Decomposition of credit growth into intensive and extensive margins

In Appendix A.2, we show that the extensive margin growth is not merely due to the same firms seeking new non-bank lenders. In fact, a majority of firms who *do not* borrow from shadow lenders at the beginning of our sample, end up doing so by the end of it.

2.4 Evolution of shadow lender types over time

Turning our attention entirely to shadow lenders, Figure 3 provides a decomposition of these institution types over time in terms of their number and total extended credit. We define a non-bank (shadow) lender as any institution that provides credit to corporations and is not a regulated bank. As such, the shadow lenders that we observe in our data span various financial institutions such as mutual finance firms, wealth management funds, insurance companies or even leasing departments of major car brands (collected under "specialized credit finance"). Panel 3(a) shows that roughly half of such loans come from insurance companies, although the largest growth in the amount of extended credit comes from wealth management funds and various investment firms. Panel 3(b) on the other hand presents the number of firms who operate as shadow lenders in our data. This number is roughly constant, at just under 300 (compared with around 40 regulated banks), until 2016 and then starts to increase, which coincides with the introduction of penalties for non-compliance with Basel III (see Section 2.8). The number of shadow lenders eventually reaches almost 400 by 2019Q1, which means that there are around one hundred new shadow lenders appearing in our sample during the course of Basel III implementation in Korea.



(a) Total credit extended

(b) Number of institutions

Note: The names of institution types are authors' own translation from Korean. Mutual finance includes various credit unions and cooperatives. Investment companies are also known as securities companies, and Specialized credit finance include credit card companies, leasing companies, and installment finance companies.

Figure 3: Decomposition of shadow bank types over time

2.5 Credit types

In our data, we observe all types of credit accounts separately such as loans, securities, and off-balance sheet items. In our baseline analysis we use the total credit, i.e. a sum of all credit accounts that we observe. In Appendix A.3, we describe each credit type and its composition in more detail. Roughly speaking, loans comprise the vast majority of regulated bank lending, although a significant portion of the change in years 2013-2019 occurred through a decline in off-balance sheet items. On the other hand, most of the shadow credit is extended through securities issuance, but the bulk of the recent change is actually due to the growth in loans.

2.6 Prior trends

A natural question that arises from the inspection of Figure 1 is whether these empirical patterns started together with the introduction of Basel III. An alternative explanation could be that they are simply part of a longer trend that precedes the reform. Unfortunately, we cannot answer this question with our micro-level data because the sample begins in 2013Q2 and is not available for earlier time periods.[8] Nevertheless, to shed some light on this issue we obtain alternative aggregate series from the Bank of Korea, starting in 2008, and plot them in Figure 21 in Appendix A.4. The analysis of this data shows that prior to year 2016 lending by regulated banks was growing steadily and then stopped, while lending by non-banks accelerated sharply when penalties for non-compliance with Basel III were introduced.

2.7 Basel III

We now turn our attention to the recent changes in bank regulation, the effects of which we seek to quantify in this paper. The Basel Committee on Banking Supervision reached an agreement in 2011 on the new global framework for capital requirements, the so-called Basel III. The new rules, originally scheduled for implementation in years 2013-2015, consisted of the following:[9]

1. The minimum fraction of **Tier 1 capital to risk-weighted assets (RWA)** to increase from 4% to 6%.

[8] For legal reasons, the credit bureau is obliged to remove old records after a certain amount of time.

[9] We present the reform in terms of the Tier 1 capital ratio requirement, which is a standardized and most commonly used measure of a bank's financial strength. In Appendix B.1 we discuss alternative measures of bank capital in the context of the Korean implementation of Basel III.

2. A **conservation buffer** of 2.5% of Tier 1 capital to RWA to be maintained at all times, bringing the total requirement to 8.5%. Banks that fall below this threshold will be constrained in their ability to distribute earnings.

3. A **counter-cyclical buffer** of 0% − 2.5% (set by national authorities) of Tier 1 capital to RWA to be created in the times of high credit growth, to prevent the build-up of systemic risk.

4. A special buffer for **Systemically Important Banks** (SIB), mandated individually by national authorities of each country.

In summary, the statutory requirement for Tier 1 capital was increased from 4% to 8.5% of a bank's risk-weighted assets, with several additional buffers left at the discretion of national authorities responsible for implementing the reform. Finally, it should be noted that while Basel III also mandated important changes to the leverage and liquidity regulations, in this paper we focus exclusively on the effect of higher capital requirements.

2.8 Basel III implementation in Korea

In South Korea, Basel III was formally introduced on December 1st 2013 but the actual implementation was gradual. In particular, any formal penalties for not meeting the minimum capital ratios were applied to commercial banks starting from January 1st 2016. Table 1 presents the schedule of minimum capital requirements over the course of Basel III implementation. Regulated banks had to gradually increase their minimum Tier 1

Table 1: Minimum Tier 1 capital ratio requirements

Period	Requirement (%)	Note
Until 2012	4	Basel II
From 2013	4.5	Basel III guideline (no penalties)
From 2014	5.5	
From 2015	6.0	
From 2016	6.625 $+ K_{it} \times 1/4$	Basel III (with penalties)
From 2017	7.25 $+ K_{it} \times 1/2$	
From 2018	7.875 $+ K_{it} \times 3/4$	
From 2019	8.5 $+ K_{it}$	

Note: K_{it} is the sum of Countercyclical Capital Buffer and Domestic Systematically Important Banks (D-SIB) capital. Alternative measures of capital ratio requirements are discussed in Appendix B.1.

capital ratios from 4 to 8.5 percent. In addition to these baseline levels, a separate capital buffer was designed for Domestic Systemically Important Banks (D-SIB), described by the variable K_{it}. The introduction of this buffer was also designed to be gradual and stretched over four years. On the other hand, the counter-cyclical capital buffer has not been activated in Korea (remains at zero percent).

The Korean implementation of Basel III also introduced a range of penalties for non-compliance with the capital requirements. Such non-compliance can occur factually, or as a result of conducting a stress test. In the event of violating a posted capital requirement, the financial authorities are entitled to influence the distribution of profit of the non-compliant bank. In particular, this may involve restrictions on the payout of dividends and a forced accumulation of retained earning. Appendix B.2 presents a schedule of restrictions that are a function of realized capital ratios. Essentially, the larger the violation, the larger the fraction of posted profit is placed under restriction.

2.9 Bank capital ratios over time

We now analyze bank balance sheets over the time period of interest. Figure 4 presents the evolution of realized bank capital ratios, with the median marked by solid red line. At least three interesting observations can be made about this graph. First, there is a wide dispersion in realized capital ratios among the banks.[10] Second, and related to the first point, all capital ratios are well above the currently applicable minimum requirement. While this may seem paradoxical, it does not mean that the regulation is non-binding. In fact, even banks with relatively high posted capital ratios occasionally fail stress tests and may be deemed as non-compliant with the regulation. Consequently, banks tend to form an endogenous capital buffer over the required minimum which depends on their specific assets structure. Finally, the distribution of capital ratios is generally stable in years 2013-2015, and then goes on an upward trend starting from 2016. This is consistent with the background facts we describe in Section 2.8, which show that the enforcement of new capital regulation only started in Korea at the beginning of 2016. As an alternative robustness check, Figure 22 in Appendix B.1 shows that the same trend is present for alternative measures of bank capital ratios. In the remainder of this paper, we will quantify, both empirically and theoretically, the effect that capital requirement tightening has on the decline of credit extended by regulated banks as well as the rise of shadow lending.

[10]The figure only includes domestic banks. This is because the branches of foreign banks operating in Korea are subject to Basel III implementation from their home country.

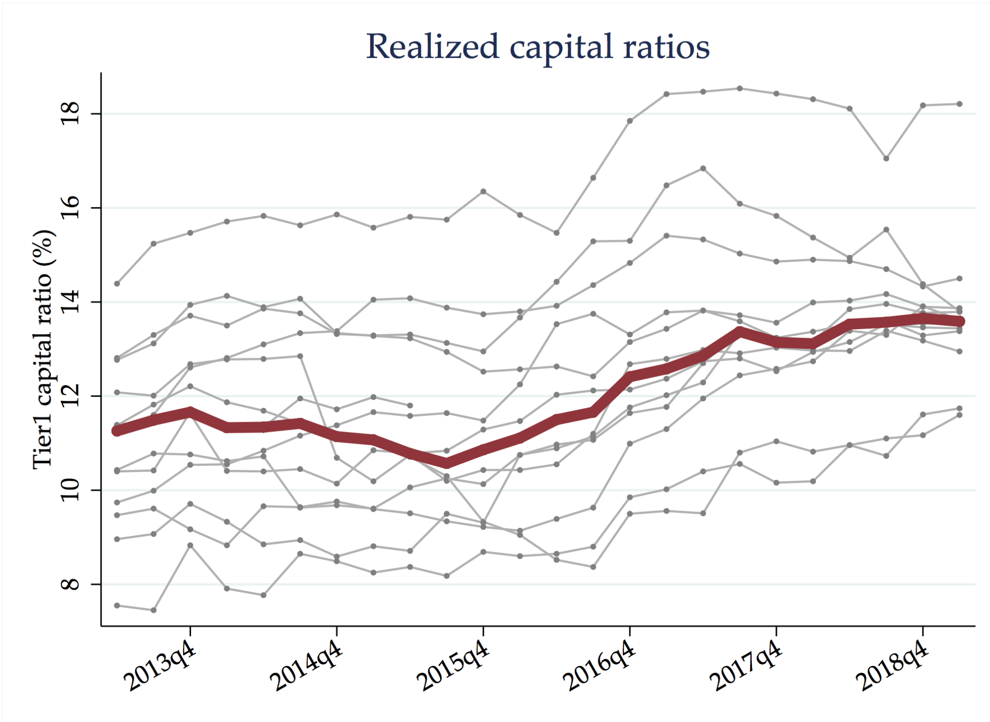


Figure 4: Realized bank capital ratios over time

3 Econometric analysis

So far, we have documented a strong correlation between the aggregate trends in corporate credit markets and changes in bank capital regulation. In this section, we employ econometric tools to show that higher capital requirements do, in fact, have a causal effect on the provision of corporate credit by both regulated banks and shadow lenders. Specifically, we estimate the elasticity of regulated bank credit with respect to the capital requirement, as well as a spillover effect of the reform onto shadow lending. To do so, we use our micro data to control for various confounding factors that could affect the demand and supply of credit at an individual firm-lender pair level.

3.1 Elasticity of bank lending with respect to capital requirement

We start by estimating the elasticity of regulated bank credit growth with respect to capital requirement. Specifically, we regress the change in total log credit extended by bank j to firm i in quarter t on log of Tier 1 Capital Ratio[11] required of bank j in quarter t, along

[11]We use Tier 1 Capital Ratio requirement in this regression, but results are robust to other types of capital ratios such as Common Equity Tier 1 or Total Capital Ratio, as Appendix C shows.

with firm i and bank j fixed effects, and a vector of controls X_{ijt}.[12]

$$\Delta \ln total\_credit_{ijt} = f_i + f_j + \beta \ln min\_cap\_req_{jt} + \Psi X_{ijt} + \varepsilon_{ijt} \tag{1}$$

Our analysis exploits the fact that Basel III was a global policy reform, which provides plausibly exogenous variation in Korea's bank regulation.[13] As a result of the Korean implementation of Basel III, this variation in capital requirement policy ($min\_cap\_req_{jt}$) occurred on two margins: across time, and across banks. The variation across time is due to the fact that the capital requirement was being raised gradually over the years, and only starting from 2016 (Table 1). Effectively, the reform was broken into a sequence of small reforms. The variation across banks arises from the core idea of Basel III, that a group of Domestic Systemically Important Banks (D-SIB) are required to hold an additional capital buffer. The introduction of this one-percentage-point buffer was also spread out over time.

To separate the effect of policy change from the usual confounding factors, we use a fixed effects approach in the spirit of Khwaja and Mian (2008). For example, when capital requirements change, the observed response of credit in equilibrium could be driven by some unobserved shocks to firms' demand for loans, or by shocks to lenders' loan supply that are unrelated to the regulation (e.g. deposit withdrawals). To control for the former, we include firm fixed effects in our specification and rely on the observation that a typical firm in the data simultaneously borrows from multiple lenders.[14] 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. Analogously, we add bank fixed effects to control for any confounding shocks to the lenders' loan supply that are unrelated to the regulation and rely on the observation that a typical lender simultaneously transacts with multiple firms.[15]

[12]In the baseline specification (Table 2, columns 3 and 4), we use the bank-firm relationship variable constructed as the lagged fraction of credit out of total firm credit, $credit_{ij,t-4} / \sum_j credit_{ij,t-4}$. In Appendix C.1 we run analogous regressions with additional control variables such as detrended GDP, stock market indices or the volume of manufacturing sector exports.

[13]The schedule was announced back in 2013 and was largely consistent with the Basel Committee's implementation guidelines. This implies that it was invariant to current economic conditions and therefore plausibly exogenous (note that the Counter-cyclical Capital Buffer was never activated in Korea).

[14]Specifically, across all periods, a median firm borrows from 4 lenders at the same time.

[15]Specifically, across all periods, a median regulated bank lends to 19 firms and a median shadow lender lends to 5 firms at the same time.

Table 2 presents the results of estimating equation (1) with and without controlling for bank-firm relationships, as well as including or not the foreign banks.[16] We find that our results are very consistent across these different specifications, and the estimated elasticity is strongly significant and amounts to around -0.14. To provide a sense of the magnitude of this estimate, suppose that before any reform takes place, the level of credit is constant. Then, an increase in bank capital requirement from 4% (as it was under Basel II) to 6.625% (under Basel III, as of 2016) would cause about a 7% *contraction* in credit for a generic firm-bank pair. Analogously, if the regulators in Korea thought that the reforms implemented so far are insufficient and decided to further raise the Tier 1 capital requirement from 8.5% to 9%, then they can expect it to cause a further 0.8% decline in corporate credit that would otherwise be constant.

Table 2: Effects of minimum capital requirements on credit growth

VARIABLES	(1) Δ ln total_credit	(2) Δ ln total_credit	(3) Δ ln total_credit	(4) Δ ln total_credit
ln min. capital req.	-0.135***	-0.138**	-0.140***	-0.143***
	(0.0433)	(0.0469)	(0.0426)	(0.0461)
Constant	0.144*	0.143	0.356***	0.368***
	(0.0777)	(0.0841)	(0.0822)	(0.0891)
Observations	83,559	77,733	83,559	77,733
Fixed Effects	Firm, Bank	Firm, Bank	Firm, Bank	Firm, Bank
Relationship controls	No	No	Yes	Yes
Sample	All	Domestic	All	Domestic
R2	0.0699	0.0722	0.0919	0.0954

Note: Sample period: 2013Q2-2019Q1. For the results in this table, the capital requirement prior to 2016 is assumed to be 4% (the "guideline" requirements prior to 2016 were not legally binding). All standard errors (in parentheses) are clustered at the bank level. *** p<0.01, ** p<0.05, * p<0.1

3.2 Robustness checks and alternative measures

Appendix C contains a number of robustness exercises to support our main results. First, to address the concern that the reform schedule may be correlated with aggregate shocks over time, we show that our results are robust to the inclusion of various macroeconomic

[16] 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. In Appendix C, we also use the foreign banks to perform a placebo test. We run the analogous regression on a sample limited to foreign banks only and we find no statistically significant effect of the change in Korean capital requirement on bank credit growth.

variables. Second, we test the importance of the "guidelines" period of 2013-2015. We show that regression (1) limited to that time period does not produce statistically significant estimates. At the same time, we show that our main results are not much affected by assuming that the entire schedule of Basel III implementation (including the guidelines) was in fact binding. Third, we show that our results do not change by much if we restrict our sample to the largest D-SIB banks. That is, our results do not rely on the cross-sectional variation in the minimum capital ratio across banks. We do find, however, that the estimated elasticities are higher in absolute value. This means that big banks tend to respond more to capital requirements than small banks. Fourth, we show that the estimation results are robust to weighting observations by lagged total credit of every firm-bank pair. This implies that our regression coefficients are not entirely driven by small firm-bank pairs that might be more susceptible to tighter capital regulation.

In Appendix C.2, we also redo all our estimations using the two alternative measures of bank capital ratio discussed in Appendix B.1. In each case, we find consistent and strongly significant estimates although the magnitudes can vary considerably. For the sake of future research, in Table 17 we provide a concise summary of our estimates for the alternative measures of capital ratio.

3.3 Spillover effect of the reform on shadow lending

The results presented so far are limited to the sample of regulated bank loans. This is due to the fact that only these banks are formally subject to Basel III requirements and have their capital ratios formally measured. We now turn our attention to the measurement of a spillover effect from the regulation onto the provision of shadow credit. Figure 1 reveals an obvious correlation between the two, but is there evidence to believe that the change in bank regulation actually leads to more credit extended by individual shadow lenders? To answer this question, we modify our baseline specification to include all lenders available in our dataset. Compared with equation (1), we replace the capital requirement variable on the explanatory side with time fixed effects and we also interact them with a dummy variable for whether institution j is a shadow lender. Specifically, we run a regression of the form

$$\Delta \ln total\_credit_{ijt} = f_i + f_j + f_t + \beta \cdot Shadow_j + \gamma_t \cdot Shadow_j + \Psi X_{ijt} + \varepsilon_{ijt} \tag{2}$$

where f_i, f_j, and f_t are firm, bank, and time fixed effects, respectively. $Shadow_j$ is an indicator which takes the value of one if institution j is a shadow lender, while γ_t are the coefficients for the interaction of time dummies with the shadow dummy.[17] We summarize the results of this regression in Figure 5 which shows the evolution of γ_t over time, along with 95% confidence intervals. Prior to 2016, i.e. before the penalties for noncompliance with Basel III came into force in Korea, credit growth from shadow lenders was on average lower by up to 7 percentage points at the firm level (although hardly distinguishable from zero). This result changes dramatically in 2016, when credit growth from shadow lenders becomes up to 10 percentage points higher on average and in a statistically significant way compared to credit growth from regulated banks. This effect gradually dissipates over time and by 2018 the difference in growth provided by the two lender types is statistically indistinguishable.

