Bank Market Power and Monetary Policy Transmission: Evidence from a Structural Estimation

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November 11, 2019

Abstract

We quantify the impact of bank market power on the pass-through of monetary policy to borrowers. To this end, we estimate a dynamic banking model in which monetary tightening increases banks’ funding costs. Given their market power, banks optimally choose how much of a rate increase to pass on to borrowers. In the model, banks are subject to capital and reserve regulations, which also influence the degree of pass-through. Compared with the conventional regulation-based channels, we find that, in the two most recent decades, bank market power explains a significant portion of monetary transmission. The quantitative effect is comparable in magnitude to that of the bank capital channel. In addition, the market power channel interacts with the bank capital channel, and this interaction can reverse the effect of monetary policy when the Federal Funds rate is low.

JEL Codes: E51, E52, G21, G28

Keywords: Monetary policy transmission, banking competition.

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We would like to thank Harjoat Bhamra, Marco Bonomo, Yasser Boualam, Dean Corbae, Olivier Darniouni, Mark Egan, Brent Glover, Valentin Haddad, Gregor Mavtos, Patricia Mosser, Stijn van Nieuwerburgh, Neil Pearson, George Pennacchi, Alexi Savov, David Srear, Olivier Wang for their helpful comments and discussions. We also thank participants at EFA, FIRS, the Chicago Booth Asset Pricing Conference, the Financial Innovation and Risk Management Conference, the FMA Wine Country Finance Conference, the FRBSF Conference on Advances in Financial Research, the Macro-Finance Society Workshop, the NBER Summer Institute, the Northeastern University Finance Conference, the RCFS Conference, the Short-Term Funding Markets Conference, the University of Connecticut Conference, the UBC Summer Conference, Stanford Institute for Theoretical Economics (SITE) Summer Workshops, SFS Cavalcade, and all seminar participants at Bank of Canada, Chicago Booth, Columbia University, CUHK, Georgetown University, Johns Hopkins University, Northwestern University, the FDIC, the Federal Reserve Bank of New York, the Federal Reserve Board, the University of Lausanne, the University of Michigan, the University of Rochester, UIUC, and Wirtschaftsuniversitat Wien.
1. Introduction

We examine the quantitative importance of bank market power as a transmission mechanism for monetary policy. This question is interesting given three decades of consolidation in the banking industry that has softened competitive pressure. Indeed, recent research offers evidence that bank market power is an important friction that affects the pass-through of monetary policy to the supply of loans (Drechsler, Savov, and Schnabl 2017; Scharfstein and Sunderam 2016). In contrast, traditional analysis of monetary policy transmission focuses on regulatory constraints, such as reserve or capital requirements, as the central friction that influences monetary policy transmission (e.g. Bernanke and Blinder 1988; Kashyap and Stein 1995). Yet the qualitative nature of all of this evidence leaves open the question of the relative importance of traditional versus market-power channels for the transmission of monetary policy.

Our paper starts to fill this void by constructing and estimating a dynamic banking model with three important frictions: regulatory constraints, financial frictions, and imperfect competition. The estimation allows our data on commercial banks to discipline the model parameters and thus expose the relative magnitude of these three frictions. We find that, in the current banking system, bank market power plays an important role in determining the degree of monetary transmission. In terms of magnitude, the effects of bank market power are comparable in magnitude to those of bank capital, while the effects of bank reserve requirements are limited.

Our analysis produces two further results. First, we show that banks face nontrivial costs when they access external financial markets. This friction plays a pivotal role in transmitting banks’ deposit market power to their lending, as external financing costs serve to connect banks’ sources with their uses of funds. Relatedly, we also show that these frictions help explain differences between big and small banks in terms of monetary policy transmission.

Second, we show that bank market power interacts with capital regulation to reverse the
sign of monetary policy when the Federal Funds rate is very low. Specifically, we estimate that, when the Federal Funds rate is below 0.9%, further cuts in the policy rates can be contractionary. Moreover, we find external validation of this reversal rate by showing in a simple regression framework that the relationship between bank capital and interest rates switches sign at approximately this interest rate.

An understanding of the intuition behind these results requires a deeper description of the model. In the model, banks act as intermediaries between borrowers and depositors. Banks’ lending decisions are dynamic because deposits are short term, while loans are long term. Monetary policy enters the picture by changing the Federal Funds rate. In this setting, because banks are not price takers in deposit or loan markets, they choose the amount of a rate increase to pass on to depositors and borrowers. The magnitude of a pass-through is influenced by the tightness of regulatory constraints, the severity of financial frictions, and the intensity of competition.

These frictions in our model map onto four monetary policy transmission channels that are emphasized in the literature. The first is the bank reserve channel, in which a high Federal Funds rate raises the opportunity cost of holding reserves (Bernanke and Blinder 1988; Kashyap and Stein 1995) and thus contracts deposit creation. The second is the bank capital channel, in which a rise in the Federal Funds rate reduces bank capital because of a maturity mismatch, thus constraining banks’ capacity to lend (Van den Heuvel 2002; Bolton and Freixas 2000; Brunnermeier and Sannikov 2016). The third is the deposit market power channel, in which a rise in the Federal Funds rate allows banks to charge higher markups on deposits, thus leading to a contraction in deposits and loanable funds (Drechsler, Savov, and Schnabl 2017). The fourth is the loan market power channel, in which banks reduce markups to mitigate the effects of falling loan demand when the Federal Reserve raises rates (Scharfstein and Sunderam 2016).

To gauge the quantitative importance of these transmission channels, we estimate our model using a panel of U.S. commercial banks. Our estimation combines methods used
in the industrial organization literature (Berry, Levinsohn, and Pakes 1995; Nevo 2001) with those used in the corporate finance literature (Hennessy and Whited 2005; Bazdresch, Kahn, and Whited 2018). We begin by using demand estimation techniques to obtain the elasticities of loans and deposits to interest rates. We then plug these estimates into our model and use simulated minimum distance to obtain estimates of parameters that quantify financial frictions and operating costs. The sequential use of these two techniques represents a methodological advance that enables us to consider a rich equilibrium model that would otherwise be intractable to estimate.

To obtain our results pertaining to the relative importance of each transmission channel, we then use these parameter estimates to simulate counterfactual experiments in which we start with a model with all frictions as estimated and then subtract each channel from the model one at a time. These counterfactuals also produce our interesting result that rate cuts can be contractionary when rates are already low. Low interest rates depress bank profits by reducing bank market power in the deposit market, as competition from cash becomes more intense. Lower profits then tighten the capital constraint and reduce lending. This result sheds light on the sluggish bank lending growth that we observe following the crisis, as an ultra-low rate policy can unintentionally reduce bank profitability, and consequently constraining banks’ capacity to lend. Overall, our results suggest that Federal Reserve actions can have complicated effects on bank lending depending on policy rates, bank capital, and the industrial organization of the banking sector.

Our paper contributes to the literature on the role of banks in transmitting monetary policy (Bernanke and Blinder 1988; Kashyap and Stein 1995; Van den Heuvel 2002; Drechsler, Savov, and Schnabl 2017; Scharfstein and Sunderam 2016; Brunnermeier and Sannikov 2016). It is the first to estimate a structural dynamic banking model to quantify various transmission channels.¹ Prior to our work, little was known about the relative importance of various transmission channels, as this type of quantitative exercise is difficult to undertake using

¹Xiao (2018) also uses a structural approach, but the main focus is on shadow banks.
reduced-form methods. Moreover, the prior literature usually studies these transmission channels separately. For example, Drechsler, Savov, and Schnabl (2017) and Scharfstein and Sunderam (2016) study market power in the deposit and loan markets separately. However, little is known about the interaction between channels. Thus, an important contribution of this paper is to provide a unified framework within which to study these interactions. For example, we show that the relative importance of the deposit and loan markets depends on the level of the Federal Funds rate. The deposit market is more important when the rate is low, while the loan market becomes more important when the rate is high.

Second, our paper is related to the literature that studies the effects of negative interest rate policies (Brunnermeier and Koby 2016; Eggertsson, Juelsrud, and Wold 2017; Wang 2019; Campos 2019). While the theoretical branch of this literature offers interesting insights, it typically treats the banking sector with a high level of abstraction. In comparison, we provide a model that is sufficiently realistic to be directly mapped onto the micro data. Our paper also contributes to a set of empirical papers on negative interest policy (Heider, Saidi, and Schepens 2018; Basten and Mariathasan 2018; Demiralp, Eisenschmidt, and Vlassopoulos 2017). These studies show that negative interest rate policy can have perverse effects on bank lending. Our results suggest that such perverse effects can begin occurring even before the policy rate turns negative because a near-zero policy rate compresses banks’ deposit spreads. Therefore, in countries such as the United States where the policy rate has never gone negative, the banking sector could nevertheless be hurt by an ultra-low-rate monetary policy.

Third, our paper is related to the literature on external financial frictions. Focused largely on industrial firms, this literature shows that financial frictions significantly affect corporate policies such as investments, cash holdings, and dividend payouts. In the banking literature, Romer and Romer (1990) argue that banks can easily replace deposits with external financing, so shocks to deposits are unlikely to affect bank lending. In contrast, Kashyap and Stein (1995) argues that external financing is costly for banks, so the quantity of deposits matters
for bank lending. Our study sheds new light on this debate, as the structural estimation approach allows us to infer the degree of bank financing costs from the relative size of their non-reservable borrowing and deposit taking. We find that the magnitude of this cost is economically significant and that frictions related to bank balance sheets play an important role in the transmission of monetary policy.

Finally, our paper contributes to the structural industrial organization literature on the banking system (Egan, Hortacsu, and Matvos 2017; Buchak, Matvos, Piskorski, and Seru 2018; Egan, Lewellen, and Sunderam 2017; Xiao 2018). While this literature usually features a static industrial equilibrium, we introduce dynamic adjustment of banks’ balance sheets to study the role of maturity transformation and financial frictions. Our paper is also broadly related to the literature that uses quantitative dynamic banking models to study optimal capital regulation (Corbae and D’Erasmo 2013; Begneau 2018; Begneau and Landvoigt 2018; Elenev, Landvoigt, and Van Nieuwerburgh 2016). Our paper contributes to this literature in two ways. First, we estimate, rather than calibrate, all of our model parameters. More substantively, we extend this type of dynamic banking model by combining it with a structural industrial organization model, in the spirit of Berry, Levinsohn, and Pakes (1995), to study the effects of imperfect competition on banking monetary policy transmission.