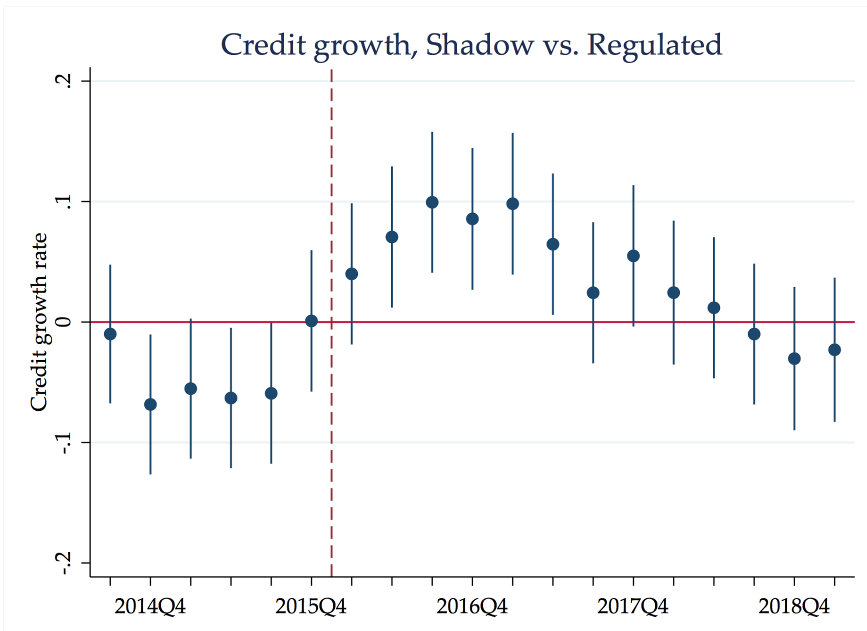


Figure 5: Estimated interaction effects of time and shadow dummies

One thing to note about the previous result is that it only accounts for the changes in credit provision on the intensive margin.[18] Yet, as it is emphasized in subsection 2.3, a significant portion of the growth in shadow credit occurs on the extensive margin. To estimate the effect of changes in capital regulation on the formation of shadow lending relationships, we now focus our analysis exclusively on the extensive margin. To this end, we restrict our sample to shadow lenders only and run a logistic regression of $\mathbb{1}\{total\_credit_{ijt} > 0\}$, a binary indicator for whether firm i had any outstanding credit

[17]The omitted time dummy is the first sample period (2013Q2) so that γ_t measures the policy effects relative to 2013Q2.

[18]This is because growth rates are undefined when credit level was equal to zero in the previous period.

from shadow lender j in time period t, on the usual set of regressors, that is $f_i + f_j + f_t + \Psi X_{ijt} + \varepsilon_{ijt}$. Figure 6 summarizes the results of this exercise by plotting the predicted marginal effects of time fixed effects along with their respective confidence intervals. As can be noticed, the probability that a firm-lender relationship exists is roughly constant at 35% over time until 2016, when the penalties for non-compliance with Basel III come into effect. Starting from then, the probability increases by up to 10 percentage points before stabilizing at around 45% in 2018. This indicates that the change in bank regulation had a sizable effect on the formation of shadow lending relationships. To further strengthen this point, in Appendix C.3 we conduct this exercise for *changes* in the extensive margin (as opposed to existence of lending relationships) and we find a similar patten of the reform effects, where the probability that a firm-lender credit account becomes active rises from 3% before the reform to up to 7% after.

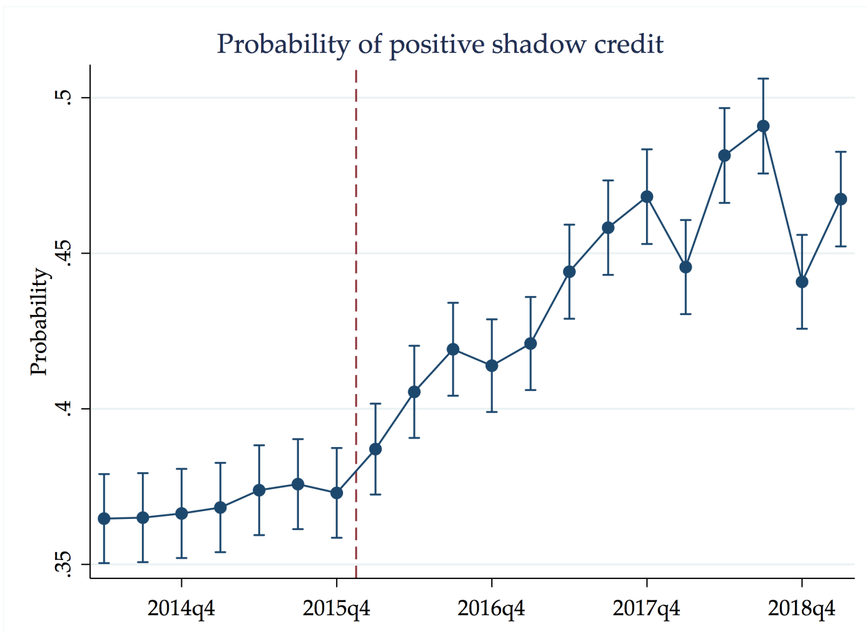


Figure 6: Predicted probability of credit from shadow lenders

4 Model

In this section we develop a dynamic general equilibrium model with frictional financial intermediation to provide theoretical foundations for our empirical results. Time is discrete, indexed by t, and goes until infinity. There is no aggregate uncertainty. Heterogeneous banks seek to smooth out an uncertain stream of dividends over time. To do so, they 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 the value of their risky assets (representing loan defaults or fluctuations in investment returns). They are subject to a capital requirement that enters in a soft form and suffer a utility cost in case it is violated. Facing stochastic fluctuations in the value of their risky assets, banks have an incentive to maintain a precautionary buffer of equity over the minimum level required by the regulator. A key feature of the model is that due to these frictions in financial intermediation, the general equilibrium price vector consists of two separate interest rates: a lower rate on riskless deposits and a higher rate on risky loans.

We embed the banking sector in a broader economy that consists of two further groups of heterogeneous agents. First, there is a mass of entrepreneurs whose stochastic business productivities follow an autoregressive process. In order to produce, entrepreneurs must invest in physical capital ahead of time which can be financed with debt (up to a borrowing limit) or their own accumulated wealth. Any excess savings may be deposited in the banking sector. As a counterpart of the bank's asset value shock, we introduce the possibility of a non-strategic default on debt for the borrowing entrepreneurs. A crucial innovation in that part of the model is that we equip the entrepreneurs with an option to pay a fixed cost and become *shadow lenders*. In such case, they continue to produce output according to their own productivity realization. However, any excess savings become risky investments with a higher expected rate of return (just as in the case of banks).

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

4.1 Timeline and summary

Figure 7 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, and redistribute the earned dividends evenly among the workers who own them. Some entrepreneurs may find it optimal to save, rather than borrow, in which case they may also add to the stock of deposits in the economy. Finally, entrepreneurs may also choose to become shadow lenders. In that case, they continue to produce and use their own excess funds to make risky loans to other entrepreneurs, earning the interest rate r^b which is higher than r^d. Such entrepreneurs then face the idiosyncratic investment risk (just as banks do). Crucially, shadow lenders are not subject to regulations of any sort.

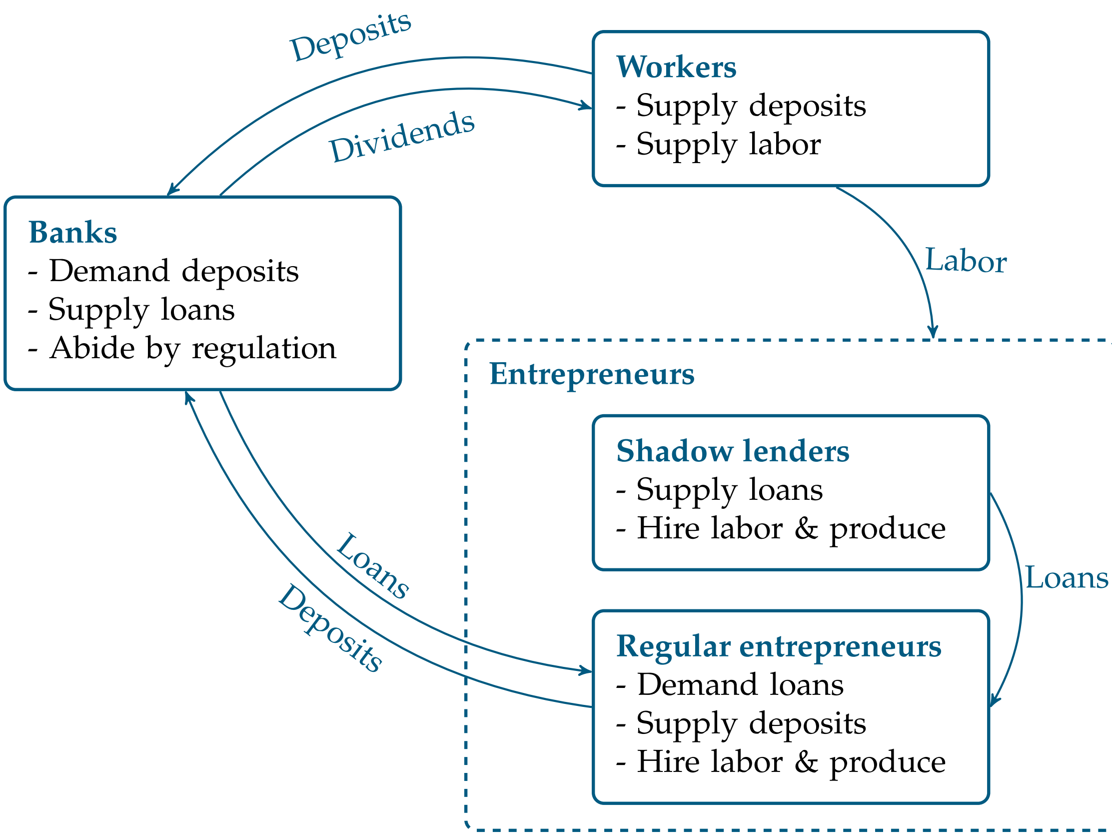
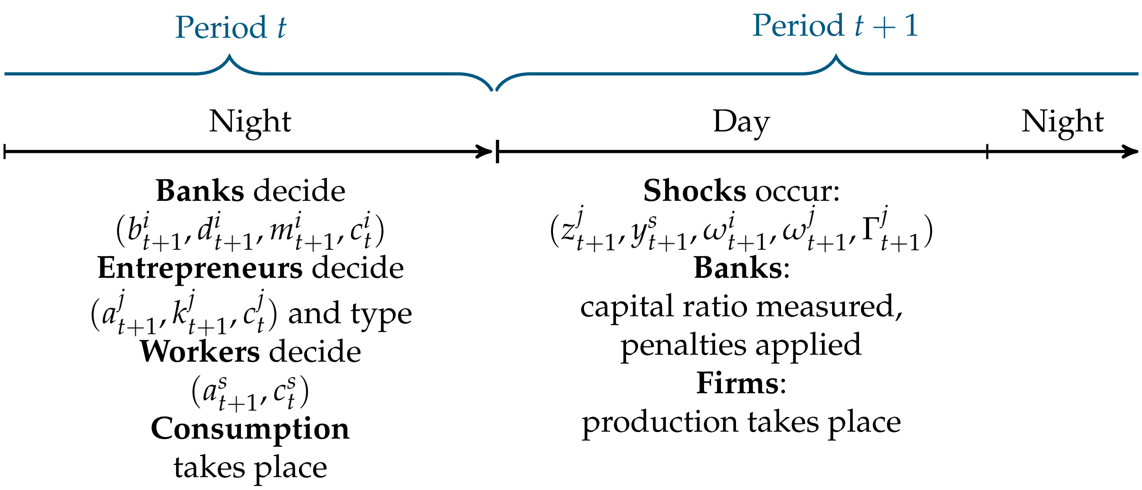


Figure 7: Diagram of linkages in the economy

It should be emphasized that we do not model any direct matching between different agents in our model. The three groups can be thought of as living on separate islands. Between the islands, there exists a clearing house which posts economy-wide prices, and randomly distributes loan default losses among lenders, such that all markets display no excess demand in the general equilibrium.

Figure 8 discusses the timing of our model. Every period is divided into two stages which can intuitively be thought of as day and night. Night time is a planning period in which all agents decide on their allocations and consume immediately. Then, shocks occur during day time, in particular the shocks to the lenders' risky assets value, as well as the borrower default shocks. Following these realizations, the financial authorities measure banks' posted capital ratios and apply the utility penalties for non-compliance with capital requirements. Finally, day time is when production takes place.



Note: Indexes i, j, and s refer to individual banks, entrepreneurs and workers, respectively.

Figure 8: Timing of the model

4.2 Banks

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

$$\mathbb{E}_0 \sum_{t \geq 0} \beta^t_b u(c^i_t) \tag{3}$$

where we assume the function $u(\cdot)$ is strictly increasing, concave and twice continuously differentiable. The discount factor is given by $\beta_b \in (0,1)$. 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 e^i_t. The budget constraint states that they can spend it on dividend payout c^i_t, risky loans investment b^i_{t+1} or risk-free reserves m^i_{t+1}. Banks can also supplement their equity with deposits d^i_{t+1} from other agents in the economy. Formally, the budget constraint is

$$c^i_t + b^i_{t+1} + m^i_{t+1} - d^i_{t+1} = e^i_t \tag{4}$$

Uncertainty Banks are subject to an idiosyncratic shock to the value of their assets, $\omega^i_{t+1} \in [0,1]$, where $\mu \equiv \mathbb{E}(\omega^i_{t+1})$ is the expected repayment rate of loans. This shock arrives during first stage of the next period and can be thought of as realization of loans default rate or fluctuations in the market value of risky 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

$$e^i_{t+1} = (1 + r^b_{t+1})b^i_{t+1}\omega^i_{t+1} + (1 + r^m_{t+1})m^i_{t+1} - (1 + r^d_{t+1})d^i_{t+1} \tag{5}$$

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

$$\frac{b^i_{t+1}\omega^i_{t+1} + m^i_{t+1} - d^i_{t+1}}{\chi b^i_{t+1}\omega^i_{t+1}} \geq \kappa \tag{6}$$

The numerator in equation (6) represents bank i's realized equity in the first stage of next period, while the denominator contains risk-weighted assets. Corporate loans are the only risky assets in this model, hence they carry a risk weight χ which is a fixed parameter. The constraint states that this ratio must be greater than an exogenously imposed parameter κ. In our actual application in Section 4.6, 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 $\rho \in [0, 1]$ of their deposits in the form of risk-free assets.

$$m^i_{t+1} \geq \rho d^i_{t+1} \tag{7}$$

4.3 Entrepreneurs

Preferences There is a continuum of heterogeneous entrepreneurs with fixed mass λ_e in the economy, indexed by j. They have preferences over an uncertain consumption stream given by

$$\mathbb{E}_0 \sum_{t \geq 0} \beta^t u(c^j_t) \tag{8}$$

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

Portfolio choice At the decision stage of each period, an entrepreneur arrives with a cash-on-hand variable x^j_t. This wealth must be spent on current consumption c^j_t, next-period physical capital k^j_{t+1}, or next-period financial asset a^j_{t+1}.

Production technology 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; a fraction δ of physical capital depreciates in the process. We assume that the production function is of the form

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

Following Lucas (1978), we introduce an entrepreneur-specific fixed factor z with a span-of-control parameter $\nu < 1$. We assume that z is a random variable and follows a Markov process with transition matrix Π_z. In every period, taking as given a realization of z_t^j, a pre-installed level of capital k_t^j, and wage w, each firm hires labor to maximize profit

$$\pi(k_t^j, z_t^j) = \max_n \left\{ f(z_t^j, k_t^j, n) - w_t n \right\} \tag{9}$$

Financial asset Each entrepreneur has access to a saving or borrowing technology via a non-contingent financial asset a_{t+1}^j. In the case of savings, $a_{t+1}^j > 0$, the asset pays a risk-free interest rate of r_{t+1}^d. In the case of debt, $a_{t+1}^j < 0$, the interest rate is $r_{t+1}^b > r_{t+1}^d$ and entrepreneurs are only allowed to borrow up a debt limit $\underline{a}_e - \varphi k_{t+1}$ which is partly unsecured and partly collateralized with the newly installed physical capital.

Non-strategic default As an underlying friction that generates fluctuations in the value of the lenders' risky assets, we introduce a non-strategic default shock on borrowers' debt. The shock takes a form of an idiosyncratic binary random variable, Γ_t^j. If $\Gamma_t^j = 1$, which happens with probability ξ, borrower j only repays the secured portion of his debt above $\underline{a}_e$ and his next-period wealth becomes

$$x_{t+1}^j = w_{t+1} + \pi(z_{t+1}^j, k_{t+1}^j) + (1-\delta)k_{t+1}^j + (1 + r_{t+1}^b)\min\{0, a_{t+1}^j - \underline{a}_e\} \tag{10}$$

On the other hand, if $\Gamma_t^j = 0$, which happens with probability $1 - \xi$, borrower j must repay the full debt and his next-period wealth is

$$x_{t+1}^j = w_{t+1} + \pi(z_{t+1}^j, k_{t+1}^j) + (1-\delta)k_{t+1}^j + (1 + r_{t+1}^b)a_{t+1}^j \tag{11}$$

Shadow lenders At the decision stage of each period, an entrepreneur has an option to become a shadow lender. In such case, he continues to produce output using physical capital, but any excess financial assets $a_{t+1}^j > 0$ are invested in corporate loans and earn the interest rate $r_{t+1}^b > r_{t+1}^d$. On the other hand, these loans are also risky and shadow lenders face the same idiosyncratic shock to their value, ω^j_{t+1}, as regulated banks do. In addition, shadow banks must pay a fixed cost f_S at the decision stage of every period.

4.4 Workers

Preferences There is a continuum of workers of fixed mass $1 - \lambda_e$ in the economy indexed by s. They have preferences over consumption given by

$$\mathbb{E}_0 \sum_{t \geq 0} \beta^t u(c^s_t) \tag{12}$$

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 workers face an idiosyncratic labor income risk and have access to a riskless, one-period non-contingent bonds through which they can borrow and save at the interest rate of r^d_t. In addition, workers receive equal dividend payments from the banks.

4.5 Clearing House

Because we abstract from any direct matching between the different types of agents in our model, we assume the existence of a clearing house that manages the flows of funds and labor. By posting market-clearing general equilibrium prices (r^b_t, r^d_t, w_t), the clearing house balances out demand and supply in each market. It is worth emphasizing, in particular, that the clearing house randomly transforms the distribution *of the fraction of loans* repaid in the process. Specifically, the fraction of loans repaid by borrowers is determined by the non-strategic default shock Γ^j_{t+1}, while the distribution of the fraction of loans repaid to the lenders is given by a continuous random variable $\omega_{t+1} \in [0, 1]$. In equilibrium, however, the quantities of defaulted loans always balance out by setting the proper value of the expected repayment rate $\mu \equiv \mathbb{E}(\omega_{t+1})$. We use this assumption as a reduced-form way to introduce the notion of imperfect risk diversification by the lenders. It should be highlighted, however, that in doing so the clearing house operates mechanically period-by-period and never earns or loses money in the process.

4.6 Recursive Formulation

In this section, we express the model in recursive formulation which 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

$$V^B(e,p) = \max_{c,b',m',d'} u(c) - h(p) + \beta_b E_{\omega'} V^B(e',p') \tag{13}$$

$$s.t.\ c + b' + m' - d' = e \tag{14}$$

$$e' = (1+r^b)b'\omega' + (1+r^m)m' - (1+r^d)d' \tag{15}$$

$$p' = \kappa\chi b'\omega' - \left(b'\omega' + m' - d'\right) \tag{16}$$

$$m' \geq \rho d' \tag{17}$$

In the problem above, formula (14) represents the bank's budget constraint which implies that current equity can be spent on dividend payouts c, risky loans to firms b', central bank reserves m', and it can be supplemented with raising deposits d'. Equation (15) shows that the equity next period will depend on the interest rates on the three portfolio components, as well as the realization of the loans default shock ω'. We introduce the capital constraint in a soft form, by assuming that banks incur utility punishments for violating the minimum capital requirement.[19] State variable p' in formula (16) captures the deviation of the bank's posted 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. Finally, expression (17) 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 unique 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, i.e. big banks are essentially a scaled-up version of small banks. As a result, a stationary distribution does not determine the aggregate level of equity. As we will show in Section 5, this is not necessarily the case in our setup because capital requirements may inhibit the ability of banks to use deposits to leverage up and make an optimal amount of risky investments. The key to achieving this result is to introduce non-homotheticity in the penalty function $h(p)$ which, as we will argue, is consistent with the core idea of Basel III.

[19] In reality, when a bank's capital ratio falls below the requirement minimum it is subject to various penalties imposed by the regulators, in particular to restrictions on the distribution of dividends. It is important to note that this can occur via a realized capital ratio, or as a result of a failed stress test.

Entrepreneurs An entrepreneur in our model enters the decision stage of each period (night time) with two state variables: net worth x, and idiosyncratic productivity of his business idea z. He decides how much to consume or save, which in turn entails a portfolio choice between selecting financial assets and installed capital for the next period. During the realizations stage of the next period (day time), he uses the pre-installed physical capital and hires workers to carry out production. The entrepreneur's income next period will then consist of the sum of his own labor income (we assume it is provided inelastically), profit from running business, undepreciated capital and the gross return on the financial assets.

Problem of a regular firm An entrepreneur who has chosen to be a regular firm solves

$$V^R(x,z) = \max_{c,a',k'} u(c) + \beta \mathbb{E}_{z',\Gamma'}\Big[V(x',z')|z\Big] \tag{18}$$

$$s.t. \quad x = c + a' + k' \tag{19}$$

$$x' = w + \pi(k',z') + (1-\delta)k' + \Big(1 + r(a')\Big)\Big(a' - s(\Gamma',a')\max\{a',\underline{a}_e\}\Big) \tag{20}$$

$$r(a') = r^d \mathbb{1}\{a' \geq 0\} + r^b \mathbb{1}\{a' < 0\} \tag{21}$$

$$s(\Gamma',a') = \mathbb{1}\{\Gamma' = 1, a' < 0\} \tag{22}$$

$$a' \geq \underline{a}_e - \varphi k' \tag{23}$$

where V is the continuation value of a generic entrepreneur who then decides again whether to become a shadow lender or not. Current net worth x can be spent on consumption c, or investment in financial assets a' or physical capital k'. Next period net worth will consist of the entrepreneur's labor income, as well as gross returns on the two types of assets. Equation (21) shows that entrepreneurs face different interest rates on their financial assets, depending on whether they have savings or loans. Firms can borrow up to a limit of $\underline{a}_e - \varphi k'$ and their debt consists of an exogenous unsecured credit line $\underline{a}_e$, and a loan collateralized with the newly installed physical capital. To match the lenders' losses on the extended credit, we introduce a possibility of a non-strategic default on the borrowers' side. An entrepreneur who has borrowed ($a' < 0$) may receive a default shock ($\Gamma' = 1$) next period which occurs with a fixed probability ξ. In such case, he is only liable for repayment of any debt in excess of the unsecured credit line $\underline{a}_e$.[20]

[20]This way of modeling debt is motivated by the fact that, in the data, roughly half of all corporate debt is collateralized. In the quantitative analysis in Section 5, we select the parameters to match this fact. In particular, the parameter $\varphi < 1$ can be interpreted as a fraction of the installed physical capital that can be easily seized and liquidated by the lenders in the case of default.

Problem of a shadow lender An entrepreneur who becomes a shadow lender solves

$$V^S(x,z) = \max_{c,a',k'} u(c) + \beta \mathbb{E}_{z',\omega'} \Big[V(x',z') | z \Big] \tag{24}$$

$$s.t. \quad x = c + a' + k' + f_S \tag{25}$$

$$x' = w + \pi(k',z') + (1-\delta)k' + (1+r^b)\omega' a' \tag{26}$$

$$a' \geq 0 \tag{27}$$

where V is the continuation value of a generic entrepreneur who then decides again whether to become a shadow lender or not. Current net worth x can be spent on consumption, or investment in financial assets a' or physical capital k'. In addition, to operate as a shadow lender, an entrepreneur must incur a fixed cost of f_S. Next period net worth 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 lender can earn interest rate r^b on their financial assets, as opposed to a (potentially lower) rate r^d. The downside of choosing to do so is that a shadow lender faces the same shock to the value of his financial assets, ω', as regulated banks do.

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

$$V(x,z) = \max \Big\{ V^R(x,z), V^S(x,z) \Big\} \tag{28}$$

Worker's problem The recursive problem of a worker is

$$V^W(x,y) = \max_{c,a'} u(c) + \beta E_{y'} \Big[V^W(x',y') | y \Big] \tag{29}$$

$$s.t. \quad x = c + a' \tag{30}$$

$$x' = wy' + (1+r^d)a' + c_b \frac{\lambda_b}{1-\lambda_e} \tag{31}$$

$$a' \geq 0 \tag{32}$$

Workers in this economy are standard and modeled as in Aiyagari (1994). In order to make the timing of workers' decisions consistent with the other parts of the economy, we pose our recursive problem in terms of a wealth (or cash-on-hand) state variable x. Each worker's labor productivity y follows a stochastic autoregressive process. Uninsurable idiosyncratic labor risk generates a motive for workers to accumulate wealth through savings in risk-free assets a', which are then deposited with the banking sector (and paid the corresponding interest rate r^d). For simplicity, we assume that workers are not allowed to borrow (see Section 4.8 for further discussion of this modeling assumption). Finally, because workers ultimately own all the banks, they receive a lump-sum transfer of the banks' aggregate dividend c_b, scaled in proportion to the respective measures of these two types of agents.

4.7 Stationary Equilibrium

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

Definition 1 *A stationary recursive competitive equilibrium consists of policy functions for banks* $\{c_b, b', m', d'\}$, *borrowing entrepreneurs* $\{c_{r-}, a'_{r-}, k'_{r-}\}$, *depositing entrepreneurs* $\{c_{r+}, a'_{r+}, k'_{r+}\}$, *shadow lenders* $\{c_s, a'_s, k'_s\}$, *and workers* $\{c_w, a'_w\}$; *labor allocations for borrowing entrepreneurs, depositing entrepreneurs and shadow lenders* $\{n_{r-}, n_{r+}, n_s\}$, *respectively; value functions of all types of agents* $\{V^B, V^{R-}, V^{R+}, V^S, V^W\}$; *cumulative distribution functions for all types of agents* $\{\Lambda_b, \Lambda_{r-}, \Lambda_{r+}, \Lambda_s, \Lambda_w\}$; *and prices* $\{r^b, r^d, w\}$ *such that:*

1. *Given the general equilibrium price vector* $\{r^b, r^d, w\}$, *the allocations solve the bank's, the regular firm's, the shadow lender's, and the worker's maximization problems.*

2. *Asset and labor markets clear:*

$$\int_E b'(e)d\Lambda_b(e) + \int_{X\times Z} a'_s(x,z)d\Lambda_s(x,z) = \int_{X\times Z} a'_{r-}(x,z)d\Lambda_{r-}(x,z) \qquad (loans)$$

$$\int_{A\times Y} a'_w(a,y)d\Lambda_w(a,y) + \int_{X\times Z} a'_{r+}(x,z)d\Lambda_{r+}(x,z) = \int_E d'(e)d\Lambda_b(e) \qquad (deposits)$$

$$\int_E m'(e)d\Lambda_b(e) = \overline{M} \qquad (reserves)$$

$$\int_{X\times Z} n_{r-}(x,z)d\Lambda_{r-}(x,z) + \int_{X\times Z} n_{r+}(x,z)d\Lambda_{r+}(x,z) + \int_{X\times Z} n_s(x,z)d\Lambda_s(x,z) = 1 \qquad (labor)$$

A thing to note is that, while not part of the formal definition of equilibrium, we also need to make sure that the amount of defaulted debt is equal for both borrowers and lenders. We achieve this by selecting the proper value of μ, the expected loans repayment rate, in the pre- and post-reform stationary equilibria. We also assume that the central bank's demand for reserves is perfectly elastic with a constant exogenous interest rate r^m.

4.8 Discussion of the model assumptions

This section provides a discussion of some important modeling assumptions.

Household debt Given the nature of our micro data, we focus on modeling the corporate debt only and do not allow workers to borrow. While this assumption is mostly made for tractability, it is also motivated by the facts. Household debt in Korea is considered much less risky by bank regulation than corporate debt. In particular, the risk weight assigned to the former is only one-third of the risk weight assigned to the latter (Kim and Jung , 2019). In the quantitative analysis, we only target a fraction of the banking sector that corresponds to corporate lending.

Shadow lenders In Section 2 we show that, in the data, non-bank lending comes from a wide variety of institution types. In particular, they do not necessarily take deposits or have any formal ties to regulated banks. For this reason, we abstract from many aspects of shadow banking that is often emphasized by the literature such as deposit-taking, off-balance sheet entities, or maturity mismatch. Instead, our model proposes a very general theory of non-bank lending and highlights the key new feature that emerges from Section 2, namely the *endogenous formation* of shadow lenders.

No aggregate uncertainty To keep the model tractable, we do not admit any aggregate shocks in the model. Instead, in Section 6 we compute the full transitional dynamics induced by the change in bank regulation. For this reason, we do not model events such as systemic bank crises or government bailouts which are often considered as rationale for higher capital requirements (our micro-data also does not cover any such episodes). Hence, even though in Section 7 we use the model to analyze the macroeconomic consequences of Basel III, our paper does not provide a general statement on the optimal level of capital regulation.

5 Quantitative Analysis

In this section, we describe the calibration of our model and discuss the mechanics of the main policy functions and the 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 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 small values for negative realizations of p, and increases sharply once p becomes positive. This has the advantage of producing a highly asymmetric cost while the function itself is differentiable and can be used to solve the model with first-order conditions.[21]

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

$$u(c) = \frac{c^{1-\gamma}}{1-\gamma}$$

The stochastic process for entrepreneurs' business productivity is

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

Similarly, the workers' labor efficiency follows the process

$$log(y_{t+1}) = \rho_y log(y_t) + \sigma_y \epsilon_{y,t+1}$$

where both $\epsilon_{z,t+1}$ and $\epsilon_{y,t+1}$ are i.i.d. normal innovations with mean zero and standard deviations of σ_z and σ_y, respectively.

We solve the model numerically using global methods by iterating over policy and value functions of different groups of agents, and then aggregating them to find their stationary distributions. Appendix D.1 discusses the details of the numerical algorithm we use to find a general equilibrium vector of prices (r^b, r^d, w).

[21] A functional form like this has wide applications in quantitative macroeconomics. For example, it has been very useful in the sovereign default literature as a proxy for the exogenous costs resulting from a government default (Aguiar et al., 2016).

5.2 Calibration

To calibrate the model, we select the values for a number of parameters to replicate several empirical characteristics of the Korean banking sector, and its structure and size within the broad macroeconomy. We split the description of our procedure into banks-related parameters, and the remaining parameters.

5.2.1 Banks

We calibrate the parameters that govern the behavior of banks as follows. The first set of them is chosen independently from the model solution. The capital requirement κ is set to 4%, the pre-Basel III level for Tier 1 Capital Ratio. The discount factor β_b and risk aversion γ_b are set to the values of 0.92 and 1, respectively, following Bianchi and Bigio (2018). In particular, the low discount factor is required to prevent bank equity from diverging in the long run. The idiosyncratic shock to lenders' risky asset value ω is assumed to follow the beta distribution. An advantage of this assumption is that beta distribution has a bounded domain of $[0, 1]$. We pick the two parameters of this distribution, a_B and b_B (with the expected repayment rate $\mu = \frac{a_B}{a_B+b_B}$), along with the two parameters of the capital requirement penalty function, ϕ_0 and ϕ_1, and the risk weight χ in a joint calibration exercise. We target the following moments from the data on the Korean banking industry in years 2010-2013:[22] the ratios of average loans and average deposits to average equity,[23] mean and standard deviation of the realized bank capital ratios, and the correlation of realized capital ratios with bank equity. The former two moments inform the model about the amount of leverage in the banking sector. The latter three moments identify the restrictiveness of penalties for violating capital requirements, as well as the degree of non-homotheticity of these penalties. This allows us to capture the endogenous equity buffers over the binding capital requirements that are evident in the data (Figure 4). Table 3 summarizes the parameter values calibrated for the banking sector.

5.2.2 Workers and entrepreneurs

To calibrate the rest of the economy, we follow the standard approach of adopting some of the parameters from existing literature, and selecting others so that the model economy replicates several essential features of the Korean economy. The parameters that govern

[22] The model moments also depend on interest rates r_b and r_d. Their selection is described subsequently, in Section 5.2.2.

[23] As explained in Section 4.8, we abstract from the riskiness of household debt. For this reason, we only consider the fraction of bank equity that corresponds to the proportion of corporate loans in total lending.

Table 3: Calibration of bank parameters

Parameter	Meaning	Value	Source
γ_b	Risk aversion	1	Literature
β_b	Discount factor	0.92	Literature
ρ	Reserve requirement	0.07	Korean data
κ	Capital requirement	0.04	Basel II
a_B	Shape parameter a	77.25	Joint calibration
b_B	Shape parameter b	0.81	Joint calibration
ϕ_0	Level parameter of penalty	2.47	Joint calibration
ϕ_1	Curvature parameter of penalty	3.79	Joint calibration
χ	Risk weight	0.82	Joint calibration
Calibration targets		**Model**	**Data**
E (loans)/E(equity)		9.10	9.13
E (deposits)/E(equity)		8.79	8.77
E (realized cap. ratio)		10.97	10.97
St. dev. (realized cap. ratio)		1.55	1.61
Corr (realized cap. ratio, equity)		0.38	0.39

the behavior of entrepreneurs and workers are fairly standard and consistent with existing literature. The discount factor is set to 0.96, and risk aversion is 2. The persistence of both workers' labor efficiency ρ_y and entrepreneurs' business productivity ρ_z are set to 0.8, a typical value in the literature. Similarly, the span-of-control parameter ν is set to 0.8, a standard value among the recent papers on entrepreneurship. We further use the National Accounts data for Korea to infer the depreciation rate δ of 0.075 and the standard deviation of entrepreneurs' business productivity shock σ_z of 0.5.[24] Finally, we set the weight on capital α in the production technology by assuming a labor share of 0.51, an average and fairly stationary value for Korea since the Asian financial crisis of 1997 (data from Penn World Tables). The remaining parameters, which include the standard deviation of workers' labor efficiency shock σ_y, the collateralizable share of capital φ, the unsecured credit line for entrepreneurs $\underline{a}_e$, the fixed cost of operating as a shadow lender f_S, and the measures of entrepreneurs and banks (λ_e and λ_b, respectively), are jointly calibrated to match six empirical moments. The standard deviation is identified by targeting the ratio of corporate bank loans to all corporate deposits, which is equal to 2.14 according to the Bank of Korea data (the missing deposits then come from workers' savings, the

[24]Specifically, using the OECD National Accounts we first infer the average capital-to-output ratio on the balanced growth path of 2.5. Fixing σ_z at 0.5 in all calibrations allows us to achieve this value approximately (we do not include this target in the moments-matching exercise to economize on computational effort). Second, we set the depreciation rate δ to match the average consumption of fixed capital to GDP, which is around 18% since 2000 according to the OECD data.

size of which is determined by the idiosyncratic labor risk they face). The collateralizable capital share and the unsecured limit are identified by matching the average share of collateralized corporate credit and the overall size of the banking sector relative to the economy,[25] while the fixed cost is pinned down by matching the fraction of shadow loans in total corporate credit of about 43% (which is inferred from the data shown in Figure 1). We further inform the two measures by targeting the average pre-reform loans and deposits interest rates of 3.44% and 1.64%, respectively. Finally, we make sure that the model is internally consistent by setting the default probability ξ so that the total loans defaulted on by the borrowers are equal to the total loans written-off by the lenders. Table 4 summarizes the calibration of the general economy in the model.