2. Data

Our main dataset is the Consolidated Reports of Condition and Income, generally referred to as the Call Reports. This dataset provides quarterly bank-level balance sheet information for U.S. commercial banks, including deposit and loan amounts, interest income and expenses, loan maturities, salary expenses, and fixed-asset-related expenses. We merge the Call Reports with the FDIC Summary of Deposits, which provides branch-level information on each bank since 1994 at an annual frequency. The resulting sample period is 1994–2017. We use the national market as the market definition for our baseline estimation so each year
is a separate market.\textsuperscript{2} In the raw data, we have 7,244 banks on average in each year. We combine tiny local banks, which are defined as banks with market shares of less than 0.001% or fewer than ten domestic branches, as one option because they have limited influence on the equilibrium but can substantially slow down our structural estimation. After combining tiny local banks into one option, we have 753 banks on average in each year in our final sample.

Our analysis requires data from several additional sources. First, we retrieve publicly listed bank returns from CRSP. We link stock returns to bank concentration measures using the link table provided by the Federal Reserve Bank of New York. We obtain banking industry stock returns from Kenneth French’s website. We collect Federal Open Market Committee meeting dates from the FOMC meeting calendar. Finally, we obtain the following time series from FRED (Federal Reserve Economic Data): NBER recession dates, the effective Federal Funds rate, two-year and five-year Treasury yields, the aggregate amount of corporate bonds issued by U.S. firms, and the aggregate amount of cash, Treasury bonds, and money-market mutual funds held by households.

Table 1 provides summary statistics for the sample for our baseline demand estimation. In the first two lines we report the asset-value-weighted mean, equal-weighted mean, standard deviation, and several percentiles of bank market shares in both the deposit and loan markets. We define the total size of the deposit market as the sum of deposits, cash, and Treasury bills held by all U.S. households. The total size of the loan market is defined as the sum of U.S. corporate and household debt. Interestingly, mean market shares in both the loan and deposit markets lie near the 90\textsuperscript{th} percentile, indicating a very skewed distribution of market shares in which a few large banks dominate the market.

On the third and fourth lines of Table 1 we report summary statistics for deposit and loan rates. Deposit rates are calculated by dividing total deposit interest expenses by total deposits and loan rates are calculated by dividing total interest income by total loans. On

\textsuperscript{2}We use the national market because many types of loans (e.g. commercial and industrial loans) do not have disaggregate information at subnational levels. Our result is robust if we use local level deposits data.
the next two lines we report summary statistics for two non-rate bank characteristics used in the estimation: the total number of branches that a bank operates nationally and the number of employees per branch. While we see little variation in the number of employees per branch, we see both high variance and skewness in the number of branches per bank. The skewness is consistent with the skewness in market shares, as the number of branches is highly correlated with bank size. Lastly, we report summary statistics for the two supply shifters we use in our estimation: salaries and fixed-asset expenses (Ho and Ishii 2011). Fixed-asset expenses include all non-interest expenses stemming from the use of premises, equipment, furniture, and fixtures. We scale both supply shifters by total assets. In the rest of table, we report other moments of banks’ balance sheets. Net noninterest expenses are defined as the difference between noninterest expenses and noninterest income. To compute asset maturity, we use repricing maturity, the time until the next interest reset, for floating rate loans and prepayment-adjusted durations for mortgage loans and mortgage-backed securities.  

3. Stylized Facts

To motivate our study of the importance of bank market power for monetary policy transmission, we first examine the prices that banks charge on their deposits and loans. Panel A of Figure 1 shows a non-parametric relationship between the Federal Funds rate and average deposit spreads for U.S. banks. We define deposit spreads as the difference between the Federal Fund rate and deposit rates. Because this latter rate measures the price that banks charge for their depository services, one would expect, in the absence of market power or other frictions, to observe constant deposit spreads that equal the marginal costs of providing depository services. However, we find a positive relationship between deposit spreads and the Federal Funds rate, with this relationship steepening when the rate is close to zero. In other words, banks charge higher prices for their depository services when the Federal Reserve

3Elenev, Landvoigt, and Van Nieuwerburgh (2016) shows that the average effective duration of mortgage loans is around four years.
raises interest rates. This pattern is consistent with the idea that banks have market power in the deposit market, as suggested by Drechsler, Savov, and Schnabl (2017). In the presence of market power, a high Federal Funds rate allows banks to raise markups above marginal costs because an important outside option for depositors, cash, becomes more costly to hold. Therefore, banks make higher profits in the deposit market when the Fed raises short-term rates. Naturally, this effect is particular strong when the Federal Funds rate is close to zero, making deposits less attractive than cash.

Panel B of Figure 1 shows a non-parametric relationship between the Federal Funds rate and average loan spreads for U.S. banks. We define loan spreads as the difference between lending rates and 5-year Treasury yields adjusted loan loss provision. In this case, a higher Federal Funds rate is associated with smaller loan spreads. This pattern is consistent with Scharfstein and Sunderam (2016), who suggest that banks may lower markups on loans when the Federal Reserve raises rates to mitigate the effects of falling demand.

In summary, Figure 1 shows that market power creates two wedges between bond market interest rates and the rates at which banks borrow and lend. Furthermore, the sizes of these wedges seem to depend on monetary policy stance. This suggests that bank market power may influence how monetary policy is transmitted to bank lending.

4. Model

While the facts documented in the previous section point to interesting interactions between bank market power and monetary policy, this time-series evidence cannot help us understand the underlying mechanisms that drive these patterns in the data. To move in this direction, we next consider an infinite-horizon, equilibrium model with three sectors: households, firms, and banks. In the model, banks act as intermediaries between households and firms by taking short-term deposits from households and providing long-term loans to firms. In practice, firms also deposit in banks. Therefore, the household sector in our model should be broadly interpreted as savers. Similarly, the firm sector in our model should be broadly interpreted as borrowers.
households and firms as solving straightforward static discrete choice problems in which they choose from a variety of saving and financing vehicles. The richness of the model lies in the banking sector, as a variety of frictions imply that monetary policy affects the extent of intermediation that banks provide. These frictions are important because, in a frictionless world, banks are simply pass-through entities and bond market interest rates summarize monetary policy. In the presence of frictions in the banking system, however, the supplies of bank deposits and loans matter for monetary policy in their own right.

Since Bernanke and Blinder (1988), researchers have identified many frictions that affect monetary transmission through banks. Our model incorporates the following prominent channels featured in the literature. First, competition in the deposit and loan markets is imperfect. With market power, banks strategically choose deposit and loan rates to maximize their profits. This profit-maximizing behavior, in turn, determines how monetary policy transmits through the banking system. Second, banks are subject to reserve regulation and capital regulation. Reserve regulation links the opportunity cost of taking deposits to the prevailing Federal Funds rate. Capital regulation incentivizes banks to optimize their lending intertemporally with an eye to preserving excess equity capital as a buffer against future capital inadequacy. Third, access to non-deposit external financing is more costly than taking deposits. This friction implies that shocks to the quantity of deposits are transmitted to supplies of bank loans, as banks cannot costlessly replace deposits with non-reservable borrowing.

4.1 Households

At each time \( t \), the economy contains a mass \( W_t \) of households, each of which is endowed with one dollar. Hereafter, we drop the time subscript for convenience, so aggregate household wealth is then \( W \). Households choose from among the following investment options for their endowments: cash, bonds, and deposits, where the deposits of each individual bank constitute a differentiated product. If we index each option by \( j \), the households’ choice
set is given by $A^d = \{0, 1, \ldots, J, J + 1\}$, with option 0 representing cash, option $J + 1$ representing short-term bonds, and options $1, \ldots, J$ representing deposits in each bank. We further assume that each depositor can choose only one option. This one-dollar, one-option assumption is without loss of generality. For example, we can interpret this setting as if households make multiple discrete choices for each dollar in their possession, and the probability of choosing each of the options can be interpreted as portfolio weights.

Each option is characterized by a yield, $r^d_j$, and a vector of product characteristics, $x^d_j$, capturing the convenience for a household of using each option. For instance, a household might value the number of branches and the number of employees per branch when it chooses the bank in which it will deposit money. The yield on cash is 0, and the yield on bonds is the Federal Funds rate, $f$.

The problem a household faces involves choosing the best option to maximize its utility:

$$\max_{j \in A^d} u_{i,j} = \alpha^d_i r^d_j + \beta^d x^d_j + \xi^d_j + \epsilon^d_{i,j},$$

(1)

where households are indexed by $i \in 1, 2, \ldots, I$. $u_{i,j}$ is the utility for household $i$ from choosing option $j$, and $\alpha^d_i$ is sensitivity to the yield $r^d_j$. We allow households to exhibit varying sensitivity to yields to capture the idea that some depositors are less yield-sensitive than others.\(^5\) We model the distribution of depositors’ yield sensitivity as a uniform distribution with a mean, $\alpha^d$, and a standard deviation, $\sigma^d_\alpha$. $\beta^d$ are sensitivities to the non-rate product characteristics, $x^d_j$. $\xi_j$ is the unobservable product-level demand shock. $\epsilon^d_{i,j}$ is a relationship-specific shock to the choice of option $j$ by household $i$. $\epsilon^d_{i,j}$ captures the horizontal differentiation across banks. For instance, if household $i$ lives close to bank $j$, then $\epsilon^d_{i,j}$ is large, which makes household $i$ more likely to choose bank $j$, holding other characteristics

\(^5\)Xiao (2018) shows that such heterogeneity in yield sensitivity has an important impact on deposit rate-setting.
constant. The optimal choice for household $i$ is given by an indicator function:

$$\Pi_{i,j}^d = \begin{cases} 
1, & \text{if } u_{i,j} \geq u_{i,k}, \text{ for } k \in A^d \\
0, & \text{otherwise.}
\end{cases}$$

(2)

We aggregate the optimal choices across all households to compute the deposit market share of each bank $j$. Assuming that $\epsilon_{i,j}^d$ follows a generalized extreme value distribution with a cumulative distribution function given by $F(\epsilon) = \exp(-\exp(-\epsilon))$, we can derive the standard logit market share:

$$s_j^d(r_j^d|f) \equiv \int_i^{l} dF(\epsilon) = \frac{\sum_i \mu_i^d \exp(\alpha_i^d r_j^d + \beta_i^d x_j^d + \xi_i^d)}{\exp(\alpha_i^d f + \beta_i^d x_{J+1}^d + \xi_i^d) + \exp(\beta_i^d x_0^d + \xi_0^d) + \sum_m \exp(\alpha_m^d i_m + \beta_m^d x_m^d + \xi_m^d)},$$

(3)

where $\mu_i^d$ is the fraction of total wealth ($W$) held by households of type $i$. Note that the first term in the denominator, $\exp(\alpha_i^d f + \beta_i^d x_{J+1}^d + \xi_i^d)$, represents the exponential utility of holding Treasury bills. The second term, $\exp(\beta_i^d x_0^d + \xi_0^d)$, is the exponential utility of holding cash.