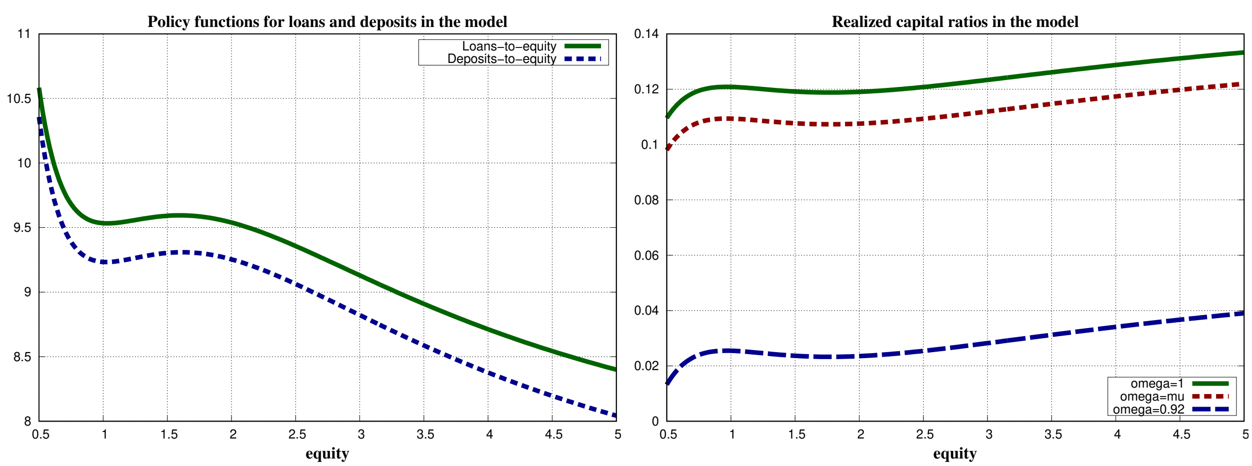
Table 4: Calibration of the parameters of general economy

Parameter	**Meaning**	**Value**	**Source**
γ	Risk aversion	2	Standard value
β	Discount factor	0.96	Standard value
ρ_y	Persistence of worker efficiency	0.8	Standard value
ρ_z	Persistence of firm productivity	0.8	Standard value
ν	Span of control	0.8	Standard value
δ	Depreciation	0.08	Korean data
α	Capital share	0.36	Labor share of 0.51
σ_z	St. dev. of firm productivity	0.5	Capital-to-output
σ_y	St. dev. of worker efficiency	0.12	Joint calibration
φ	Collateralizable share of capital	0.36	Joint calibration
$\underline{a}_e$	Unsecured credit line	−11.44	Joint calibration
f_s	Fixed cost to shadow lending	0.32	Joint calibration
λ_b	Mass of banks	0.01	Joint calibration
λ_e	Mass of entrepreneurs	0.03	Joint calibration
ξ	Default probability	0.02	Joint calibration
Calibration targets		**Model**	**Data**
Corp. bank loans to deposits ratio		2.70	2.14
Share of collateralized corp. loans		0.44	0.54
Bank equity / output ratio		4.55%	4.30%
Fraction of shadow loans		42.93%	42.70%
Interest rate on loans		3.44%	3.44%
Interest rate on deposits		1.64%	1.64%
Defaulted loans balance		0.00	0.00

[25]Because our model ignores household debt, we target a fraction of bank equity that corresponds to corporate loans only. According to the data from Bank of Korea, total bank equity to GDP in 2013 was 7.6%. Then, with corporate loans taking up 56.5% of all bank lending, we choose to target an aggregate equity to output of 4.3%, correspondingly.

5.3 Model mechanics

Banks decisions We first analyze the mechanics of a bank's decision making in the model, visualized in Figure 9. Panel 9(a) depicts the policy functions for loans and deposits (relative to equity) at different levels of bank equity. The main observation here is that banks' decisions are highly non-linear with respect to equity, with small banks being more leveraged and large banks investing less overall and contributing a larger share from their own capital. This contrasts with the result of Bianchi and Bigio (2018) where all policy functions are linear in equity. The curvature in our model is precisely due to the non-homothetic nature of the regulatory penalty function. Small banks must build up enough equity to create a safe buffer above the requirement. On the other hand, large banks are exposed to a disproportionately higher penalty in the event of a bad shock to loans value and hence prefer to decumulate some of their equity. Indeed, this non-homotheticity is consistent with the spirit of Basel III which has mandated that the largest ("systemically important") banks be put under a special supervision and subjected to an additional capital requirement. We capture this mandate with our non-homothetic specification of the penalty function and discipline its parameters by targeting the correlation of equity with realized capital ratios in the calibration.



(a) Loans and deposits

(b) Capital ratios

Figure 9: Bank policy functions in the model

Capital ratios The effect of capital requirements on bank behavior can be further appreciated by inspecting Figure 9(b) which presents realized capital ratios as function of current equity and for different realizations of the idiosyncratic shock ω. A few remarks related to the empirical observations of bank capital ratios in Figure 4 are in order. First, notice that banks tend to maintain sizable equity buffers over the required minimum, with the average buffer in fact being a targeted moment in our calibration. Hence, for a wide range of likely realizations of the ω shock, capital requirements are seemingly non-binding for most banks.[26] Second, when the shock realization is low enough (in this example, assets lose 8% of value), the posted ratios will fall below the requirement even for the largest banks. Finally, the realized ratios generally increase with the level of equity, which is once again a targeted moment enabled by the non-homothetic nature of the penalty function.

Formation of shadow lenders We next consider the behavior of firms in our model, with a focus on the determinants of shadow lender formation in the economy. Figure 10 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 in a bank account. On the other extreme, the firms who are not

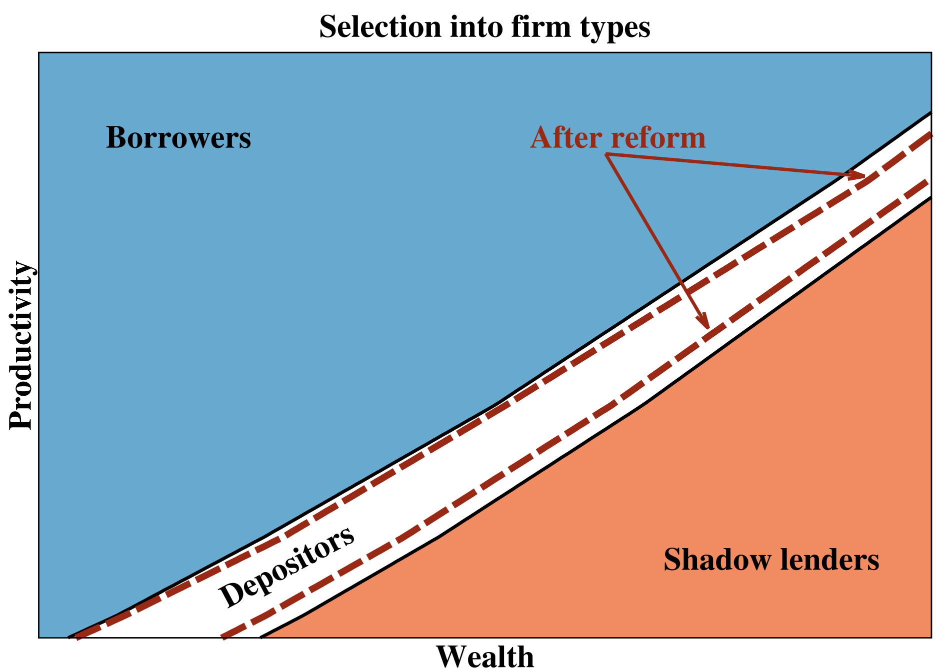


Figure 10: Endogenous selection into borrowers and shadow lenders in the model

[26]In reality, most of the incidents of non-compliance with capital regulation is detected through bank stress-testing. The supervisor simulates capital ratios under a range of hypothetical scenarios that aim to mimic large or systemic shocks to the financial system. Because our model does not capture such events, we capture stress-testing in the reduced-form way with our penalty function $h(\cdot)$.

very productive but have high wealth tend to become shadow lenders, lending out excess cash that cannot be used productively in their core business. The dashed red lines in the figure illustrate how the two decision thresholds change in the aftermath of a reform that raises the capital requirement for banks. In particular, the outer threshold moves to the left, which implies that former depositors are now becoming shadow lenders.[27] This occurs despite the fact that 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 effects of higher capital requirement

The first column of Table 5 shows the general equilibrium of our model under a baseline capital requirement of 4%. All quantities are expressed relative to average pre-reform bank equity which is normalized to 100. In this benchmark economy, banks' loans are roughly 9 times the equity level. Loans from shadow lenders make up about 43% of all lending and just over 7% of all entrepreneurs choose to engage in this activity. The loan and deposit interest rates which clear the asset markets are the targeted values of 3.44% and 1.64%, respectively. The spread of 1.8 percentage points between them reflects the banks' investment risk, and regulatory frictions such as reserve and capital requirements.

Table 5: Comparison of stationary equilibria before and after the reform

	Before reform	After (PE)	After (GE)
Capital requirement	4%	8.5%	8.5%
Banks			
Equity	100.00	19.04	115.54
Loans	910.15	98.64	780.29
Capital ratio (%)	10.97	20.80	16.01
Shadow lenders			
Loans	684.74	684.74	803.85
Share in all loans (%)	42.93	87.41	50.74
Share in all firms (%)	7.05	7.05	9.08
r_b (in %)	3.44	3.44	3.46
r_d (in %)	1.64	1.64	1.49
$w \times 100$	30.84	30.84	30.83

[27] While the outer threshold always shifts to the left, the direction of the shift of the inner threshold depends on parametrization. This is because a higher interest rate spread that arises as consequence of the reform (see Table 5) makes it less attractive both to become a borrower and a depositor.

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 (which we postpone until Section 6) and instead calculate the new stationary distribution under the requirement of 8.5% (mimicking Basel III). As a first step, the second column of Table 5 presents the partial equilibrium results, i.e. the invariant distribution under fixed prices. Notice that higher capital requirement causes the regulated banking sector activity to collapse, while credit from shadow lenders remains unchanged. This is because the reform does not affect shadow lenders in any way, and the equilibrium prices are held constant. The last column of Table 5 summarizes the new general equilibrium in which a price vector is found such that all markets clear.[28] In this equilibrium, average bank equity is about 16% higher than in the benchmark while bank loans fall by about 14%. Naturally, the price vector that supports this equilibrium includes a higher interest rate on loans and a lower interest rate on deposits. These new interest rates in turn change the incentives of entrepreneurs who are discouraged from saving in a bank account, and they find it more attractive to incur the fixed cost and engage in shadow lending. In our calibration, the shadow lending sector is very responsive to this change, leading the total shadow loans quantity to increase by 17%, while the fraction of credit extended by such lenders rises to 51% of total. At the same time, the fraction of entrepreneurs who decide to operate as a shadow lender increases from 7% to 9%, i.e. we observe an entry of new firms into the business of shadow lending as a result of the reform, consistent with the evidence from our data.

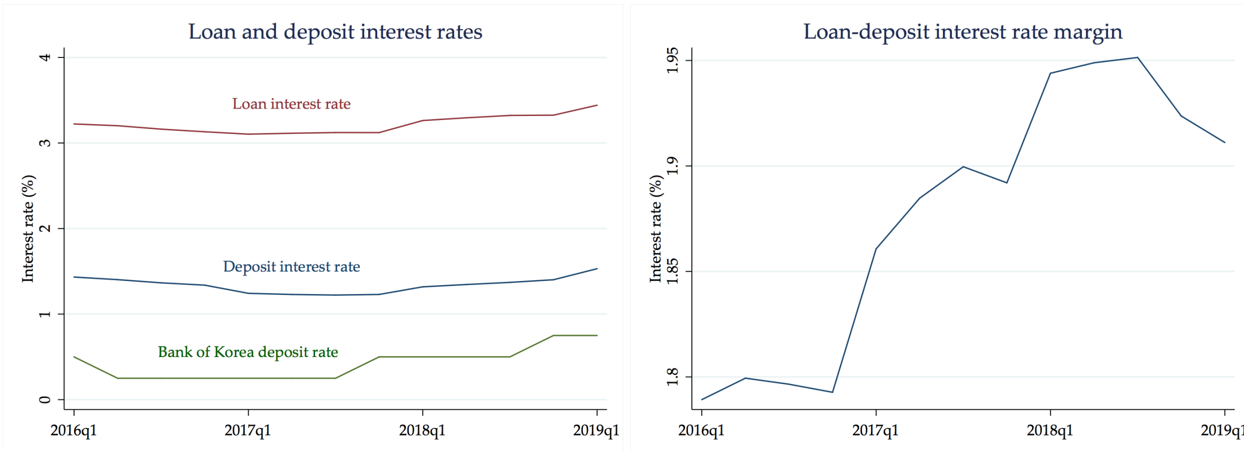
5.5 Aggregate interest rates in the data

As Table 5 makes it clear, the rise of shadow lenders in our model is driven by the change in general equilibrium interest rates that results from the new capital requirement. In this section, we provide empirical validation for this channel by examining interest rate movements in Korea over the time period of interest. Figure 11(a) plots the evolution of loan, deposit and a reference risk-free interest rate in years 2016-2019, while Figure 11(b) calculates the corresponding loan-deposit interest spread. The rates are averages across regulated banks and weighted by their share in total credit.[29] As can be noticed, the rates do not vary significantly during this period, but the spread indeed increases sharply in 2016, right when the reform becomes binding and the largest shifts in the volumes of

[28] We also need to find a new value of $1-\mu$ in the post-reform equilibrium, the mean fraction of credit that the lenders write off. In practice, the change in this variable needed to make sure that defaulted loans balance out is negligible (relative to the parameters in Table 3), which is why we do not report it here.

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

corporate credit occur. At its highest point, the loans-deposits spread reaches 1.96% which can be referenced against the prediction of our model in Table 5 of 1.97%.



(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 credit in data. Sample includes regulated banks, excluding special banks. Bank of Korea deposit rate is Base rate - 100bp, sourced from Bank of Korea.

Figure 11: Interest rates for regulated banks in the data

5.6 Effects of higher capital requirement on banks and firms

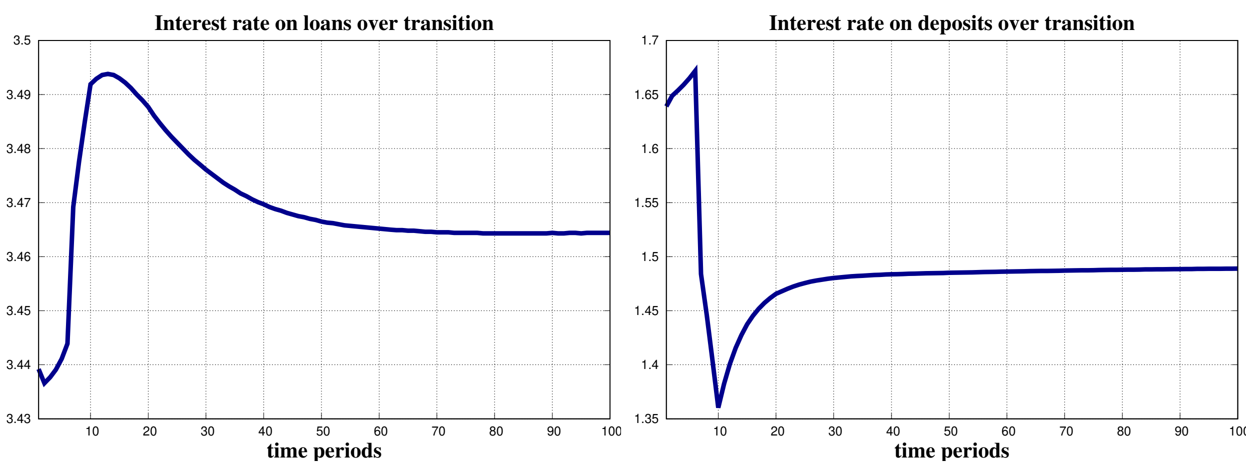
Appendix E provides additional analysis of the distribution of agents in the stationary equilibria of this model. In particular, it is worth pointing out that in the aftermath of the reform, both the mean and the standard deviation of posted capital ratios increase, while the correlation of equity with posted capital ratio drops (these are the targeted moments before the reform). All three movements are in fact observed in the data between 2013 and 2019. We also show that the inflow of new shadow lenders makes them more numerous but smaller on average, while the borrowers are mostly able to offset the tighter credit and suffer a minor reduction in average output.

6 Transitional dynamics: model meets data

In this section, we link the results from our model to the estimated impact of higher capital requirements on regulated bank lending and shadow lending in Section 3. To do so, we calculate the transition between the two stationary equilibria induced by the reform. As it is standard in the literature, we assume the transition is deterministic, i.e. all agents have perfect foresight as for the future path of prices from the moment they find out about the reform.[30] We make the transition as realistic as possible by assuming that the reform is announced in 2010 and follows the schedule of increases just as described in Table 1 (we ignore the non-binding period prior to 2016). Starting from year 2019, the new permanent capital requirement is 8.5%.

6.1 Prices and aggregates over the transition

Figure 12 shows the paths of market-clearing interest rates on loans and deposits over the transition between the two steady states. It should be noticed that the spread between these two rates increases slightly more on impact of the reform than what the mere comparison of the stationary equilibria in Table 5 suggested (the maximum predicted spread is around 2.11%). It is also worth noting that the transition of the deposit rate occurs faster than the one for lending rate, and has a prominent anticipatory trend (before the reform becomes enforceable) which goes in the opposite direction.