The demand function for deposits of bank $j$ is then given by the market share multiplied by total wealth,

$$D_j(r_j^d|f) = s_j^d(r_j^d|f) W.$$

(4)

4.2 Firms

There is a mass $K$ of firms, each of which wants to borrow one dollar, so aggregate borrowing demand is $K$. Firms can borrow by issuing long-term bonds or taking out bank loans. We assume that each individual bank is a differentiated lender, where this assumption is motivated by such factors as geographic location and industry expertise. Letting each option

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6 This distributional assumption is standard in the structural industrial organization literature and allows for a closed-form solution for market shares.
be indexed by \( j \), the firms’ choice set is given by \( \mathcal{A} = \{0, 1, \ldots, J, J + 1\} \), where option \( J + 1 \) represents bonds, option \( 1, \ldots, J \) represents loans from each bank, and option 0 is the option not to borrow at all.\(^7\)

For tractability, we assume that both bonds and bank loans have the following repayment schedule. In each period the firm has to pay back a fraction, \( \mu \), of its outstanding principal plus interest. For instance, if the firm borrows one dollar at fixed interest \( r \), the repayment stream, starting in the next period, is \( \mu + r, (1 - \mu) \cdot (\mu + r), (1 - \mu)^2 \cdot (\mu + r), \ldots \). Accordingly, all firm debt has an average maturity of \( \frac{1}{\mu} \) periods.

The long-term bond interest rate is given by its default cost plus an expected weighted average of future Federal Funds rates, \( \bar{f}_t \):

\[
\bar{f}_t = \mu f_t + \mathbb{E}_t \left[ \sum_{n=1}^{\infty} \mu(1 - \mu)^n f_{t+n} \right].
\] (5)

Each of the firm’s financing options is characterized by a rate, \( r_{lj} \), and a vector of product characteristics, \( x_{lj} \), capturing the convenience of using each of the financing options. For instance, borrowers may value the number of branches and the number of employees per branch when they choose from which bank to borrow.

The problem a firm faces involves choosing the best option to maximize its profits:

\[
\max_{j \in \mathcal{A}} \pi_{i,j} = \alpha_i r_{lj} + \beta_i x_{lj} + \xi_i + \epsilon_{i,j},
\] (6)

where \( \pi_{i,j} \) is the profits of firm \( i \) from choosing option \( j \), and \( \alpha_i \) is sensitivity to the interest rate \( r_{lj} \), which follows a uniform distribution with a mean, \( \alpha_i \), and a standard deviation, \( \sigma_{\alpha_i} \). \( \beta_i \) are the sensitivities to non-rate characteristics, \( x_{lj} \). \( \xi_i \) is the unobservable product-level demand shock. \( \epsilon_{i,j} \) is an idiosyncratic shock when firm \( i \) borrows from bank \( j \). The optimal

\(^7\)Our index choices recycle the notation \( i \) to index firms and \( j \) to index a firm’s borrowing options.
choice of household $i$ is given by an indicator function:

$$I_{i,j}^l = \begin{cases} 
1, & \text{if } \pi_{i,j} \geq \pi_{i,k}, \text{ for } k \in A^l \\
0, & \text{otherwise.} 
\end{cases}$$ (7)

We aggregate the optimal choices across all the firms to compute the loan market share of each bank $j$. Assuming that $\epsilon_{i,j}^l$ follows a generalized extreme value distribution with a cumulative distribution function given by $F(\epsilon) = \exp(-\exp(-\epsilon))$, we can derive the standard logit market share:

$$s_{j}^l (r_{j}^l | f) \equiv \int I_{i,j}^l dF(\epsilon) = \sum_{i=1}^{I} \frac{\mu_i \exp(\alpha_{i}^l r_{j}^l + \beta_{i}^l x_{j}^l + \xi_{i}^l)}{\exp(\alpha_{i}^l \overline{f} + \beta_{i}^l x_{j+1}^l + \xi_{j+1}^l) + \exp(\beta_{i}^l x_{0}^l + \xi_{0}^l) + \sum_{m=1}^{J} \exp(\alpha_{i}^l r_{m}^l + \beta_{i}^l x_{m}^l + \xi_{m}^l)},$$ (8)

where $\mu_i^l$ is the fraction of type $i$ firms; $\overline{f}$ is the long-term bond interest rate. Note that the first term in the denominator, $\exp(\alpha_{i}^l \overline{f} + \beta_{i}^l x_{j+1}^l + \xi_{j+1}^l)$, represents the exponential utility of issuing bonds. The second term, $\exp(\beta_{i}^l x_{0}^l + \xi_{0}^l)$, is the exponential utility of not borrowing. The demand function for loans is given by the market share multiplied by the total loan market size,

$$B_{j} (r_{j}^l | f) = s_{j}^l (r_{j}^l | f) K.$$ (9)

### 4.3 The Banking Sector

Given the Federal Funds rate, $f_t$, each bank simultaneously sets its deposit rate, $r_{j,t}^d$, and its loan rate $r_{j,t}^l$, thereby implicitly choosing the quantities of deposits to take from households and credit to extend to firms. For example, given each bank $j$’s choice of $r_{j,t}^d$, households solve the utility maximization problem as described in Equation (1), which yields the quantity of deposits supplied to bank $j$, $D_j(r_{j,t}^d)$. Because households have the outside option of holding
zero-nominal return cash, banks face a zero lower bound for the deposit rates.

\[ r_{j,t}^d \geq 0. \tag{10} \]

Similarly, given each bank \( j \)'s choice of \( r_{j,t}^l \), firms solve their profit-maximization problem, which yields the quantity of loans borrowed from bank \( j \), \( B_j(r_{j,t}^l) \). To simplify notation, in what follows we suppress the dependence of loans and deposits on the relevant interest rates, denoting them simply as \( D_{j,t} \) and \( B_{j,t} \).

This lending activity involves a maturity transformation. Let \( L_{j,t} \) denote the amount of loans that the bank currently holds. In each period, as in the case of bonds, a fraction, \( \mu \), of a bank’s outstanding loans matures. This assumption about long-term loans captures a traditional maturity transformation role for banks, in which they convert one-period deposits into long-term bank loans with maturity \( \frac{1}{\mu} \). As noted above, banks can also issue new loans at an annualized interest rate of \( r_{j,t}^l \). The new loans, once issued, have the same maturity structure as the existing ones, and the interest rate is fixed over the entire life span of the new loans. From the bank’s perspective, the present value of interest income equals:

\[ I_{j,t} = \sum_{n=0}^{\infty} \frac{(1 - \mu)^n B_{j,t} r_{j,t}^l}{(1 + \gamma)^n}, \tag{11} \]

where \( \gamma \) is the bank’s discount factor. As such, a bank’s outstanding loans evolve according to:

\[ L_{j,t+1} = (1 - \mu) (L_{j,t} + B_{j,t}). \tag{12} \]

We assume that a random fraction of loans, \( \delta_t \in [0, \mu] \), falls into delinquency in each period, with delinquency occurring when a loan comes due but the borrower fails to pay. Although we assume that delinquent payments are written off by the bank, with charge-offs equal to \( L_t \times \delta_t \), defaulting on a payment in one period does not exonerate the borrower from payments in future periods. Therefore, delinquency does not affect the evolution of loans in
We summarize the rest of the bank’s activities in the balance sheet represented in Table 2, where we suppress the subscript for bank identity, $j$, for convenience. Here, we see that a bank’s assets consist of existing plus new loans, reserves, and holdings of government securities. Its liabilities consist of deposits and borrowing that is not subject to reserve requirements. The difference is then bank equity. We now discuss these items in detail.

In each period, the bank can rely on deposits or internal retained earnings to finance its loans. When the supply of funds falls short of loan demand, the bank can also borrow via non-reservable securities, $N_t$. A typical example of non-reservable borrowing is large-denomination CDs. As argued by Kashyap and Stein (1995), because non-reservable borrowing is not insured by FDIC deposit insurance, purchasers of this debt must concern themselves with the default risk of the issuing bank. These considerations make the marginal cost of non-reservable borrowing an increasing function of the amount raised, and motivate our next assumption, which is that non-reservable borrowing incurs a quadratic financing cost beyond the prevailing Federal Funds rate, as follows:

$$
\Phi^N(N_t) = \frac{\phi^N}{2} \cdot \frac{N_t^2}{D_t}.
$$

This cost of non-reservable borrowing represents an important friction because, in its absence, banks could always raise wholesale funding to compensate for the shortfall in deposits. This activity would disconnect banks’ deposit-taking decisions from their lending decisions, so changes in bank deposits induced by the Federal Funds rate shocks would have no impact on lending.

Banks also incur costs for serving depositors, such as hiring tellers and managers. We assume that costs are linear in the amount of deposits:

$$
\Phi^d(D_t) = \phi^d D_t.
$$
Similarly, we also assume that lending activity itself incurs separate costs, such as the labor input necessary to screen loans or maintain client relationships. Again, we assume a linear functional form, as follows:

$$\Phi^l(B_t) = \phi^l B_t.$$  \hfill (15)

In addition to variable cost, banks may also incur some fixed operating cost. Outside of their loan portfolios, banks may also earn noninterest income. We assume both the fixed operating cost and the noninterest income are independent of the deposit-taking and lending decisions. We use a parameter $\psi$ to represent the difference between the fixed operating expenses and noninterest income per unit of the steady state equity capital, $\bar{E}$. Therefore, the net fixed operating cost for each period is $\psi \bar{E}$.

If the total supply of funds exceeds demand from the lending market, the bank can invest in government securities, $G_t$, where the return is the Federal Funds rate, $f_t$. The bank’s holdings of loans, government securities, deposits, reserves, and non-reservable borrowing must satisfy the standard condition that assets equal liabilities plus equity:

$$L_t + B_t + R_t + G_t = D_t + N_t + E_t,$$  \hfill (16)

where $R_t$ denotes bank reserves and $E_t$ is the bank’s beginning-of-period book equity. $E_t$ itself evolves according to:

$$E_{t+1} = E_t + \Pi_t \times (1 - \tau) - C_{t+1},$$  \hfill (17)

where $\tau$ denotes the linear tax rate, and $\Pi_t$ represents the bank’s total operating profits from its deposit-taking, security investments, and lending decisions. This identity ends up being a central ingredient in the model, as it links bank competition, which is reflected in profits, with bank capital regulation.
The profits in (17) are in turn given by:

\[ \Pi_t = I_t - D_t \times r^d_t + G_t \times f_t - \Phi^I(B_t) - \Phi^d(D_t) - N_t \times f_t - \Phi^N(N_t) - L_t \times \delta_t - \psi \bar{A}. \] (18)

Finally, \( C_{t+1} \) in equation (17) represents the cash dividends distributed to the bank’s shareholders. We assume that a bank can increase its inside equity only via retained earnings, that is, there is no new equity issuance, so:

\[ C_{t+1} \geq 0 \quad \forall t. \] (19)

This constraint reflects a bank’s limited liability, which prevents it from obtaining any external equity financing from shareholders. This constraint implies that banks cannot raise equity capital to replace deposits or non-reservable borrowing. In Section 7, we find that allowing for equity issuance has only limited impacts on the results because banks’ equity issuances are both tiny and rare.

We now introduce the capital requirement and the reserve requirement:

\[ E_t \geq \kappa \times (L_t + B_t), \] (20)
\[ R_t \geq \theta \times D. \] (21)

Equation (20) implies that the bank’s book equity at the beginning of the next period has to be no smaller than a fraction, \( \kappa \), of total loans outstanding. Equation (21) is the bank’s reserve requirement, which says that the bank has to keep \( \theta \) of its deposits in a non-interest-bearing account with the central bank. Zero interest on reserves implies that the bank has no incentive to hold excess reserves, so equation (21) holds with equality.\(^8\)

\(^8\)The Federal Reserve began paying interest on reserves in October 2008. In section 6, we show that paying interest on reserves has a limited impact on the equilibrium.
4.4 Monetary policy

Monetary policy is modeled as a process of the Federal Funds rates determined by the central bank. Since our focus is on the banking sector, we assume that monetary transmission in the bond market is simply pinned down by the expectations hypothesis, i.e. the long-term bond yield equals the average of expected future short rates. By doing so, we assume away frictions in the bond market which may drive the long-term bond yield away from the expectations hypothesis benchmark. Formally, define $f_t^n$ as $n$-year yield at time $t$. We have

$$f_t^n = \frac{1}{n} E[f_t + f_{t+1} + \ldots + f_{t+n}].$$  \hspace{1cm} (22)

Monetary policy affects banks in two ways. First, by setting the short rate, monetary policy affects the marginal funding cost banks pay in the non-reservable funding market. Second, by setting the short rate and influencing the long rate through expectations, monetary policy affects the relative attractiveness of various saving and financing vehicles for households and firms, which ultimately affects banks’ market power in the deposit and loan markets.

We allow the Federal Funds rate to correlate with the process of loan charge-offs. Formally, the law of motion for bank loan charge-offs and the Federal Funds rate is given by:

$$
\begin{bmatrix}
\ln \delta_{t+1} - \mathbb{E}(\ln \delta) \\
\ln f_{t+1} - \mathbb{E}(\ln f)
\end{bmatrix}
= 
\begin{bmatrix}
\rho_\delta & \rho_\delta f \\
0 & \rho_f
\end{bmatrix}
\begin{bmatrix}
\ln \delta_t - \mathbb{E}(\ln \delta) \\
\ln f_t - \mathbb{E}(\ln f)
\end{bmatrix}
+ 
\begin{bmatrix}
\sigma_\delta & 0 \\
0 & \sigma_f
\end{bmatrix}
\cdot 
\mathcal{N}_2,
$$  \hspace{1cm} (23)

where $\mathcal{N}_2$ stands for the density function of a standard bi-variant normal distribution.

\hspace{1cm} \text{Note that } f_t = f^1_t \text{ because the smallest increment of time is 1 year in the model. In practice, the Federal Funds rate is an overnight rate.}
4.5 Bank’s problem and equilibrium

Figure 2 summarizes the sequence of events in a typical time period. The bank enters the period and observes the Federal Funds rate, $f_t$, and the realization of the default fraction, $\delta_t$. Next, banks interact with households and firms by setting the loan and deposit spreads, receiving the corresponding amount of deposits from households, and extending the corresponding amount of loans to firms. Depending on the extent of these activities, the banks adjust their reserves, holdings of government securities, and non-reservable borrowing. Finally, banks collect profits at the end of the period and distribute dividends to shareholders.

As discussed above, loan and deposit demand depend on the rates put forth by all banks in the economy. Accordingly, when each bank chooses its own deposit and loan rates ($r^d_t$ and $r^l_t$) as well as its non-reservable borrowings ($N_t$) and investment in government securities ($G_t$), it rationally takes into account the choices made by other banks in both the current and future periods. As such, all of a bank’s optimal choices depend on the composition of the banking sector, that is, the cross-sectional distribution of bank states, which we denote by $\Gamma_t$. Letting $P^\Gamma$ denote the probability law governing the evolution of $\Gamma_t$, we can express the evolution of $\Gamma_t$ as:

$$\Gamma_{t+1} = P^\Gamma(\Gamma_t). \quad (24)$$

In every period, after observing the Federal Funds rate ($f_t$) and the random fraction of defaulted loans ($\delta_t$), banks choose the optimal policy to maximize their discounted cash dividends to shareholders:

$$V(f_t, \delta_t, L_t, E_t | \Gamma_t) = \max_{\{r^d_t, r^l_t, G_t, N_t, R_t, C_{t+1}\}} \frac{1}{1 + \gamma} \left\{ C_{t+1} + \mathbb{E} V(f_{t+1}, \delta_{t+1}, L_{t+1}, E_{t+1} | \Gamma_{t+1}) \right\}, \quad (25)$$

s.t. \quad (10), (13), (14), (15), (16), (17), (24).

We define equilibrium in this economy as follows.
Definition 1 A stationary equilibrium occurs when:

1. All banks solve the problem given by (25), taking as given the other banks’ choices of loan and deposit rates.

2. All households and firms maximize their utilities given the list of rates put forth by banks.

3. Each period, the deposit and loan markets clear.

4. The probability law governing the evolution of the industry, $P^\Gamma$, is consistent with banks’ optimal choices.

One of the state variables for the banks’ problem ($\Gamma_t$) is an object whose dimension depends on the number of banks in the economy. This dimensionality poses a challenge to numerically solving the banks’ problem. To simplify the model solution, we follow Krusell and Smith (1998) by considering a low-dimensional approximation of $\Gamma_t$. Specifically, we postulate that all information about $\Gamma_t$ that is relevant to banks’ optimization can be summarized by the contemporaneous Federal Funds rate ($f_t$). Accordingly, we define the equilibrium “average” loan and deposit rates $\bar{r}_l,i(f_t)$ and $\bar{r}_d,i(f_t)$, respectively, as

$$\exp(\alpha_d r_d,i(f_t) + \beta_d x_d + \xi_d) \equiv \mathbb{E}\left[ \exp(\alpha_d r_j,d + \beta_d x_d + \xi_d) | f_t \right],$$

and

$$\exp(\alpha_l r_l,i(f_t) + \beta_l x_l + \xi_l) \equiv \mathbb{E}\left[ \exp(\alpha_l r_j,l + \beta_l x_l + \xi_l) | f_t \right],$$

where $\bar{r}_l,i(f_t)$ and $\bar{r}_d,i(f_t)$ summarize the choices of other banks, thereby allowing each bank to derive its choices of deposit and loan rates. In solving the model, we ensure that $\bar{r}_l,i(f_t)$ and $\bar{r}_d,i(f_t)$ are consistent with equilibrium bank choices by iterating over their values until we reach convergence. We then regress the simulated evolution of the aggregate deposit and loan rates on the perceived law of motion based on the banks’ belief. The R-squares for our approximation are over 95% on the deposit market, and 99% on the loan market. Thus, although the banks do not consider the full distribution, $\Gamma_t$, in the economy, the errors in forecasting rates that result from this omission are very small. This is mainly a result
of two mechanisms in the model: 1) without any financial or regulatory constraint, banks have a static optimal deposit/loan rate. For example, on the lending market, the optimal level of loans serves to equalize the expected marginal interest income to the funding cost, which is a function of the current Federal Funds rate only. Therefore, the static optimal rate depends only on the Federal Funds rate, but not other aggregate moments; 2) taking the loan market as an example, constrained banks deviate from the static optimum by lowering the loan quantity and charging higher loan spreads. However, these banks cannot widen their spreads too much if they are to avoid having their market shares largely stolen by other competing banks and financing vehicles. The competitive force on the market ensures that banks that deviate from the static optimum introduce only modest distortions into the other banks’ rate forecasts.