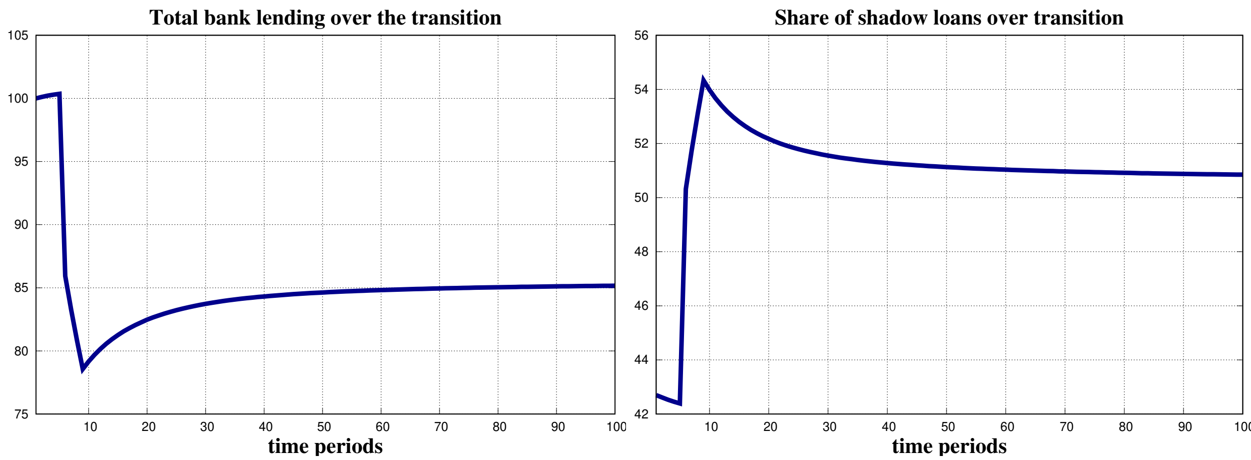
(a) Interest rate on loans

(b) Interest rate on deposits

Figure 12: General equilibrium interest rates over the transition

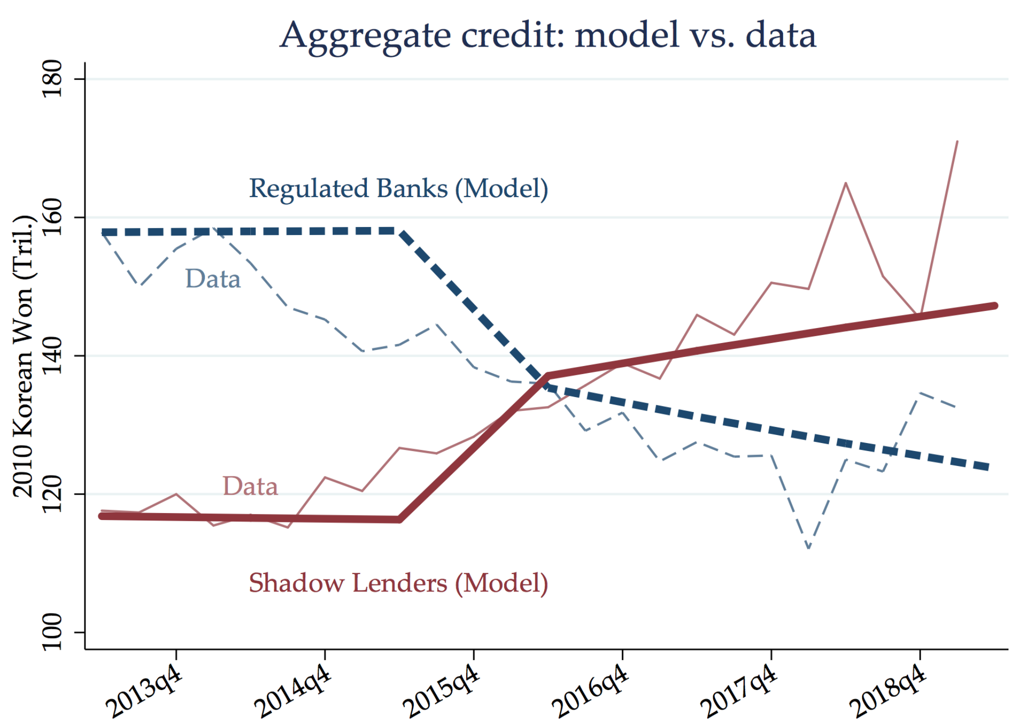
Figure 13 presents the normalized paths of lending to entrepreneurs on transition. Panel 13(a) shows that total lending by regulated banks drops fast on impact of the reform and dips below 80% of the pre-reform level at its lowest, before stabilizing at just under 85%. On the other hand, panel 13(b) shows that the share of shadow loans in total credit expands to 54% at the peak, before reverting back and gradually converging to around 51% as predicted by the new stationary equilibrium.

[30] Appendix D.2 describes the details of the algorithm we use to compute the transition.



(a) Total bank lending (b) Share of shadow loans

Figure 13: Equilibrium lending over the transition

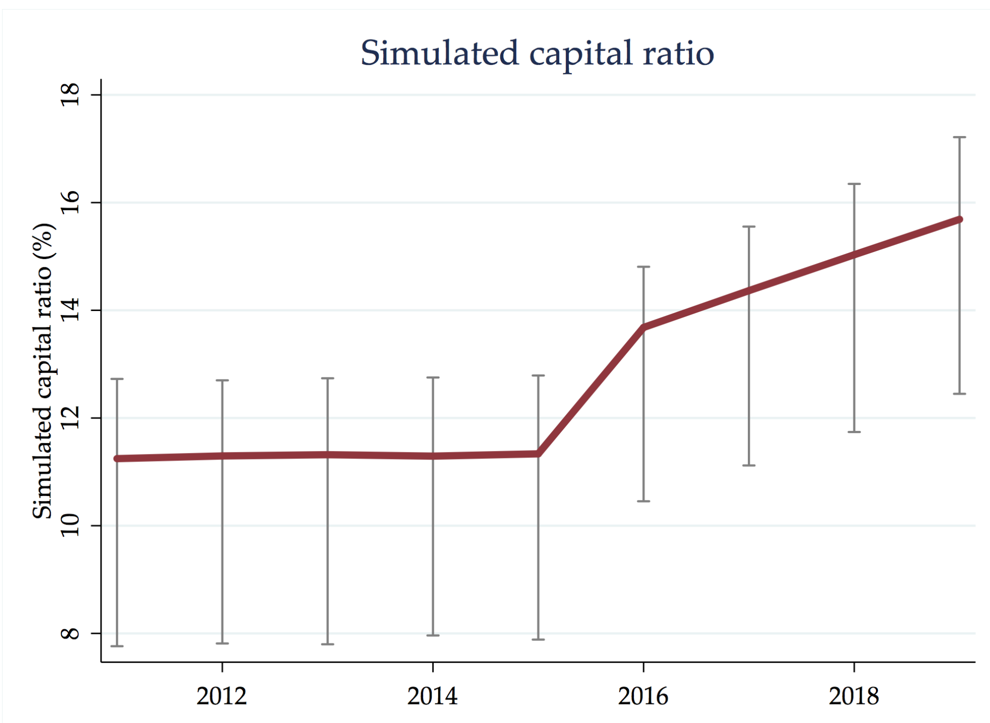


Note: Thick lines depict the transition of total credit from regulated banks and shadow lenders predicted by the model. Thin lines show the data counterpart from Figure 1. Both model-generated series are normalized by the total regulated bank credit observed in the data for 2013Q2. Because the former is in annual frequency, we associate each year in the model with second quarter.

Figure 14: Total credit from regulated banks and shadow lenders in the model

Figure 14 presents a synthesis of these results by constructing the model counterpart to our main observation from Figure 1. It plots the total credit extended by regulated banks and shadow lenders over the period of the transition path that corresponds to years 2013-2019. For comparison, we include the data series originally shown in Figure 1. The picture conveys our main finding that Basel III explains almost all of the decline in regulated bank lending, and about three quarters of the observed increase in shadow financing.[31]

Figure 15 constructs the model counterpart to our empirical observation on the behavior of bank capital ratios in Figure 4. It plots the distribution of realized capital ratios in the model for the periods of the transition that correspond to years 2013-2019. Recall from Section 5 that the mean and standard deviation of capital ratios are targeted moments in our calibration for the pre-reform stationary equilibrium. As Basel III becomes binding in 2016, the capital ratios move upwards similarly as in the data, with the median increasing to about 16% (in the data, the median is around 14% in 2019Q1).



Note: The solid red line represents the capital ratio of a median bank. The gray lines stretch from the 5-th to 95-th percentile of realized capital ratios in the simulated sample.

Figure 15: Realized bank capital ratios in the model simulation

[31] The mismatch in years 2014-2015 indicates that the change in credit provision in anticipation of the reform was potentially stronger in reality than what our model predicts.

6.2 Micro estimates in the model

We now use the model to estimate the impact of higher capital requirements on the credit provision by regulated banks and non-bank shadow lenders. To do so, we simulate a large number of banks along with a large number of entrepreneurs and track them over the transition. We then run the model-analogs of regressions (1) and (2), which we used in our econometric analysis, for the corresponding time period, and we compare the results.

Table 6 shows the estimation results for regression (1) using our simulated bank data. We run several variants of this specification, in particular we include bank fixed effects or not, and we control for the ω shocks or not.[32] Similarly as in the data, we find consistent and strongly negative coefficients on the capital requirement. The size of this coefficient of –0.113, falls well within the confidence interval of the original estimate of –0.14 which we found with the micro data (Table 2). It should be emphasized that our model does not use any information from the micro data in its construction or calibration.

Table 6: Effects of capital requirements on credit growth in model simulated data

VARIABLES	(1) Δ ln loans	(2) Δ ln loans	(3) Δ ln loans	(4) Δ ln loans
ln min. capital req.	-0.113***	-0.113***	-0.114***	-0.113***
	(0.0015)	(0.0014)	(0.0016)	(0.0014)
ω			-1.386***	0.0172
			(0.0465)	(0.0415)
Constant	0.152***	0.152***	1.524***	0.135***
	(0.0024)	(0.0023)	(0.0458)	(0.0409)
Observations	70,056	70,056	70,056	70,056
Fixed Effects	Bank	None	Bank	None
R2	0.184	0.0699	0.197	0.0699

Note: Because our actual data ends at 2019Q1, we only use years 2013-2018 in these model-based regressions. All standard errors (in parentheses) are clustered at the bank level. *** p<0.01

We next run regression (2), which estimates the spillover effect of the change in capital regulation on shadow credit growth, using a panel of simulated entrepreneurs generated by the model. Similarly as for the empirical data, we include time and lender fixed ef-

[32]Because we do not have direct matching between banks and firms, controlling for ω, the shocks to banks' loan value, is the closest counterpart to firm fixed effects that we can include in our data regressions.

fects.[33] Figure 6.2 presents our results in the form of a graph that is a direct counterpart to Figure 5. Before the reform becomes binding in 2016, the growth of credit provided by shadow lenders does not significantly out-pace the one by regulated banks. This changes in 2016 when the capital requirement increases for the first time on our transition schedule, leading to a coefficient estimate of 0.15. This point estimate is somewhat larger than the 0.1 one we found in the data, but still within the 95% confidence interval. The spillover effect in the model then dissipates along with the data estimates in years 2017 and 2018.

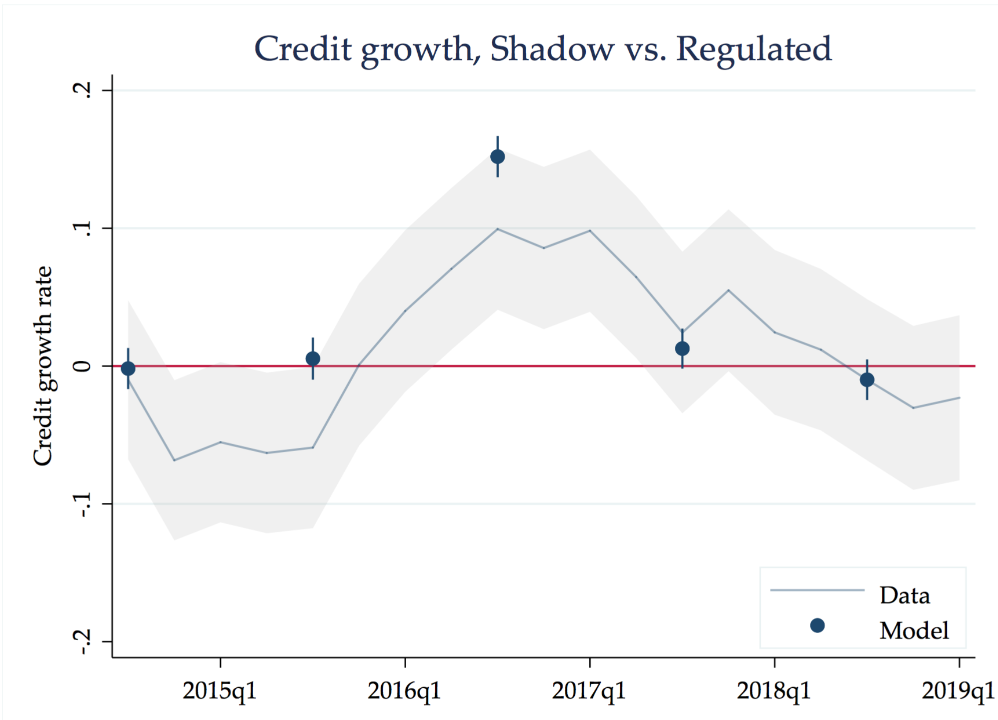


Figure 16: Estimated interaction effects of time and shadow dummies: model vs. data

Note: The navy line represents estimated coefficients from the data (Figure 5), and the gray area represents the 95% confidence interval of estimated coefficients. The navy dots and bars represent model estimates and their 95% confidence intervals, respectively. Annual estimation from the model is assigned to the third quarter of each data coefficients. All coefficients are estimated relative to the year 2013.

7 Macroeconomic effects of bank regulation

In this section, we analyze the broader macroeconomic effects of capital regulation. We consider both the comparison of stationary equilibria, and the transition induced by Basel

[33]Naturally, in the simulated data we observe agents becoming shadow lenders and exiting in every period. Because the regression uses log differences, we only include agents in the sample if they have remained a shadow lender for at least two consecutive periods.

III. To highlight the role of shadow lenders in the economy, as well as the role of the reform implementation, we design two counterfactual scenarios:

1. **Government goes after shadow lenders:** Along with introducing higher capital requirements, the government simultaneously increases the fixed cost of operating as a shadow lender, f_S, to prevent the share of shadow loans from increasing;

2. **Sudden and drastic change:** Instead of pre-announcing the reform ahead of time and spreading the increase in capital requirement over time, the government announces a one-time jump effective immediately.

The first counterfactual exercise is motivated by the fact that the recent rise of shadow finance has been perceived by many as an unwelcome and potentially destabilizing force.[34] The second exercise aims to investigate the role of implementation design in the broader macroeconomic effects of capital regulation.

7.1 Comparison of stationary equilibria

Table 7 presents the comparison of the real effects of capital regulation across the different stationary equilibria. Notice that we implement the first counterfactual scenario by increasing the fixed cost of operating as a shadow lender by about 40%. As a result, the share of shadow credit in the new general equilibrium is kept at an unchanged level. Notice also that the second counterfactual scenario is missing here because it only affects the transition path.

Overall, we find that, apart from the shift from regulated credit to shadow credit, bank capital regulation has generally negligible long-run effects on the real economy. In particular, aggregate output declines by 0.01-0.05% in the post-reform equilibria. While a higher loans rate discourages the potential borrowers with high productivity, we also observe that the lower deposit rate induces some depositors to invest more of their resources in physical capital, while others choose to become shadow lenders and provide the missing credit.[35] On the other hand, in the counterfactual world where the expansion of shadow loans is thwarted, banks have incentive to bulk up and provide a similar amount of credit while staying compliant with the regulation. This results in a 30% higher aggregate bank equity, and a further widening of the equilibrium interest rate spread.

[34] See e.g. "Shadow Banks Need Regulation to Rein in Financial Risks", *Bloomberg*, November 1 2019; or "The clean-up of the non-bank sector needs to begin now", *Financial Times*, April 19 2020.

[35] See Appendix E for a detailed analysis of firm distribution across the stationary equilibria.

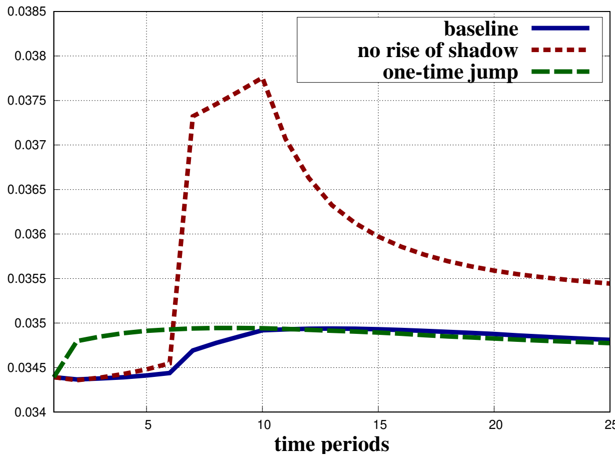
Table 7: Real effects of the reform across stationary equilibria

	Before	After (PE)	After (GE)	Counter I (GE)
Parameters				
Capital requirement	4%	8.5%	8.5%	8.5%
Fixed cost for shadow	0.31	0.31	0.31	0.44
Real economy				
Output	100.00	100.00	99.99	99.95
Capital/output ratio	2.66	2.66	2.66	2.66
Wealth/output	3.46	3.46	3.45	3.45
Debt/output	0.73	0.73	0.72	0.71
Consumption/output	0.82	0.81	0.82	0.82
Bank equity/output (in %)	4.55	0.89	5.25	5.98
Share of shadow loans (in %)	42.93	87.15	50.74	42.94
Share of shadow lenders (in %)	7.05	7.06	9.08	6.64
Prices				
r_b (in %)	3.44	3.44	3.46	3.53
r_d (in %)	1.64	1.64	1.49	1.51
$w \times 100$	30.84	30.84	30.83	30.82

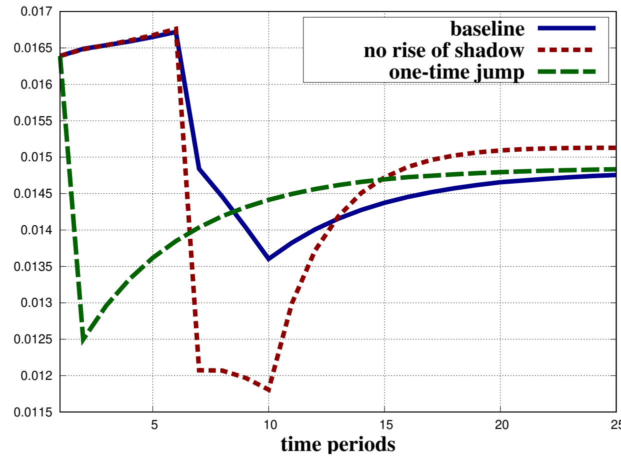
7.2 Comparison of transition paths

We now turn to the analysis of the macroeconomic effects of bank regulation on transition under different scenarios. Figure 17 presents an overview of the interest rate paths, along with the parameter schedules that define each scenario. Panel 17(a) shows that the increase in lending rate is quite modest in the baseline and the "one-time jump" scenario relative to the counterfactual exercise where the government increases fixed cost of operating as a shadow lender to prevent the share of shadow loans from expanding (the period-by-period fixed costs needed for that are shown in panel 17(d)). Likewise, panel 17(b) demonstrates that the deposit rate falls more in this scenario. Overall, we find that the loans-deposits interest spread is up to 27% higher when shadow lenders are not allowed to expand than in the baseline reform exercise.