4.6 Monetary policy transmission

In this section, we use a simplified version of the model to illustrate the key transmission mechanisms.

4.6.1. Frictionless benchmark

First, we examine how the economy behaves in a frictionless benchmark model. By frictionless, we mean a simplified version of our model with the following six features: (1) the bank has no market power in either the deposit or the loan market, i.e. the deposit and loan demand elasticities are infinite; (2) there are no frictions related to non-reservable borrowing, so $\phi^N = 0$; (3) the bank faces no capital requirement, so $\kappa = 0$; (4) there is no reserve requirement, so $\theta = 0$; (5) there is no maturity transformation; and (6) the operating costs, $\phi^d$ and $\phi^l$, are zero. These features imply that the banks’ problem can be viewed as a static problem.

In this static frictionless model, banks choose deposit rates, $r^d$, and loan rates, $r^l$, to
maximize one-period profits

$$\Pi = \max_{\{r^l, r^d\}} r^l B - r^d D - f (B - D).$$ \hspace{1cm} (28)$$

When deposits fall short of loans, a bank can make up any funding shortfall, $B - D$, with non-reservable borrowing at a cost equal to the Federal Funds rate, $f$. There are no additional financing costs associated with non-reservable borrowing. When there are excess deposits, the bank can invest any of this surplus, $D - B$, in government securities and earn the Federal Funds rate, $f$.\textsuperscript{10} In the absence of balance sheet friction, the bank can optimize its choices for deposit and loan amounts separately.

The optimal lending rates are given by the Federal Funds rate plus markups:

$$r^l = f + \left( \frac{-B'}{B} \right)^{-1},$$ \hspace{1cm} (29)

and the optimal deposit rates are given by the Federal Funds rate minus markups:

$$r^d = f - \left( \frac{D'}{D} \right)^{-1}.$$ \hspace{1cm} (30)

When there is perfect competition among banks, the demand elasticities, $-\frac{B'}{B}$ and $\frac{D'}{D}$, become infinite and the markups converge to zero. Deposit and lending rates converge to the Federal Funds rate:

$$r^d \to f, \enspace r^l \to f.$$ \hspace{1cm} (31)

Under the frictionless benchmark, banks function as the bond market, passing through the interest rate changes to the exact same degree.

\textsuperscript{10}In reality, the Federal Funds rate is slightly higher than the risk-free Treasury yield because the Federal Funds rate contains a small risk premium while the Treasury yield contains a small convenience yield. This difference is, however, quite small.
4.6.2. Imperfect competition

When competition is imperfect, market power creates a wedge between the Federal Funds rate and the rates at which banks borrow and lend. Monetary policy can affect the market power of banks by influencing the attractiveness of bank deposits or loans relative to other outside options available to households or firms.

In the model, bank deposits face competition from both bonds and cash. Investors enjoy higher returns from investing in bonds but endure low liquidity. On the other hand, cash holdings offer high liquidity but a zero return. Bank deposits fall somewhere in between, offering investors both liquidity and a non-zero return. An increase in the Federal Funds rate increases the opportunity cost of holding cash, which allows banks to charge larger markups on deposits (e.g., Drechsler, Savov, and Schnabl 2017), so:

$$\frac{\partial (D')}{\partial f} - 1 < 0.$$ 

(32)

In the lending market, an increase in the Federal Funds rate makes bank loans less attractive to firms relative to the outside option of not borrowing to make any investment. Therefore, total lending shrinks and banks optimally lower their markups on loans to mitigate the effects of lower loan demand.\(^\text{11}\)

$$\frac{\partial (-B')}{-\partial f} - 1 > 0.$$ 

(33)

Figure 3 summarizes the effects of market power on monetary transmission. Bank market power creates an “intermediation wedge” between the rate paid by borrowers and the rate received by depositors. Furthermore, banks vary the “intermediation wedge” to maximize

\(^{11}\text{Note that the transmission of the Federal Funds rate to the lending rate differs from the standard cost pass-through problem in the industrial organization literature. The standard cost pass-through problem concerns only the pass-through of marginal costs to prices while the demand side is held constant (Bulow and Pfleiderer 1983). In contrast, in the setting of monetary transmission, the Federal Funds rate not only affects banks’ marginal funding cost, it also affects borrowers by changing the attractiveness of the outside option.}\)
profits as monetary policy changes the attractiveness of the outside options for depositors and borrowers.

4.6.3. Balance sheet frictions

In the frictionless benchmark, the deposit market and loan market are entirely separable because banks can costlessly use non-reservable borrowing and government securities as buffers. Now consider the case in which banks face balance sheet frictions, so they incur additional costs when using non-reservable borrowing. In this case, the banks’ optimization problem becomes:

$$\Pi = \max_{\{r^l, r^d\}} r^l B - r^d D - f(B - D) - \Phi(N),$$  \hspace{1cm} (34)

where $\Phi(N)$ is the cost of non-reservable borrowing or investing excess funding and $N = B - D$ is the funding imbalance. In the presence of balance sheet frictions, the bank cannot costlessly replace any lost deposits with wholesale borrowing. Therefore, shocks to deposits will be transmitted to loans.

4.6.4. Reserve requirement

Now consider the case in which banks face a reserve regulation requiring that, for every dollar of deposits, the bank needs to keep a fraction, $\theta$, of these deposits as reserves. Assuming that the interest on reserves is zero, banks’ optimization becomes

$$\Pi = \max_{\{r^l, r^d\}} r^l B - r^d D - f(B + R - D), \text{ s.t. } R \geq \theta D.$$  \hspace{1cm} (35)

Because the interest rate on reserves is zero, the reserve constraint is binding. We can solve for the optimal deposit rate as

$$r^d = f - \left(\frac{D'}{D}\right)^{-1} - \theta f.$$  \hspace{1cm} (36)
Here we see that higher Federal Funds rates increase the opportunity cost of holding reserves, $\theta f$, which lowers deposit rates. Lower deposit rates, in turn, reduce the quantity of deposits and optimal supply of loans.

### 4.6.5. Capital regulation

Now consider the case in which banks face a capital regulation that requires bank capital to exceed a certain fraction of bank assets. In this case, the banks’ optimization problem becomes:

$$\Pi = \max \{r^d B - r^d D - f (B - D), s.t. E_0 + (1 - \tau_c)\Pi \geq \kappa B. \}$$

(37)

In the presence of capital regulation, shocks to bank capital affect lending capacity. One way that monetary policy affects bank capital is through maturity mismatch. Because deposits are short-term, an increase in the Federal Funds rate raises the rate the bank has to pay on all deposits. Loans are long-term, however, so only a fraction of loans matures, with the remaining outstanding loans commanding the same pre-fixed rate. Hence, an increase in the Federal Funds rate temporarily reduces bank capital and tightens the bank capital constraint in equation (20).

Another way that monetary policy affects bank capital is through market power. When the Federal Funds rate increases, banks can charge higher rents from the deposit market, as the competition from cash softens, but bank profits from the loan market decrease as borrowers are less willing to borrow at higher rates. The relative importance of the two forces vary with varying Federal Funds rate environments, leading to variations in the tightness of banks’ capital constraints.

### 5. Estimation

We begin by describing our estimation strategy. We then discuss the parameter estimates and assess the fit of our model. Lastly, we use the estimated model as a laboratory to explore
how banks’ market power influences their transmission of the Fed’s monetary policy.

5.1 Estimation procedure

We divide the estimation procedure into two stages. In the first stage, we estimate the demand functions for deposits and loans, following Berry, Levinsohn, and Pakes (1995). In the second stage, we estimate the remaining parameters that indicate banks’ balance sheet frictions using the simulated method of moments (SMM).

We first estimate deposit demand, and loan demand follows analogously. Deposit demand is characterized by the following preference parameters, \( \Theta^d = (\alpha^d, \sigma^d_\alpha, \beta^d) \), where \( \alpha^d \) and \( \sigma^d_\alpha \) are the mean and standard deviation of the sensitivity to deposit rates; and \( \beta^d \) are the sensitivities to non-rate characteristics.

Following Berry, Levinsohn, and Pakes (1995), we construct a nonlinear GMM estimator for the preference parameters by exploiting a moment condition that is a product of instrumental variables, \( Z \), and the unobservable demand shocks, \( \xi^d \). Formally, the GMM estimator is

\[
\hat{\Theta}^d = \arg \min_{\Theta^d} \xi (\Theta^d)' Z' W^{-1} Z \xi (\Theta^d),
\]

where \( W \) is a consistent estimate of \( E[Z' \xi \xi' Z] \).

A key challenge in identifying the demand parameters is the natural correlation between deposit rates \( r^d_j \) and unobservable demand shocks \( \xi^d_j \). Banks may lower deposit rates if they observe a positive demand shock. To identify the associated yield sensitivity, we use a set of supply shifters, \( c_j \), as instrumental variables. Our particular supply shifters are salaries and non-interest expenses related to the use of fixed assets. These shifters are used in previous studies, such as Dick (2007) and Ho and Ishii (2011). Our identifying assumption is that customers would not care about the cost per se once product characteristics are controlled for. Therefore, these supply shifters are orthogonal to unobservable demand shocks and thus shift the supply curve along the demand curve, allowing us to trace out the slope of the
demand curve. Formally, the vector of instrumental variables $Z$ is defined as follows:

$$Z = [x, c],$$

(39)

where $x$ is a vector of non-rate bank characteristics including the number of branches, the number of employees per branch, bank fixed effects, and time fixed effects, and $c$ is a vector of supply shifters including salaries and non-interest expenses related to the use of fixed assets. Note that our identification of the demand curve does not use variations in monetary policy. In fact, any aggregate demand shocks are observed by time fixed effects. Therefore, our identification strategy avoids a common challenge that studies on monetary transmission face, namely, the endogeneity of monetary policy to the aggregate bank credit supply.