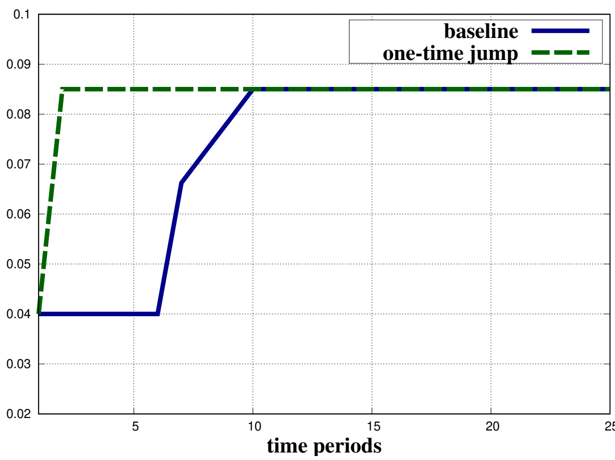
Finally, Figure 18 plots the paths of total output under the three scenarios. We find that, first of all, the baseline increase in capital requirement has a modest impact on GDP in the economy. This effect is marginally worse under the alternative implementation schedule, where the increase takes the form of a one-time jump and is announced without anticipation. In both cases, the largest drop in output is below 0.1%. On the other hand, output drops by 0.2% in the world where the government simultaneously prevents the expan-



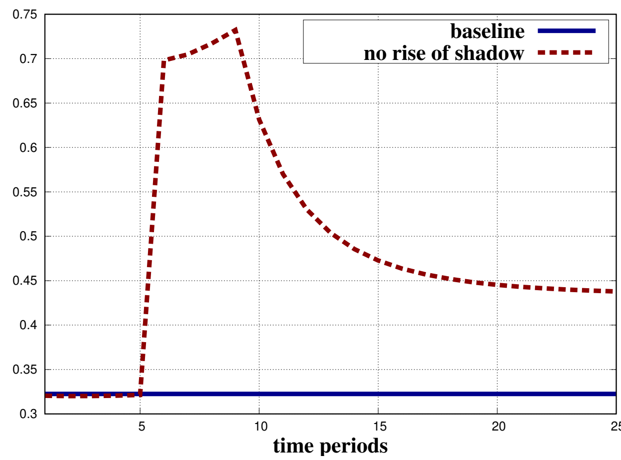
(a) Interest rate on loans



(b) Interest rate on deposits



(c) Capital requirement schedules



(d) Shadow lending fixed cost schedules

Figure 17: Overview of transition paths under different scenarios

sion of shadow lenders by imposing a higher fixed cost on them.

More generally, although higher capital requirements lead to rather dramatic shifts in the financial intermediation markets, we find that their quantitative effects on the real economy are limited. While that is a result in itself, it may also be caused by some features of the model. The main issue potentially arises from the assumption of full commitment to repay loans by borrowers (abstracting from the non-strategic default). As a result, the most productive entrepreneurs may not borrow enough to invest an efficient amount of physical capital due to being liable for possible losses with their own wealth. In addition, entrepreneurs in our model are able to switch between physical and financial capital without any adjustment costs. Extending the model to overcome these limitations is plausible but would come at the expense of complicating the analysis and the computation.

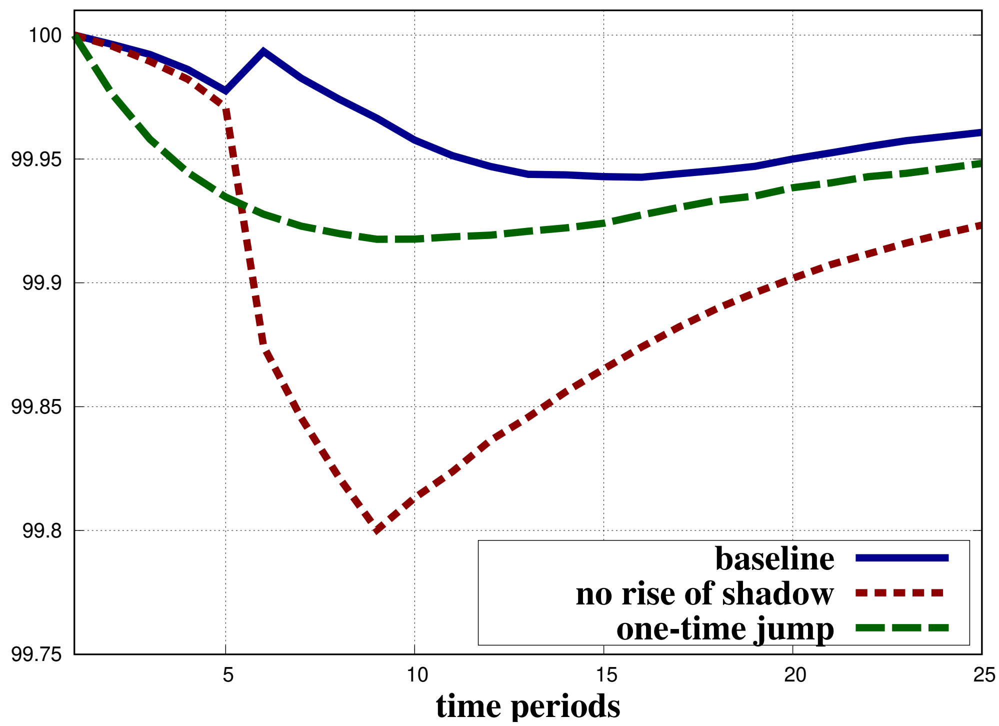


Figure 18: Output paths over transition under different scenarios

8 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 estimate the strongly negative effect of capital requirements on corporate credit growth at the bank-firm level, and a positive effect on non-bank (shadow) lending. We then corroborate these findings in a general equilibrium model with heterogeneous banks and firms. While our empirical work and the model are fully independent from each other, both produce consistent quantitative results. Our main finding is that Basel III can account for most of the observed decline in regulated bank lending, and about three quarters of the increase in shadow lending.

Our work is significant because it helps us understand and quantify the unintended consequences of the new regulatory framework such as Basel III on credit markets. Any future changes in bank capital requirements, for example Basel IV, must take these effects into account. While we do not directly address the question of the optimal level of capital requirement, the current paper can be used to inform future research about the quantitative impact of such changes on financial intermediation markets.

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Appendices

A Further information on credit data

In this section, we provide various additional details regarding our main dataset.

A.1 Summary statistics

Table 8 presents summary statistics of the matched credit data from South Korea. Under **Credit level**, we describe the (firm $\times$ lender $\times$ time) observations of credit both in level (*total credit*) and log differences ($\Delta \ln$ *total credit*). Only observations with positive credit are recorded.[36] We hand-collected information on mergers between lenders and imputed them in the data. More specifically, if lender A is merged with lender B at time t, we add any credit from lender A to lender B starting from time $t+1$. There is one notable merger between two large commercial banks in 2015Q3 (Hana Bank and Korea Exchange Bank merged to KEB Hana Bank), and we treat this case separately form other mergers. Since the merger has been approved by the regulators in 2012 and negotiations had been underway throughout our sample period, we treat the two banks as one for the entire sample period. By doing so, if a firm borrows from both Hana Bank and Korea Exchange Bank before 2015Q3, we sum up two credit observations and treat it as one observation associated with KEB Hana Bank. All growth measures and log differences are at annual frequency and all levels are deflated using GDP deflator with base year 2010.

In the next block of the summary statistics, **Lender level: regulated banks**, we describe regulated banks' aggregate credit level at each time period as well as their balance sheet information.[37] This part contains domestic commercial banks excluding special banks, and foreign bank branches.[38] These summary statistics are again based on unbalanced panel, selecting only the banks with positive amount of credit in the data. We report only aggregate credit level for non-banks (**Lender level: shadow lenders**), mainly because we could collect their balance sheets only for some parts of the observations.[39]

[36] The observations do not include any credit from special banks and 5 benefit societies (Gong-je-jo-hap), which entered only part of the sample period

[37] Bank balance sheet information was obtained from Financial Statistics Information System.

[38] Discrepancies in observation numbers of total credit and balance sheet info occur in foreign bank branches. After bank branches exit (e.g. BBVA branch), outstanding credit may still show up on the credit data. There is one takeover of foreign branch: RBS PLC branch took over existing operation of RBS branch starting from 2013Q4. We treat observations of RBS before 2013Q4 with RBS PLC, and match with RBS balance sheet.

[39] Since non-banks are comprised of various institutions, the frequency and standard of balance sheet

Finally, we describe our credit data at **Firm level**, aggregating credit by (firm $\times$ time) observations and excluding any special bank credit. Our sample is restricted to listed firms in three of the trading boards: KOSDAQ, KOSPI, and KONEX, and any firms that were listed for at least one quarter during the sample period are included, even if they are delisted later.[40] In what follows, we provide descriptions of listed firms compared to the universe of firms using two main data sources: KisValue for listed firms and KOSIS for the census of corporations. Total number of employees working for listed companies in Korea is around 1.53 million based on the data from KisValue. This is approximately 15% of total number of employees among for-profit corporations in Korea, which is 10.03 million. (KOSIS, Profit Corporation Statistics 2017). In terms of assets, listed companies constitute about 35% of all for-profit corporations, based on KisValue and KOSIS. (Total assets of listed companies: 3,441 tril. KRW, and total assets of for-profit corporations: 9,634 tril. KRW).

Table 8: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Credit level					
total credit	21,083	91,017	0.88	6,771,667	309,292
Δ ln total credit	-0.09	1.08	-10.82	11.18	202,373
Lender level: regulated banks					
total credit	3,495,717	7,312,573	34	35,403,686	943
total assets	41,729,254	80,336,832	24,367	346,082,176	936
total liabilities	38,582,159	74,307,737	936	320,660,096	936
total equity	3,147,095	6,075,405	11,545	25,880,234	936
Lender level: shadow lenders					
total credit	457,158	1,740,774	0.88	21,718,998	7,053
Firm level					
total credit	130,478	699,635	0.88	22,533,432	49,976

Note: Total credit, assets, liabilities, and equity are in millions of 2010 Korean Won. Differences are between times t and $t-4$. Summary statistics exclude observations of special banks. Credit level is by (firm x lender x time) observations, lender level is by (lender x time), and firm level is by (firm x time) observations. All summary statistics include only observations with positive amount of credit.

disclosure varies (most of cooperatives report semi-annually), if any, and matching of financial institutions from our credit data and publicly available financial information is not straightforward. We performed string matching by names and manual matching as well, but it is still patchy.

[40] We do not see the name of firms but only their detailed industry code and artificial identifier provided by the credit bureau.

A.2 Transition matrix of extensive margin

Figure 19 shows the transition matrix of firms by utilization of different credit sources. We consider firms at the beginning (2013Q2) and end (2019Q1) of our panel and divide them into four groups for each period: **none** (not borrowing from any of the lenders), **banks only** (borrowing from regulated banks only), **shadow only** (borrowing from shadow lenders only), and **both** (borrowing both from regulated banks and shadow lenders). An element in row i and column j means the fraction of firms from group i in 2013Q2 that moved to group j in 2019Q1. For example, among all firms that were borrowing from both regulated banks and shadow lenders (**both**) at the beginning of our sample, 18% are borrowing only from shadow lenders (**shadow only**) at the end of sample. The figure shows that a majority of firms at the end of sample are borrowing from both regulated banks and shadow lenders, including those that were only borrowing from banks at the beginning of sample period (59% from banks only to both). It is noteworthy that a significant fraction of firms moved to "shadow only" group towards the end, while "banks

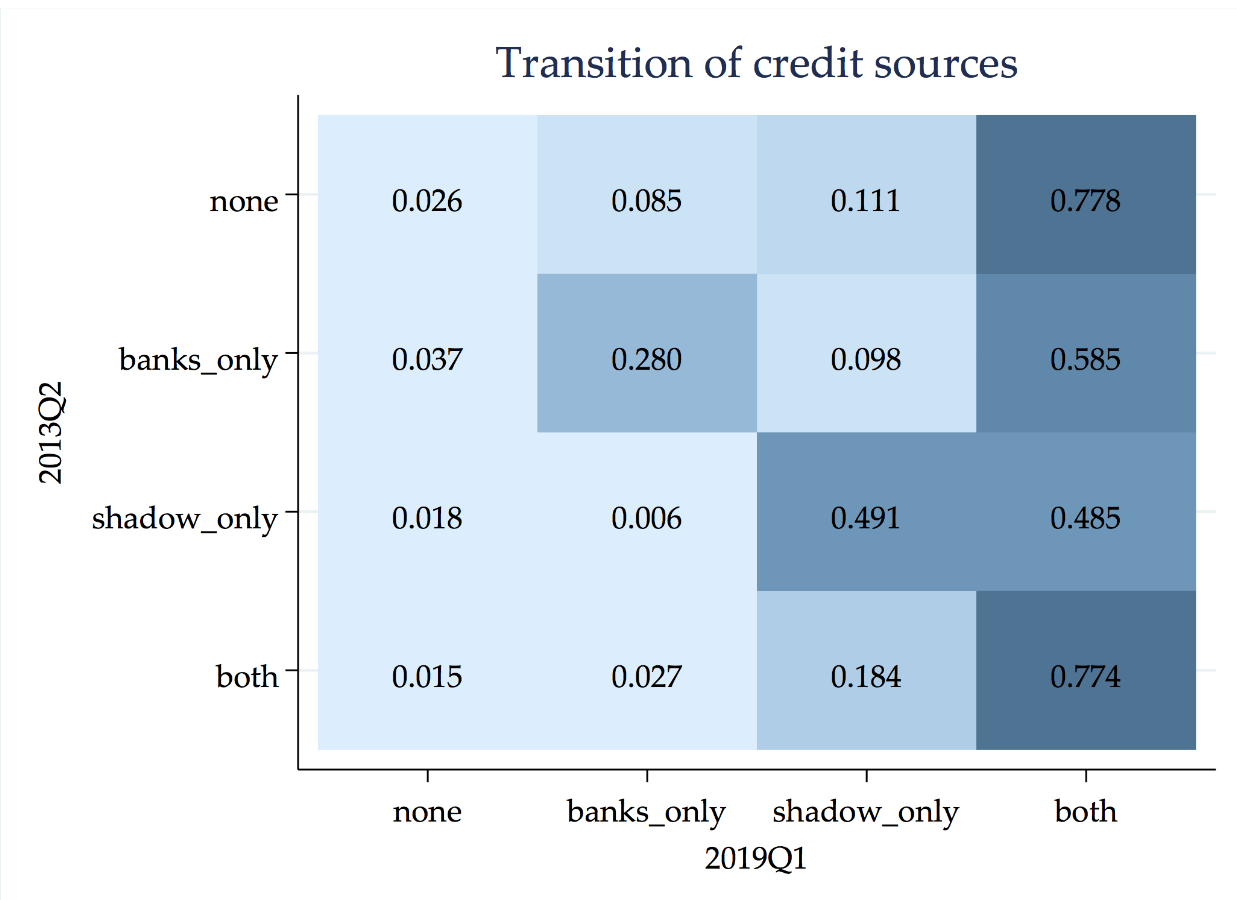
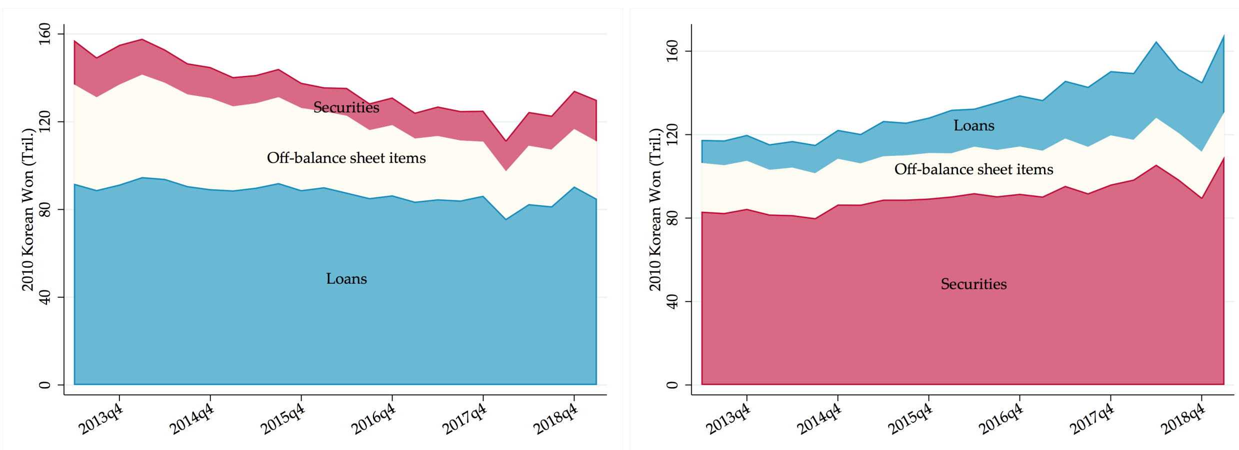


Figure 19: Transition of credit source at firm level, 2013Q2 to 2019Q1

only" group did not experience such an inflow from other groups.

A.3 Credit types

The Korean credit data used in this paper contains information about the types of credit. There are three broad types: *Loans, securities, and off-balance sheet items*. In Figure 20, we depict the break-down of total credit into these three types, for both regulated and shadow banks. Classification of credit types follows the regulatory guideline published by the Financial Services Commission (article 2014-9). Primary items included in *off-balance sheet items* are acceptances and guarantees. *Securities* comprise CP, bonds, and securities lent. *Loans* consist of a variety of financial products, from short-term and long-term loans to repurchase agreement, factoring, and financial/capital leasing.



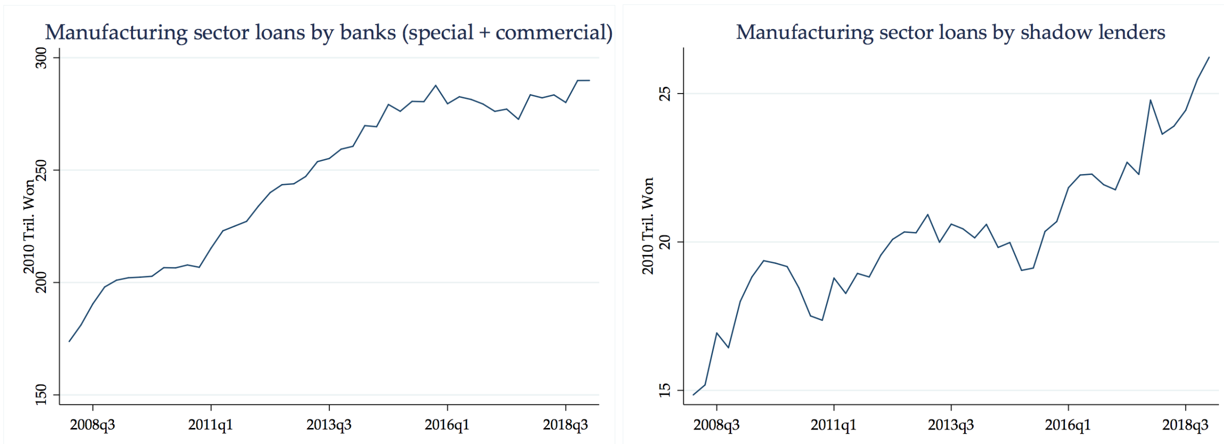
(a) Regulated banks (b) Shadow lenders

Figure 20: Decomposition of credit types

A.4 Prior trends

In this section, we analyze prior trends in corporate lending using aggregate series from the Bank of Korea. There are two main differences between these series and our data. First, we cannot obtain data for the same collection of Korean firms that are present in our data; instead we choose to plot lending to manufacturing firms only. Second, the Bank of Korea statistics include lending by state-owned banks which we have excluded from our analysis. With these caveats in mind, it is immediate to notice that prior to year

2016 lending by regulated banks was growing steadily and then stopped,[41] while lending by shadow banks accelerated sharply when penalties for non-compliance with Basel III were introduced.



(a) Banks

(b) Non-banks

Source: Bank of Korea. Aggregate series for banks (left) **include** state-owned banks. Shadow lenders (right) are restricted only to deposit-taking non-bank financial institutions, such as credit unions, cooperatives, and mutual savings.

Figure 21: Aggregate lending to manufacturing sector including prior trends

B Further information on Basel III

In this section, we provide further details regarding the implementation of Basel III in Korea, and the banks' response to it.

B.1 Alternative measures of capital ratio

Table 9 extends the content of Table 1 by showing the implementation of Basel III in terms of two alternative measures of capital: the Common Equity Tier 1 Capital, and the Total Capital. It can be noticed that, while the requirements for different measures vary in terms of level, they all tend to be spread out over time.

[41] The reason that the decline in not as pronounced in this data, as in our main Figure 1 is that it includes lending by Korean state-owned banks. Especially during the years of Basel III implementation, such banks increased their lending to many troubled companies, most notably to the failing shipbuilding industry.

Table 9: Minimum capital ratio requirements - alternative measures

Capital Ratio (%)	CET1		Tier 1		Total		Note
Until 2012	None		4		8		Basel II
From 2013 Jan 1st	3.5		4.5		8		Basel III guideline
From 2014 Jan 1st	4.0		5.5		8		(no penalties)
From 2015 Jan 1st	4.5		6.0		8		
From 2016 Jan 1st	5.125	$+ K_{it} \times 1/4$	6.625	$+ K_{it} \times 1/4$	8.625	$+ K_{it} \times 1/4$	Basel III
From 2017 Jan 1st	5.75	$+ K_{it} \times 1/2$	7.25	$+ K_{it} \times 1/2$	9.25	$+ K_{it} \times 1/2$	(with penalties)
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 Tier 1. CET1 $\subseteq$ Tier 1 $\subseteq$ Total. K_{it} is the sum of Countercyclical Capital Buffer and Domestic Systematically Important Banks (D-SIB) capital.

Figure 22 tracks the evolution of realized bank capital ratios over time for the two alternative measures of capital. The main observations from Figure 4 are equally applicable here. The capital ratios tend to be dispersed and exhibit a buffer over the posted requirement. Most importantly, the entire distribution tends to shift upwards starting from 2016 when the Basel III framework is implemented in Korea with penalties for non-compliance.

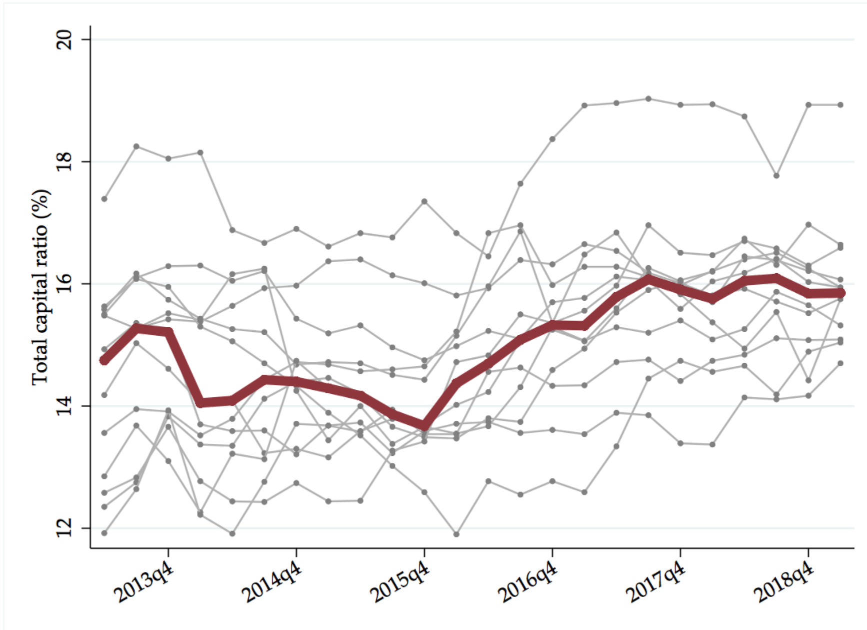
B.2 Basel III penalties

In this section, we discuss the penalties related to non-compliance with capital requirements in South Korea. Table 10 lists the thresholds for capital ratios below which any penalties are imposed. Additionally, the size of the restriction depends on how much the realized capital ratio fell below the required minimum. Specifically, in the event of violating the regulation, a minimum conservancy ratio is applied to the bank's profit. This means that the bank is forced to buy back stocks or withhold dividend payments in proportion specified by the size of the capital ratio violation.

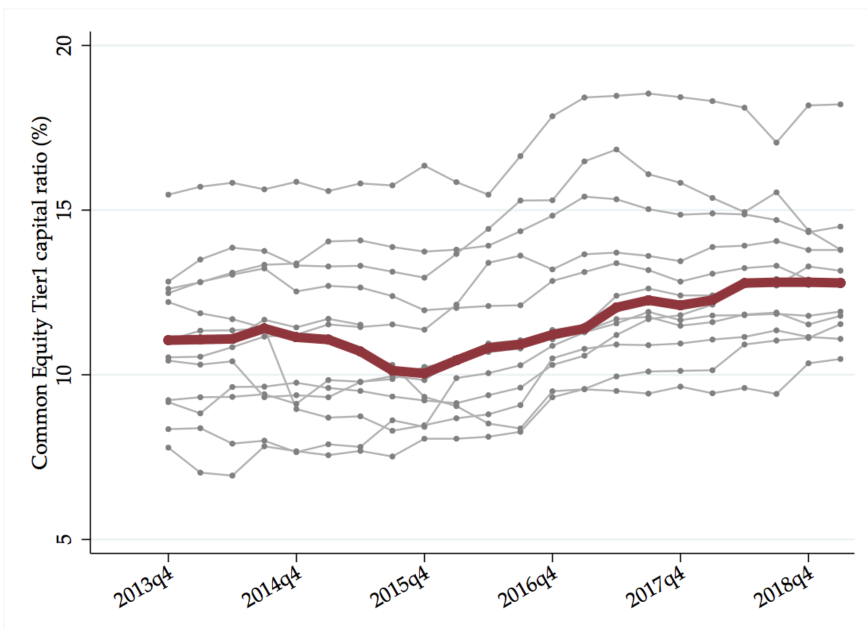
Table 10: Restrictions on profit distribution under Basel III (From 2019 Jan 1st)

Min. conserv. ratio	100%	80%	60%	40%	0%
CET1 capital ratio	$< 5.125 + K_{it}$	$< 5.75 + K_{it}$	$< 6.375 + K_{it}$	$< 7 + \mathrm{K}$	$\geq 7{+}K_{it}$
or Tier 1 capital ratio	$< 6.625 + K_{it}$	$< 7.25 + K_{it}$	$< 7.875 + K_{it}$	$< 8.5 + \mathrm{K}$	$\geq 8.5{+}K_{it}$
or Total capital ratio	$< 8.625 + K_{it}$	$< 9.25 + K_{it}$	$< 9.875 + K_{it}$	$< 10.5 + \mathrm{K}$	$\geq 10.5{+}K_{it}$

Note: CET1 denotes Common Equity Tier 1. CET1 $\subseteq$ Tier 1 $\subseteq$ Total. K_{it} is the sum of Countercyclical Capital Buffer and Domestic Systematically Important Banks (D-SIB) capital.



(a) Total capital ratios



(b) Common Equity Tier 1 capital ratios

Figure 22: Alternative measures of realized bank capital ratios over time

C Robustness Checks

In this Appendix, we conduct a battery of robustness checks for our econometric results in Section 3. We start by considering various alternative specifications for estimating the elasticity of regulated bank credit with respect to capital requirement. Then, we investigate the robustness of our estimates for the spillover effect on shadow financing.

C.1 Robustness of bank credit elasticity

Pre-2016 guidelines only A natural concern regarding the estimates presented in Table 2 involves the anticipation period, following the announcement of the reform and prior to its actual coming into effect. Indeed, Figure 1 shows that some of the total decline in regulated bank credit occurred prior to 2016 when the reform became legally binding.[42] To understand the impact of this non-binding period of Basel III implementation on bank lending, we re-run regression (1) limited to years 2013-2015 and assuming that the "soft guidelines" presented in Table 1 were actually enforced with penalties. It should be emphasized that this exercise is *not* a placebo test; instead it is a test of the presence of any anticipation effects under the soft guidelines prior to 2016.

Table 11: Effects of pre-2016 "guideline" capital requirements on credit growth

VARIABLES	(1) Δ ln total credit	(2) Δ ln total credit	(3) Δ ln total credit	(4) Δ ln total credit
ln min. Tier1 req.	-0.219	-0.162	-0.206	-0.143
	(0.153)	(0.158)	(0.150)	(0.156)
Constant	0.382	0.280	0.513*	0.416
	(0.268)	(0.278)	(0.264)	(0.274)
Observations	31,593	29,655	31,593	29,655
Fixed Effects	Firm, Bank	Firm, Bank	Firm, Bank	Firm, Bank
Sample	All	Domestic	All	Domestic
Relationship control	No	No	Yes	Yes
R2	0.181	0.188	0.207	0.214

Note: Sample period: 2013Q2-2015Q4. All standard errors (in parentheses) are clustered at the bank level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 11 shows that under the "soft guidelines" changes in capital requirement prior to 2016, we cannot find any statistically significant impact of such a reform on bank-firm

[42] As explained in Section 2.8, Basel III regulations were introduced in Korea since 2013 but legal penalties for violating capital requirements were applied only from 2016.

credit growth. While the magnitude of this elasticity is even higher than for our benchmark results (in absolute value), the estimates are also very noisy and lack consistency across various specifications. This reflects the finding that, while there is an obvious negative correlation between capital requirements and credit growth on the aggregate level, the banks were not responding in any clear way to these non-binding guidelines. Instead, it is the regulator-enforced penalties that lead the banks to reduce lending in response to the change in capital requirements.

Full schedule, including guidelines Table 12 presents the results of running regression (1) under the full schedule of Basel III implementation in Korea (Table 1). That is, we treat the "guidelines" period of 2013-2015 as binding. As we can see, the results are similarly strong and consistent across different specifications. The estimated elasticity of bank credit growth amounts to about -0.22.

Table 12: Effects of Tier 1 capital requirements on credit growth, including guidelines before 2016

VARIABLES	(1) Δ ln total_credit	(2) Δ ln total_credit	(3) Δ ln total_credit	(4) Δ ln total_credit
ln min. Tier1 req.	-0.216***	-0.215***	-0.237***	-0.238***
	(0.0249)	(0.0256)	(0.0246)	(0.0253)
Constant	0.378***	0.379***	0.561***	0.575***
	(0.0497)	(0.0511)	(0.0496)	(0.0510)
Observations	83,599	77,774	83,599	77,774
Fixed Effects	Firm, Bank	Firm, Bank	Firm, Bank	Firm, Bank
Relationship control	No	No	Yes	Yes
Sample	All	Domestic	All	Domestic
R2	0.0704	0.0728	0.0929	0.0964

Note: Guidelines are set to be 4.5% in 2013, 5.5% in 2014, and 6% in 2015 according to Table 1. All standard errors (in parentheses) are clustered at the bank level. *** p<0.01, ** p<0.05, * p<0.1

D-SIB only Table 13 presents the results of running our main regression equation (1) on a sample restricted to regulated banks that have been designated as Systemically Important (D-SIB). It can be noticed that the estimated coefficients are higher (in absolute value) than for the whole sample case. This means that larger banks generally respond to capital requirements more than smaller banks.

Table 13: Effects of capital requirements on credit growth for D-SIB only

VARIABLES	(1) Δ ln total_credit	(2) Δ ln total_credit
ln min. Tier1 req.	-0.172**	-0.184**
	(0.0556)	(0.0531)
Constant	0.220*	0.493***
	(0.100)	(0.104)
Observations	63,394	63,394
Fixed Effects	Firm, Bank	Firm, Bank
Sample	DSIB	DSIB
Relationship control	No	Yes
R2	0.0895	0.120

Note: All standard errors (in parentheses) are clustered at the bank level. *** p<0.01, ** p<0.05, * p<0.1

Additional controls In Table 14, we check the omitted variable bias by adding different control variables to the main regression in Table 2. Additional variables are: detrended real GDP, two stock market indices (KOSPI and KOSDAQ), and volume index of manufacturing sector exports. All variables are at quarterly frequency, and all data series are from the Bank of Korea. Each variable is in log and detrended using HP-filter, and stock market indices are averaged at a quarterly level (original series is at daily frequency). The estimated elasticity after adding various control variables remain significantly negative, ranging from -0.15 to -0.163. These are slightly bigger in magnitude compared to the baseline estimation (around -0.14), which suggests that our baseline estimation is on the conservative side compared to the figures in robustness checks.

Table 14: Effects of minimum capital requirements on credit growth, additional controls

VARIABLES	(1) Δ ln total_credit	(2) Δ ln total_credit	(3) Δ ln total_credit	(4) Δ ln total_credit	(5) Δ ln total_credit	(6) Δ ln total_credit
ln min. Tier1 req.	-0.154***	-0.161***	-0.151***	-0.158**	-0.158***	-0.163***
	(0.0440)	(0.0473)	(0.0478)	(0.0517)	(0.0430)	(0.0464)
Constant	0.175**	0.181*	0.375***	0.393***	0.182**	0.184**
	(0.0779)	(0.0838)	(0.0860)	(0.0934)	(0.0769)	(0.0831)
Observations	83,559	77,733	83,559	77,733	83,559	77,733
Fixed Effects	Firm, Bank	Firm, Bank	Firm, Bank	Firm, Bank	Firm, Bank	Firm, Bank
Sample	All	Domestic	All	Domestic	All	Domestic
Relationship control	No	No	Yes	Yes	No	No
GDP	Yes	Yes	Yes	Yes	Yes	Yes
Stock mkt	No	No	No	No	Yes	Yes
Exports	No	No	No	No	No	No
R2	0.0700	0.0723	0.0919	0.0954	0.0700	0.0723

VARIABLES	(7) Δ ln total_credit	(8) Δ ln total_credit	(9) Δ ln total_credit	(10) Δ ln total_credit	(11) Δ ln total_credit	(12) Δ ln total_credit
ln min. Tier1 req.	-0.155***	-0.160**	-0.154***	-0.158**	-0.150***	-0.154**
	(0.0480)	(0.0521)	(0.0473)	(0.0510)	(0.0548)	(0.0596)
Constant	0.381***	0.395***	0.176**	0.176*	0.373***	0.385***
	(0.0862)	(0.0942)	(0.0840)	(0.0907)	(0.0957)	(0.105)
Observations	83,559	77,733	83,559	77,733	83,559	77,733
Fixed Effects	Firm, Bank	Firm, Bank	Firm, Bank	Firm, Bank	Firm, Bank	Firm, Bank
Sample	All	Domestic	All	Domestic	All	Domestic
Relationship control	Yes	Yes	No	No	Yes	Yes
GDP	Yes	Yes	Yes	Yes	Yes	Yes
Stock mkt	Yes	Yes	Yes	Yes	Yes	Yes
Exports	No	No	Yes	Yes	Yes	Yes
R2	0.0920	0.0955	0.0700	0.0723	0.0920	0.0955

Note: All standard errors (in parentheses) are clustered at the bank level. *** p<0.01, ** p<0.05, * p<0.1

Foreign banks only Foreign bank branches are included in our regulated bank sample but they are not subject to the domestic Basel III regulations. While Basel III is a set of global banking regulation that was implemented in most developed countries, its time schedule and regulation details differ across countries. Therefore, we view foreign bank branches as being under "soft" domestic regulation, and we expect the elasticity of minimum capital requirements to be lower than those from domestic banks. Table 15 shows that estimated coefficients are not significant and point estimates are lower than the main results (around -0.14) across different sets of controls. While lower number of observations compared to the main regression in Table 2 may have contributed to the higher standard errors, the result suggests that foreign banks were less affected by the capital regulation reform compared to the domestic banks.

Table 15: Effects of Tier 1 capital requirements on credit growth, foreign banks only

	(1)	(2)	(3)
VARIABLES	Δ ln total_credit	Δ ln total_credit	Δ ln total_credit
ln min. Tier1 req.	-0.123	-0.125	-0.127
	(0.0815)	(0.0855)	(0.107)
Constant	0.211	0.363**	0.226
	(0.146)	(0.157)	(0.188)
Observations	5,812	5,812	5,812
Fixed Effects	Firm, Bank	Firm, Bank	Firm, Bank
Sample	Foreign	Foreign	Foreign
Relationship control	No	Yes	Yes
GDP	No	No	Yes
Stock mkt	No	No	Yes
Exports	No	No	Yes
R2	0.0542	0.0706	0.0567

Note: All standard errors (in parentheses) are clustered at the bank level. *** p<0.01, ** p<0.05, * p<0.1

Weighted regression Finally, we run a weighted regression with lagged total credit, in order to verity that firm-bank pairs with large amount of loans are also affected by the tighter capital regulation. Compared to the main results in Table 2, coefficients are larger in scale which indicates that bank-firm pairs with larger amount of credit in fact declined more than those with smaller outstanding credit. After controlling for other aggregate variables as in Table 14, the elasticity becomes even larger as column (5) of the table shows. It is partly because a significant number of firms with large outstanding credit in our sample are exporters and their credit comoves with some of the control variables such as exports and GDP. In our main estimation, we take non-weighted regression as our benchmark in order to bring the empirical result as close as possible to the model, which does not have direct matching between firm and banks.