We compute the unobservable demand shocks, $\xi^d$, using the nested fixed-point algorithm described in Nevo (2001). Specifically, for a given set of demand parameters $\Theta^d$ and the actual market shares in the data, $s_0$, we can solve

$$\xi^d (\Theta^d) = s^{-1} (s_0 \mid \sigma_{\alpha^d}) - (\alpha^d r^d_j + \beta^d x^d_j)$$

(40)

where $s^{-1} (.)$ is the inverse of the demand function specified by equations (3).

Using the demand parameter estimated in the first stage, we can construct the empirical demand system. Note that our data contain a large number of banks even after we combine tiny local banks into one option in the demand estimation. This feature of the data poses a challenge for the second-stage SMM estimation because estimating a dynamic model with a large number of heterogeneous banks would be intractable. Therefore, we use the estimated demand parameters in the first stage to construct a demand system with $\hat{J}$ ex ante symmetric representative banks, where the number of representative banks $\hat{J}$ is calibrated to match the average local banking concentration as indicated in the data. Because the size distribution has a heavy left tail, this approach substantially reduces the number of banks in the model while keeping the market concentration similar to that we observe in the data. We define
\( q \) as the quality value for each of the \( \hat{J} \) representative banks, which summarizes the utility from the non-rate product characteristics.\(^{12}\) We choose the quality value \( q \) such that the sum of the exponential utility of the \( \hat{J} \) symmetric banks is the same as that of \( J \) heterogeneous banks:

\[
\hat{J} \exp(q^d) = \sum_{j=1}^{J} \exp \left( \hat{\beta}^d x_j^d + \hat{\xi}_j^d \right)
\]

(41)

The above formula transforms the heterogeneous non-rate characteristics into symmetric quality values while preserving market concentration and the sum of exponential utility. In the case when banks have exactly the same deposit rates, the total market share of \( \hat{J} \) symmetric banks is the same as that of \( J \) heterogeneous banks. With the quality value in hand, we parameterize the deposit demand functions as:

\[
D_j(r_j^d | f) = \sum_{i=1}^{I} \mu_i^d \frac{\exp \left( \hat{\alpha}_i^d r_j^d + q_i^d \right)}{\exp \left( \hat{\alpha}_i^d f \right) + \exp \left( q_i^c \right) + \sum_{m=1}^{J} \exp \left( \hat{\alpha}_m^d r_m^d + q_m^d \right)} W
\]

(42)

where \( j = 1, 2, ..., \hat{J} \). \( \hat{\alpha}_i^d \) is drawn from a discretized uniform distribution with a mean of \( \hat{\alpha} \) and a standard deviation of \( \hat{\sigma}_\alpha \). \( \mu_i \) represents the fraction of each type of depositors. \( q_i^d \) and \( q_i^c \) represent the quality value of bank deposits and cash, respectively. We normalize the quality value of Treasury bills to zero.

We estimate the loan demand function in a procedure that is similar to the one we used to estimate deposit demand except that we assume a homogeneous sensitivity to loan rates.\(^{13}\) We include the same set of supply shifters and non-rate characteristics as in the deposit market but allow the sensitivities to these characteristics to diverge from those in the deposit market. Using the estimated demand parameters for the loan market, we can

\(^{12}\)Note that non-rate product characteristics include the number of branches, the number of employees per branch, bank fixed effects, and time fixed effects.

\(^{13}\)We find that introducing heterogeneity in loan-rate sensitivity considerably slows down the estimation but has a limited impact on banks’ rate-setting decisions.
construct the quality value by solving the following equation:

$$\hat{J} \exp(q^l) = \sum_{j=1}^{J} \exp\left(\tilde{\beta}^l x_j^l + \tilde{\xi}_j^l\right).$$ (43)

With the quality value in hand, we parameterize the loan demand functions as:

$$B_j(r^l_j|f) = \frac{\exp(\tilde{\alpha}^l r^l_j + q^l_{lj})}{\exp(\tilde{\alpha}^l f) + \exp(q^l_n) + \sum_{m=1}^{J} \exp(\tilde{\alpha}^l r^l_m + q^l_{lm})} K,$$ (44)

where $q^l_j$ and $q^l_n$ represent the quality value of bank loans and not borrowing, respectively. Note that the quality value of not borrowing, $q^l_n$, cannot be estimated from the demand estimation because we do not observe its share. Therefore, we relegate this parameter to our second-stage estimation.

The final plug-in problem consists of inserting the estimated demand functions described in equations (42) and (44) into the banks’ dynamic problem (25). This plug-in problem operationalizes the notion that banks set deposit and loan rates facing the above-specified demand curves for deposits and loans.

In the second stage, we estimate seven additional parameters using SMM, which chooses parameter values that minimize the distance between the moments generated by the model and their analogs in the data. We use ten moments to identify the remaining seven model parameters. Parameter identification in SMM requires choosing moments whose predicted values are sensitive to the model’s underlying parameters. Our identification strategy ensures that there is a unique parameter vector that makes the model fit the data as closely as possible.

First, we use banks’ average non-reservable borrowing as a fraction of their deposits to identify the cost of holding non-reservables, $\phi^N$. Intuitively, higher financing costs induce banks to finance loans mainly through deposits, and less via borrowing. Next, we use the average deposit and loan spreads to identify banks’ marginal costs of generating deposits, $\phi^d$,.
and servicing loans, $\phi^l$. Higher marginal costs lead to higher spreads that banks charge in the
deposit and lending markets.\textsuperscript{14} In addition to marginal costs, banks also incur the net fixed
operating cost, $\psi$, which is identified by two moments—the first moment is total non-interest
expenses minus non-interest income. This moment directly measures the out-of-pocket costs
that banks pay outside of their routine deposit-intaking and loan-servicing business; the
second moment is banks’ leverage ratio, which indirectly reflects the fixed operating costs
that banks are facing. Higher fixed costs induce banks to operate with higher leverage.
Next, we use banks’ average dividend yield to identify the discount rate, $\gamma$. Intuitively, a
high discount rate makes banks impatient, so they pay out a larger fraction of their profits
to shareholders instead of retaining the funds to finance future business. Finally, to identify
the relative size of the deposit market, $W/K$, and the value of firms’ outside option of not
borrowing, $q_n^l$, we include banks’ average deposit-to-asset ratio and the sensitivity of total
borrowing to the Federal Funds rate, which is estimated through a vector autoregression
(VAR).\textsuperscript{15} These two moments suit this purpose because keeping the market shares of the
banks constant, when $W/K$ increases, it implies that the dollar amount of deposit intake
will increase relative to the loan value, leading to a higher deposit asset ratio. When when
the outside option becomes less valuable, its market share remains low regardless of the
current Federal Funds rate. Thus, the sensitivity of aggregate corporate borrowing to the
Federal Funds rate should fall as $q_n^l$ falls. In addition, a high loan-to-deposit ratio should
be inversely related to $q_n^l$ because when aggregate borrowing from the corporate sector is
high, bank loans face proportionally higher demand. Last, we also include banks’ average
market-book-ratio to ensure that our model predicts the right valuation for banks.

\textsuperscript{14}Deposit spreads are defined as the difference between the Federal Funds rate and deposit rates, while
loan spreads are the difference between loan rates and Treasury yields matched by maturity.
\textsuperscript{15}Details of the VAR can be found in the Online Appendix.
5.2 Baseline Estimation Results

Table 3 presents the point estimates for the 22 model parameters. In Panel A, we start with the parameters that we can directly quantify in the data. Specifically, we set the corporate tax rate to its statutory rate of 35%. The capital regulation stipulates that banks keep no less than 6% of their loans as book equity. The reserve regulation requires a 10% reserve ratio for transaction deposits, 1% for saving deposits, and 0% otherwise. In our model, we include only one type of deposit, so our estimate of the deposit ratio is a weighted average of these three requirements, where the weights are the shares of a particular type of deposit in total deposits. We model the Federal Funds rate and the bank-level loan default rate as log AR(1) processes, and we directly calculate their means, standard deviations, and autocorrelations from the data. Finally, we set the maturity of loans in our model to the average asset maturity in the data, which is approximately 3.5 years.\(^{16}\)

Panel B in Table 3 presents the demand parameters from the first-stage BLP estimation.\(^{17}\) Not surprisingly, we find that depositors react favorably to high deposit rates while borrowers react negatively to high loan rates. Both yield sensitivities are precisely estimated, and the economic magnitudes are significant as well. A 1% increase in the deposit rate increases a bank’s market share by approximately 0.8%, while a 1% increase in the loan rates decreases its market share by 0.9%.\(^{18}\) We also find that depositors exhibit significant dispersion in their rate sensitivity. Finally, we estimate depositors’ and borrowers’ sensitivities to non-rate bank characteristics such as the number of branches and the number of employees per branch. The estimates are also both statistically and economically significant. A 1% increase in the number of branches increases bank market share by 0.868% in the deposit market and 1.117% in the loan market. In comparison, the sensitivity to the number of employees per branch is smaller. A 1% increase in the number of employees per branch increases bank

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\(^{16}\)Note that we use the asset-weighted average value instead of the equal weighted average to calibrate the model.

\(^{17}\)Detailed estimation results are presented in Table 5.

\(^{18}\)Note that the above sensitivities are semi-elasticities rather than elasticities.
market share by 0.587% in the deposit market and 0.694% in the lending market. Using these estimates combined with bank and time fixed effects, we can calculate the implied quality parameter using (41), which we plug into the second-stage SMM estimation.

Panel C in Table 3 presents the balance sheet parameters from our second-stage SMM estimation. We find that banks have a subjective discount rate of 4.5%, which is higher than the average Federal Funds rate observed in the data. Given the discount rate, banks pay out 3% of their equity value as dividends. We also find the cost of non-reservable borrowing to be both statistically and economically significant. At the average level of non-reservable borrowing (30% of total deposits), a marginal dollar of non-reservable borrowing costs a bank 30 basis points above the cost implied by the prevailing Federal Funds rate.\textsuperscript{19} Note that the mean of deposit spreads is 1.3%. Because banks equate the marginal costs of their funding sources, these numbers imply that the marginal cost of expanding deposit averages 1.6%, suggesting a large role for deposit market power. This result implies that banks cannot easily replace deposits with other funding sources. Therefore, shocks to bank deposits are likely to be transmitted to bank lending. Finally, we find that banks incur a 0.9% cost of maintaining deposits and a slightly lower 0.7% marginal cost of servicing their outstanding loans.

In Table 4, we compare the empirical and model-implied moments. The model is able to match closely the banks’ balance sheet quantities, the spreads they charge, and their valuation. In both the data and the model, banks borrow non-reservable securities, which amount to 30% of the deposit intake. The spreads that banks charge in the deposit market are significantly smaller than those in the loan market. This result arises because, as the Federal Funds rate approaches zero, bank deposits face increasing competition from cash. Thus, banks’ market power falls and deposit spreads become compressed.

To indicate external validation of the model, in Figure 4 we plot how banks’ deposit and loan rates react to the Fed’s monetary policy. Note that, in our moment-matching exercise,
we target only the average levels of these rates, not their functional relationship with the underlying Federal Funds rate. First, the results shown in Figure 4 indicate that the pass-through of the Federal Funds rates in both the deposit and loan markets is less than one to one, as indicated by the slope of the plots. This result is consistent with the message in Table 5 and indicates that banks do have significant market power. In addition, our model-predicted deposit and loan rates quite closely track the pattern that we see in the actual data, indicating that our model can capture quantitatively how banks price their products on both the deposit and loan markets.

We also examine how the market value of bank equity will react to an unexpected Federal Funds rate shock. In the data, a one-percentage-point increase in the Federal Funds rate leads to a 1.93% drop in bank equity value. Models without market power tend to overpredict this response. For example, if we model a bank as a replicating portfolio with a long position on 3.5-year Treasuries and a short position on the Federal Funds rate with a leverage of 10, then a one-percentage-point increase in the Federal Funds rate would lead to an 18% drop in equity value. Although our model is not geared to match asset-pricing moments, it generates a 2.84% drop in equity value when the Federal Funds rate increases unexpectedly by one percentage point, which is broadly in line with what the data suggest. The intuition involved here is the same as in Drechsler, Savov, and Schnabl (2018)—bank market power allows banks to borrow at deposits rates that are relatively insensitive to the policy rate, thereby dampening the impact of rate hikes on the net interest margin. This result also highlights the importance of taking their market power explicitly into account when analyzing banks’ reactions to monetary policy shocks.

\[ \text{With a maturity mismatch of 3.5 years, the asset value drops by 3.5\% for a one-percentage-point increase in the Federal Funds rate. With a book leverage of 10 and market-to-book ratio of approximately two, the equity value drops by } 18\% = 3.5\% \times 10/2. \]
6. Counterfactuals

6.1 Decomposing Monetary Policy Transmission

We now examine the quantitative forces that shape the relationship between monetary policy, as embodied in changes in the Federal Funds rate, and aggregate bank lending. To this end, we start with the baseline model in row (1) of Table 6, where we see that, on average in our model, a one-percentage-point change in the Federal Funds rate translates into a 1.55% decrease in aggregate bank lending. In the data, if we run an impulse response of aggregate lending to monetary shocks, the coefficient is roughly -1.6 over a three-year horizon.\footnote{The impulse response of aggregate lending to monetary shocks is shown in the Online Appendix.} Although we do not explicitly target this moment in our estimation process, it turns out that the degree of monetary transmission predicted by the model matches what we see in the data.

We proceed by eliminating the regulatory constraints and banks’ local market power one at a time to examine the effects of removing these frictions. As such, we analyze how the absence of each model ingredient influences the transmission of the Federal Reserve’s monetary policy.

To this end, we first estimate the effects of the reserve requirement and the capital requirement by removing them from the baseline model in which all frictions are present. Row (2) presents the results from a version of the model without the reserve requirement. We find that the sensitivity of bank lending to the Federal Funds decreases by 8% after we eliminate the reserve requirement. The modest magnitude reflects the fact that the amount of non-interest-bearing reserves held by banks is quite small in our sample period.\footnote{Since 2008, bank reserves have increased substantially. However, in this period, reserves started bearing interest, which effectively eliminated the reserve channel.} As a result, monetary policy has a limited effect on banks’ marginal costs of lending through the reserve requirement. This result sheds light on a recent policy debate over interest on excess
reserves. In October 2008, the Federal Reserve started paying interest on reserves and some worry that such a policy may render monetary policy unable to affect bank lending. Our results show, however, that this concern is unwarranted as the bank reserve channel has not been an important transmission channel since the 1990s. This result is also consistent with Xiao (2018), who shows that the reserve requirement is not a quantitatively important feature that distinguishes commercial banks from shadow banks.

Row (3) presents the results derived using a version of the model that excludes the capital requirement. It shows that the presence of the capital requirement enhances monetary policy transmission by 28% ($\frac{1.548 - 1.120}{1.548} = 28\%$). This result connects two long-standing but somewhat separate sets of reduced-form evidence on bank capital channel. The first strand of the literature establishes that, as a result of the maturity mismatch on banks’ balance sheets, monetary policy shocks can trigger subsequent changes in bank capital (Flannery and James 1984; English, Van den Heuvel, and Zakrajšek 2018); the second strand of the literature shows that bank capital has an economically significant impact on banks’ lending decisions (Peek and Rosengren 2000; Mora and Logan 2012)—due to endogeneity concerns, this literature often exploits exogenous shocks to bank capital such as the exposure to overseas credit loss instead of directly focusing on the role of monetary policy. Our paper connects the two bodies of empirical evidence by tracing out the effects of monetary policy on bank lending through the bank capital requirement. Estimating a structural model also sheds light on the quantitative magnitude of this long-established channel.

Does banks’ market power play a more or less important role in monetary policy transmission than the traditional regulatory-based mechanisms? To answer this question, we remove banks’ market power in the deposit market from the model, as seen in row (4) of Table 6. In this case, banks receive fixed lump-sum profits equal to their oligopolistic profits.

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23 For instance, a January 2019 Wall Street Journal article titled “The Fed’s Obama-Era Hangover” argues that “by paying banks not to lend, the central bank diminished its ability to control interest rates” (Gramm and Saving 2019). Another example can be found in an article in the American Banker on June 22, 2019 titled “Fed must stop rewarding banks for not lending,” which argues: “It was thanks to interest on excess reserves that the Fed ended up stimulating so little in the economy, despite its efforts to ease so much” (Michel and Selgin 2017).
in the baseline case, and they use marginal cost pricing for deposit-intake decisions—they set
the deposit rate equal to the Federal Funds rate minus the bank’s marginal cost of servicing
deposits, and they take as many deposits as depositors offer, given that deposit rate. If
deposit market power is in place, when the Federal Funds rate increases, the opportunity
cost for households to hold cash increases, making cash relatively less attractive than bank
deposits. Banks react by charging higher deposit spreads and consequently lowering the
amount of deposit intake. Banks’ lending decisions partially echo this decline in deposit
intake, because when the amount of loans exceeds deposits, banks need to use expensive
non-reservable borrowing to finance their loans. Thus, the banks’ market power, combined
with the non-reservable borrowing cost, contributes to a negative relationship between bank
lending and the Federal Funds rate. Our results confirm this intuition. Once we eliminate
market power in the deposit market, bank lending becomes less sensitive to changes in the
Federal Funds rate. A 1% increase in the Federal Funds rate causes an almost one-to-one
decrease in aggregate lending. This sensitivity is 36% \( \left( \frac{1.548 - 0.992}{1.548} = 36\% \right) \) smaller than the
1.55% sensitivity observed in the baseline case. Finally, this result is important insofar as
it highlights the interconnectedness of banks’ deposit-taking and lending businesses. Banks’
market power in the deposit market is passed on to the loan market and contributes to the
sensitivity of bank lending to the Federal Funds rate.

We turn next to consider banks’ market power in the lending market. To isolate the
effect of loan market power, we allow banks to retain their oligopolistic market power on the
deposit market. When the quantity of deposits fall short, banks turn to the external financing
market where they face the same quadratic external financing cost. On the loan market,
banks are assumed to act as price takers. They adopt marginal cost pricing and set their loan
rates equal to the funding cost. By removing loan market power from this benchmark, our
results show that the presence of banks’ loan market power makes the aggregate quantity
of loans less sensitive to the Federal Funds rate, with the sensitivity declining by −24%
\( \left( \frac{1.548 - 1.910}{1.548} = 24\% \right) \). This result is consistent with Scharfstein and Sunderam (2016) and
Corbae and Levine (2019), which show that loan market power allows banks to cushion the effects of monetary tightening on lending.

Finally, we compare the magnitude of regulatory-based transmission channels with that of channels based on bank market power. We find that market power-based channels have comparable, if not larger, effects than the regulatory-based channel. This has important implications for policy because current policy discussions focus on regulatory transmission channels while often ignoring the industrial organization of the banking system. Our result highlights the importance of accounting for the market structure of the banking system in assessing the monetary transmission mechanism.

6.2 Reversal Rate

In our previous analysis, we did not break down the effects of changes in the Federal Funds rate as a function of the rate level. We now turn to this question in Figure 5. In the top graph of Panel A, we plot the amount of bank lending for varying levels of the Federal Funds rate. We find that aggregate bank lending in the economy is inversely U-shaped. When the Federal Funds rate rises above a certain threshold, a further increase in the Federal Funds rate has the usual effect of tightening lending. However, when the Federal Funds rate is below the threshold, an increase in the Federal Funds rate actually has the opposite effect by expanding lending.

In Panel B, we also plot the impulse response of aggregate bank lending to monetary policy shocks conditional the current Federal Funds rate. Overall, and as expected, there is a negative overall relationship between the Federal Funds rate and the amount of lending. This negative relation is reversed, however, in the region where the Federal Funds rate is below 0.9%. We call this region in which the Federal Funds rate is below 0.9% a “reversal-rate” environment.