Table 16: Effects of Tier 1 capital req. on credit growth, weighted by lagged credit

VARIABLES	(1) Δ ln total_credit	(2) Δ ln total_credit	(3) Δ ln total_credit	(4) Δ ln total_credit	(5) Δ ln total_credit
ln min. Tier1 req.	-0.219**	-0.251**	-0.231**	-0.264**	-0.357**
	(0.0945)	(0.109)	(0.0998)	(0.115)	(0.143)
Constant	0.133	0.183	0.254	0.323	0.486*
	(0.169)	(0.194)	(0.192)	(0.221)	(0.270)
Observations	83,559	77,733	83,559	77,733	77,733
Fixed Effects	Firm, Bank	Firm, Bank	Firm, Bank	Firm, Bank	Firm, Bank
Sample	All	Domestic	All	Domestic	Domestic
Relationship control	No	No	Yes	Yes	Yes
GDP	No	No	No	No	Yes
Stock mkt	No	No	No	No	Yes
Exports	No	No	No	No	Yes
R2	0.115	0.131	0.120	0.137	0.140

Note: All standard errors (in parentheses) are clustered at the bank level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

C.2 Bank credit elasticity under alternative measures

In this part, we redo our main estimations of bank credit elasticities for the alternative two measures of bank capital ratio, Total and CET1, previously introduced in Appendix B.1. As expected, we obtain equally significant and consistent results across different variants of the regression. While the estimated coefficients are around similar magnitude using CET1 capital ratio (Table 19), note that those for Total Capital Ratios (Table 18) are generally higher (in absolute value) than with Tier 1 capital ratio in Table 2. This is because the Total capital ratios (which include a bank's total capital) changed by smaller magnitude over time, and hence the elasticities are correspondingly higher. In the following regressions, we control for bank-firm relationships only, so that the estimated coefficients are directly comparable to the main results.

To make our results more useful for future research, Table 17 summarizes our estimated elasticities for the three measures of capital ratio and two possible specifications.

Table 17: Summary of bank credit elasticity estimates for alternative measures of capital ratio

Measure	Elasticities
Tier 1	-0.14
Common Equity Tier 1	-0.15
Total capital (BIS)	-0.30

Note: The reported numbers are median of the estimates obtained in each Table.

Table 18: Effects of total (BIS) capital requirements on credit growth

VARIABLES	(1) Δ ln total_credit	(2) Δ ln total_credit	(3) Δ ln total_credit	(4) Δ ln total_credit
ln min. Total req.	-0.287**	-0.287*	-0.322***	-0.323**
	(0.125)	(0.134)	(0.114)	(0.123)
Constant	0.534*	0.528	0.813***	0.822**
	(0.274)	(0.296)	(0.259)	(0.279)
Observations	83,559	77,733	83,559	77,733
Fixed Effects	Firm, Bank	Firm, Bank	Firm, Bank	Firm, Bank
Sample	All	Domestic	All	Domestic
R2	0.0693	0.0715	0.0914	0.0948

Note: All standard errors (in parentheses) are clustered at the bank level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 19: Effects of Common Equity Tier 1 capital requirements on credit growth

VARIABLES	(1) Δ ln total_credit	(2) Δ ln total_credit	(3) Δ ln total_credit	(4) Δ ln total_credit
ln min. CET1 req.	-0.142***	-0.144**	-0.149***	-0.152**
	(0.0483)	(0.0523)	(0.0465)	(0.0503)
Constant	0.130	0.127	0.346***	0.356***
	(0.0775)	(0.0840)	(0.0812)	(0.0880)
Observations	83,559	77,733	83,559	77,733
Fixed Effects	Firm, Bank	Firm, Bank	Firm, Bank	Firm, Bank
Sample	All	Domestic	All	Domestic
R2	0.0698	0.0720	0.0918	0.0953

Note: All standard errors (in parentheses) are clustered at the bank level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

C.3 Robustness of the effect on shadow lending

Figure 23 plots the predicted marginal effects of the time fixed effects estimated in a logistic regression of $\mathbb{1}\{total\_credit_{ijt-1} = 0, total\_credit_{ijt} > 0\}$, a binary indicator for whether firm i started borrowing from shadow lender j in time period t, on the usual set of regressors, that is $f_i + f_j + f_t + \Psi X_{ijt} + \varepsilon_{ijt}$. We find that the probability a firm-lender credit account becomes active rises from around 3% before the reform to up to 7% after.

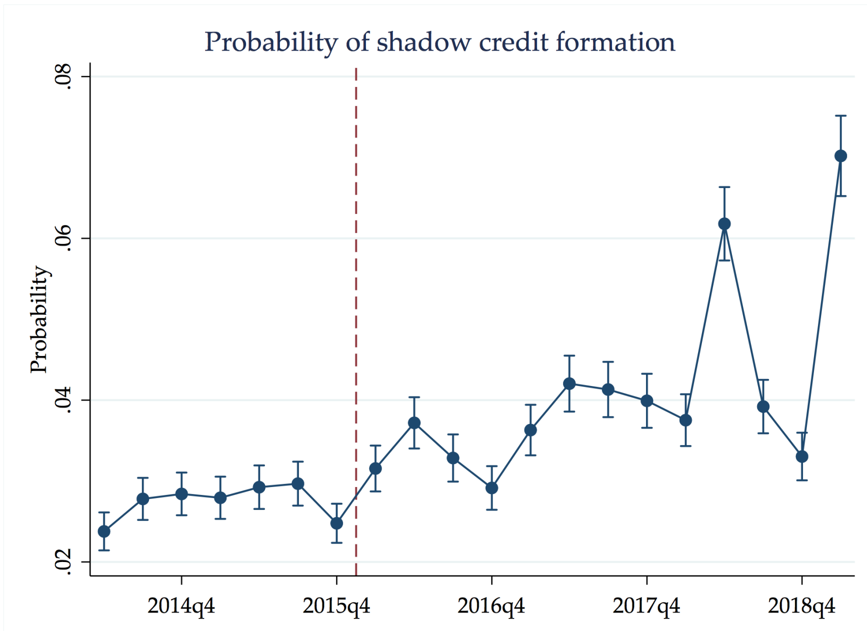


Figure 23: Predicted probability of new shadow lending relationships

D Numerical Algorithms

In this Appendix we describe the numerical algorithms used to analyze the model. We start by describing the approach to find a general equilibrium with stationary distributions of agents. Then, we present the algorithm used to calculate a deterministic transition path induced by the change in bank capital requirements.

D.1 Stationary equilibrium

To compute a stationary equilibrium of the model, we use the following algorithm.

0. Create separate grids for banks' equity e, workers' wealth x_w and labor income y, and entrepreneurs' wealth x and business productivity z. Use the Tauchen method to discretize the stochastic processes for entrepreneurial productivity and workers' labor income.

1. Assume an initial vector of general equilibrium prices $\{r_b, r_d, w, \mu\}$.[43]

2. Taking the prices as given, solve the bank's problem as follows:

   i. Guess the dividend function $c^0(e)$.

   ii. For each equity grid point, find the optimal policies $\{b'(e), m'(e), d'(e)\}$ by solving the system of first-order conditions implied by the bank's problem, and back out the resulting dividend function $c^1(e)$. Use linear interpolation to evaluate the off-grid values of next-period dividend.

   iii. Evaluate the maximum deviation between the functions $c^0(e)$ and $c^1(e)$. If it is below a pre-specified tolerance level ε then stop; otherwise update the dividend function $c^0(e) = \lambda c^1(e) + (1 - \lambda)c^0(e)$ and go back to step ii.

   iv. After the dividend function has converged, calculate the stationary distribution of bank equity by iterating on the banks' CDF.

   v. Calculate the aggregate bank loans and deposits, as well as the average dividend payout to workers in the stationary equilibrium.

3. Taking as given the equilibrium price vector and average dividend payout from the banks, use value function iteration to solve for the workers' optimal policies and a stationary distribution of wealth and savings (Aiyagari, 1994).

[43] The mean repayment rate for loans, μ, is technically not a price, but we still need to vary it in order to balance out the quantities of defaulted loans. With a slight abuse of terminology, we include it here in the vector of general equilibrium prices for conciseness.

4. Taking the equilibrium price vector as given, solve the entrepreneurs' problem as follows:

    i. Guess the initial value functions $v_i^0(x,z)$, for each entrepreneur type $i \in \{borrower, depositor, shadow\ lender\}$.

    ii. For each entrepreneur type i and for each grid point (x,z), find the optimal portfolio allocations $\{a_i'(x,z), k_i'(x,z)\}$ by maximizing the return function. Use linear interpolation to evaluate the off-grid values of next-period wealth. Use the Gauss-Legendre quadrature to approximate the expectations with respect to ω', the idiosyncratic shock to loan value. Back out the implied consumption policy $c_i(x,z)$.

    iii. Using the policy functions (c_i^1, a_i', k_i') found in the previous step, update the value functions for each entrepreneur type:

    $$v_i^1(x,z) = u\Big(c_i(x,z)\Big) + \beta\mathbb{E}\max\Big\{v_b^0(x,z), v_d^0(x,z), v_s^0(x,z)\Big\}$$

    iv. Using the value functions calculated in the previous step, find the cash-on-hand thresholds for each productivity grid point, $\bar{x}_1(z)$ and $\bar{x}_2(z)$, at which an entrepreneur is indifferent between borrowing and saving, and between saving and becoming a shadow lender, respectively.

    v. Evaluate the maximum distance between the value functions $v_i^0(x,z)$ and $v_i^1(x,z)$ for each entrepreneur type i. If it is below a pre-specified tolerance level ε then stop; otherwise update the functions as follows

    $$v_i^0(x,z) = \lambda v_i^1(x,z) + (1-\lambda)v_i^0(x,z)$$

    and go back to step ii. λ is a parameter that determines the speed of updating.

    vi. After the value functions have converged, iterate on the CDF to calculate the stationary distribution of entrepreneurs in terms of wealth and productivity.

    vii. Calculate the entrepreneurs' aggregate saving, borrowing and labor hiring.

5. Evaluate the aggregate excess demand for loans, deposits, labor, and defaulted loans. If the maximum excess demand is below a pre-specified tolerance criterion ε then stop. Otherwise, update the vector of prices $\{r_b, r_d, w, \mu\}$ in the direction that reduces the excess demand and go back to step 2.[44]

[44] We define the "excess demand" for defaulted loans as the difference between loans defaulted on by the borrowers and loans written-off by the lenders.

D.2 Transition induced by the reform

To compute the transitional dynamics induced by the change in capital requirement, we use the following numerical algorithm.

0. Calculate the stationary equilibrium before and after the reform; record the associated equilibrium price vectors as $\{r_b^*, r_d^*, w^*, \mu^*\}$ and $\{r_b^{**}, r_d^{**}, w^{**}, \mu^{**}\}$, respectively.[45] Save the associated post-reform policy functions for all agents, and the associated pre-reform stationary distributions for all agents.

1. Assume the transition occurs over $T = 200$ number of periods. Construct a vector of capital requirements $\{\kappa_t\}_{t=1}^T$ that resembles the Basel III implementation in Korea (summarized in Table 1). Assume this reform schedule is announced to all agents unexpectedly at the beginning of period $t = 1$.

2. Guess the initial path for general equilibrium prices over the transition $\{r_{t,b}^0, r_{t,d}^0, w_t^0, \mu_t^0\}_{t=1}^T$. In particular, assume that $\{r_{1,b}^0, r_{1,d}^0, w_1^0, \mu_1^0\} = \{r_b^*, r_d^*, w^*, \mu^*\}$ and $\{r_{T,b}^0, r_{T,d}^0, w_T^0, \mu_T^0\} = \{r_b^{**}, r_d^{**}, w^{**}, \mu^{**}\}$.[46]

3. Taking the paths of prices and capital requirements as given, calculate the full transition in two steps:

   i. Solve for optimal policy and value functions over the transition for $t = T - 1, T - 2, ..., 1$ (i.e. iterate backwards). For each period t, use policy and value functions just derived from period $t + 1$ to solve the problem. The functions in period $t = T$ are the ones derived from the post-reform stationary equilibrium. Save the value and policy functions for all agents over the entire transition.

   ii. Compute the evolution of all three distribution functions over the transition for $t = 2, 3, ..., T$ (i.e. iterate forward). For each period t, use the distribution functions just derived from period $t - 1$, as well as the corresponding policy functions obtained in step *i*, to update the CDFs. The distributions in period $t = 1$ are the ones derived from the pre-reform stationary equilibrium. Calculate aggregate borrowing, saving, labor, and defaulted loans for all agents over the entire transition. Calculate the paths of excess demands in all markets.

[45] Similarly as in Section D.1, while μ is technically not a price, we include it in the price vector with a slight abuse of terminology. We then define the excess demand for defaulted loans as the difference between loans defaulted on by the borrowers, and loans written-off by the lenders.

[46] When calculating the transitional dynamics in the counterfactual scenario ("Government goes after shadow lenders"), we augment the price array with a time series for fixed cost of shadow lending, $\{f_{t,S}\}_{t=1}^T$. In every iteration, we vary the elements of this series period-by-period, as described in step 5, to guarantee that the share of shadow loans in total lending stays constant over the transition.

4. If the largest excess demand from step $3i$ is smaller than a pre-specified tolerance criterion ε then stop. Otherwise, proceed to next step.

5. For each period $t = 2, 3, ..., T$,[47] find the vector of prices $\{r^1_{t,b}, r^1_{t,d}, w^1_t, \mu^1_t\}$ that reduces the absolute value of excess demands in period $t-1$ below ε. In doing so, take as given the value and policy functions saved in step $3i$, as well as just-derived distribution functions from period $t = 1$. Once the market-clearing price vectors has been found, update the CDFs for all agents.

6. After the new paths of general equilibrium prices $\{r^1_{t,b}, r^1_{t,d}, w^1_t, \mu^1_t\}_{t=1}^T$ are found, update the initial paths using some dampening parameter λ as follows

$$\left\{r^0_{t,b}, r^0_{t,d}, w^0_t, \mu^0_t\right\}_{t=1}^T = \lambda\left\{r^1_{t,b}, r^1_{t,d}, w^1_t, \mu^1_t\right\}_{t=1}^T + (1-\lambda)\left\{r^0_{t,b}, r^0_{t,d}, w^0_t, \mu^0_t\right\}_{t=1}^T$$

   and go back to step 3.

[47] Optionally, we can also go backwards, i.e. $t = T, T-1, ..., 2$. Depending on the calibration, either forward iterations, or backward iterations, or alternating between the two yields best convergence properties.

E Additional model results

In this appendix, we provide various additional results from the model that were omitted in the main text of the paper.

Table 20 presents further a more detailed comparison of the stationary equilibria of our model (relative to Table 5). In particular, it also presents the statistics for the counterfactual exercise discussed in Section 7, where together with an increase in capital requirements we also raise the fixed cost of operating as a shadow lender. It is in particular worth pointing out that the model predicts both mean and standard deviation of capital ratios to go up as a result of the reform, while the correlation of equity with capital ratio to drop. All these movements indeed occur in the data, although to a smaller extent.

Table 20: Stationary equilibria before the reform, after and in the counterfactual

	Before reform	After (PE)	After (GE)	Counter (GE)
Capital requirement	4%	8.5%	8.5%	8.5%
Banks				
Equity	100.00	19.04	115.54	131.34
Deposits	878.84	86.59	723.31	826.18
Loans	910.15	98.64	780.29	890.36
Reserves	61.52	6.06	50.63	57.83
Dividend	7.16	0.93	7.92	9.33
Capital ratios (in %)				
Mean	10.97	20.80	16.01	15.74
St.dev.	1.55	4.30	1.58	1.45
Corr w/ equity	38.33	28.82	-35.74	-18.33
Prices				
r_b (in %)	3.44	3.44	3.46	3.53
r_d (in %)	1.64	1.64	1.49	1.51
$w \times 100$	30.84	30.84	30.83	30.82

Table 21 presents further information about the behavior of firms in the model equilibria before and after the reform. All variables except for labor and productivity are expressed in terms of aggregate output which is normalized to 100. With the capital requirement of 4%, about 75% of firms choose to borrow, while around 18% 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. They are also the most productive, on average, but at the same time they consume the least. On the other side, shadow lenders have the highest wealth and because they can achieve a higher return on their financial assets than regular depositors, they install less physical capital.

Table 21: Stationary distribution of firms before the reform, after, and in the counterfactual

Before reform (capital requirement 4%)			
Aggregates:	Borrowers	Depositors	Shadow lenders
Share	75.23	17.72	7.05
Output	107.49	76.34	79.58
Assets	-96.40	86.42	441.76
Capital	276.84	235.19	228.56
Profit	52.35	37.18	38.75
Consumption	26.83	33.42	48.31
Wealth	207.27	355.03	720.32
Labor	34.01	24.15	25.18
Productivity	1.62	0.73	0.82

After reform (capital requirement 8.5%)			
Aggregates:	Borrowers	Depositors	Shadow lenders
Share	76.24	14.68	9.08
Output	107.31	75.30	78.41
Assets	-94.50	68.58	402.72
Capital	276.86	235.78	224.51
Profit	52.26	36.67	38.19
Consumption	26.90	32.50	46.48
Wealth	209.27	336.87	675.40
Labor	33.96	23.83	24.81
Productivity	1.61	0.69	0.82

Counterfactual (capital requirement 8.5%, f_S 50% higher)			
Aggregates:	Borrowers	Depositors	Shadow lenders
Share	76.11	17.24	6.64
Output	107.13	76.39	78.85
Assets	-93.24	84.16	458.74
Capital	275.52	238.65	224.61
Profit	52.17	37.20	38.40
Consumption	26.87	33.41	48.64
Wealth	209.14	356.22	734.23
Labor	33.91	24.19	24.96
Productivity	1.62	0.71	0.82