\(^{24}\)For example, (x,y) in the plot means that, if the current Federal Funds rate is x, the aggregate lending will change by y percent if there is a one-percentage-point Federal Funds rate shock.
To understand why monetary policy, as embodied in changes in the Federal Funds rate, can have opposite effects on bank lending, we also plot in Figure 5 levels of bank capital and the optimal amounts of bank lending in a world with no capital requirements. Note that optimal lending is the smaller of two quantities: desired lending and feasible lending. The former is the optimal amount of lending in the absence of a capital requirement, and the latter is maximal lending permitted by a bank’s equity capital. In equilibrium, desired lending is always decreasing with the Federal Funds rate, as high funding costs deter firms from borrowing. Hence, in high-rate regions, the capital requirement is slack, and the actual quantity of lending is the desired amount. On the other hand, when the Federal Funds rate is low, desired lending exceeds that allowed by the bank’s equity. Thus, the capital requirement binds, and the actual lending tracks the bank’s equity capital, which increases with the Federal Funds rate.

The excess of desired over capital-constrained lending makes sense given firms’ equilibrium heavy demand for loans in a low-interest-rate environment. However, the question remains of the forces behind the positive relationship between bank equity capital and the Federal Funds rate when the latter is low. This result stems from the relative magnitudes of profits from lending and deposit-taking. First, changes in the Federal Funds rate have opposite effects on bank profits in the deposit and lending markets. When the Federal Funds rate is high, holding cash is highly unattractive from the depositors’ point of view, and banks face consistent weak competition from cash in the deposit market. Hence, bank profits from the deposit market rise with the Federal Funds rate. In contrast, bank profits from lending decrease with the Federal Funds rate, as higher funding costs makes the firms’ outside option of not investing more appealing. Our parameter estimates imply that, when the Federal Funds rate is low, the effect on profits from the deposit market dominates the effect of the lending market. Thus, an increase in the Federal Funds rate leads to higher bank profits, which in turn feed into the equity capital base, as banks find it optimal to shore up capital to deflect future financing costs by not paying out all of their profits to shareholders. Figure
5 confirms this intuition by showing that the relationship between bank equity capital and the Federal Funds rate is also U-shaped, with 2% being the threshold where the slope of bank equity w.r.t the underlying Federal Funds rate flips sign. When the Federal Funds rate is high, the effect on bank capital reinforces its effect on desired lending. When the Federal Funds rate further decreases, the constrained optimal lending diverges from the desired level, eventually reversing the relationship between constrained optimal lending and the Federal Funds rate.

To understand more fully the dynamic response of bank lending to monetary policy shocks, in Figure 6 we report the simulated response of bank lending to Federal Funds rate shocks. The economy starts at time zero in an initial steady state with the Federal Funds rate equal to the inflection point of 0.9%. At time 1, the Federal Funds rate either increases to 2% or decreases to 0.1%, and it stays at that level afterwards until the economy reaches a new steady state. Each variable in the graph is scaled by its level in the old steady state, that is, when the Federal Funds rate is 0.9%.

The top panel of Figure 6 depicts the response to an increase in the Federal Funds rate. In this case, banks faces less competition from household demand for cash in the deposit market. Thus, they can behave more like monopolists by charging higher spreads and cutting the amount of deposits. Lower deposit intake increases the marginal costs of lending because when banks’ lending exceeds their capital plus deposit intake, they must turn to the market for non-reservable borrowing, in which they face increasing marginal external financing costs. A positive shock to the Federal Funds rate also increases the cost of capital in the corporate sector, making firms more likely to switch to the outside option of not borrowing. Both effects shrink lending. Because deposits have shorter durations than loans, deposits drop sharply and converge almost instantaneously to the new steady state. In contrast, loan quantity converges slowly as the bank replaces only a fraction, $\mu$, of its long-term loans in each period. Non-reservable borrowing increases to fill the gap between deposits and loans.

The bottom panel of Figure 6 depicts the response to a decrease in the Federal Funds rate.
When the Federal Funds rate decreases, on the one hand, banks profit from having maturity mismatch on their balance sheets as the rates they pay on the short-term liabilities decrease instantaneously while the unmatured long-term assets keep generating higher rates of return. This effect diminishes gradually over time as existing loans mature and are repriced. On the other hand, a lower Federal Funds rate leads to increasingly intense competition from cash in the deposit market. The effect is especially strong as the Fed Funds rate approaches the zero lower bound, in which case, the spreads that banks can charge in the deposit market are squeezed, leading to a sharp drop in banks’ profits. Given the persistence of the Federal Funds rate, lower profits translate into slower retained earnings accumulation and lead to lower bank capital. In the new steady state, banks take larger deposits in the deposit market, which can support increased lending—our impulse response plot shows that aggregate lending indeed increases in the first year. However, banks cannot sustain this higher level of lending in the long term because their capital requirements tighten in this extremely low Federal Funds rate environment. Because total lending decreases, banks face less of a need to seek external financing, and they use less non-reservable borrowing.

It is interesting to note that, in the two graphs in Figure 6, the loan amount decreases when the Federal Funds rate changes in either direction. Although the loan amount moves in the same direction, the driving force differs in the two cases. When the Federal Funds rate increases, loans fall because higher spreads in the deposit market discourage households from making deposits. Banks turn to non-reservable borrowing to fund loans, and because of increasing costs in this market, the amount of lending is highly dependent on the quantity of deposits. Instead, when the Federal Funds rate decreases, the loan amount decreases because of the binding capital requirement, which in turn echoes changes in the banks’ profit accumulation. The distinct driving forces underlying the two abovementioned plots are also reflected by the differential trends in banks’ deposit intake and non-reservable borrowing.

We obtain external validation of the reversal-rate prediction from a reduced-form regression. Specifically, we examine the relationship between bank equity returns and monetary
policy news on Federal Open Market Committee (FOMC) meeting days. We use changes in the two-year Treasury yield on FOMC meeting days to measure monetary policy news released during the FOMC meetings, following Hanson and Stein (2015). The advantage of examining the two-year Treasury yield instead of the Federal Funds rate is that the former captures the effects of “forward guidance” in the FOMC announcement, which has become increasingly important in recent years (Hanson and Stein 2015). The identifying assumption is that unexpected changes in interest rates in a one-day window surrounding scheduled Federal Reserve announcements arise largely from news about monetary policy because macroeconomic fundamentals would not change discretely within such a short window. While our sample period runs from 1994 through 2017, we exclude the dot-com bubble burst (2000–2001) and the subprime financial crisis (2007–2009) because, in these crisis times, confounding information other than monetary policy news could also be released in the FOMC meetings.

In Table 7 we report the regression estimates. Based on the relationship between bank capital and the Federal Funds rate shown in Panel 4 of Figure 5, we split our sample into low- and high-interest environments based on Federal Funds rates, using 2% as the cutoff. As shown in Column 1, in a high-interest environment, an increase in rates reduces bank equity value. However, this conventional negative relationship reverses sign in a low-interest environment. As shown in Column 2, an increase in rates is associated with positive significant returns for bank equity. In other words, the market expects that an increase in rates leads to an increase in bank capital. This result is not driven by a steepening of the term structure, as we control for changes in term spreads. As shown in Figure 7, the contrast between the results in Columns 1 and 2 can be seen in a simple scatter plot of bank industry excess

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25We also use one-year Treasury yields and the results are robust. The result is shown in the Online Appendix.

26For instance, on March 18, 2008, the Fed lowered its Federal Funds rate by 75 basis point, from 3% to 2.25%. The size of this rate cut is much larger than the conventional 25 basis point change in normal times. This unusual action might have sent signals to the market about the Fed’s willingness to support the banking system. Such actions may affect stock prices through the “Fed put” channel, which is outside our model (Cieslak and Vissing-Jorgensen 2017).
returns against monetary policy shocks on FOMC days. Moreover, in the Online Appendix, we examine returns for all 49 Fama-French industries. We find that the banking industry is the only industry exhibiting a switch from a negative interest sensitivity to positive interest sensitivity in the low-interest environment.

In Columns 3 and 4 of Table 7, we report the results of interacting changes in the Federal Funds rate with a reduced-form measure of deposit market power, the Herfindahl-Hirschman index (HHI) of the local deposit market in which the bank operates, where we define a local deposit market as a county. If a bank operates in several counties, the bank-level HHI is the weighted average of local HHIs, weighted by the deposits of the bank in each county. We find that in a low-interest environment, banks with greater market power in the deposit market experienced higher positive returns. In summary, we find that monetary policy has a nonmonotonic effect on bank capital. When the Federal Funds rate is high, the relationship between the short-term rates and bank capital seems to be negative, but when the Federal Funds rate is low, this relationship becomes positive. To the best of our knowledge, this paper is the first to document this empirical fact.

Our findings suggest that ultra-low-interest-rate policy may impede lending growth because it depresses banks’ profitability and slows down capital accumulation. This result is related to Heider, Saidi, and Schepens (2018), who show that the introduction of negative policy rates by the European Central Bank in mid-2014 reduces lending by euro-area banks with greater reliance on deposit funding. Our results show that such perverse effects can occur even when the rates are positive because banks’ deposit spreads are compressed by the low-rate environment.

Our results shed light on the sluggish bank-lending recovery in the U.S. after the recent crisis. As shown in Figure 8, bank lending in the recent recovery has grown at a slower pace than in all previous recoveries since the 1960s. By the end of 2018, bank lending had increased only about 25% cumulatively from its August 2009 level, the month when the recovery started. Although many factors such as tightening banking regulations may
contribute to this slow recovery, the ultra-low rate policy could be an important factor because it may unintentionally reduce bank profitability, which slows down bank capital accumulation and constrain banks’ capacity to lend.

While our results show that ultra-low-rate policy may have side effects on bank lending, it may also have many benefits for the broader economy through other channels. Therefore, we do not advocate that policy rates should never fall into the reversal region. Instead, a more targeted policy such as time-varying capital requirements can alleviate such side effects. For instance, banking regulators could lower capital requirements in an ultra-low-rate environment to offset its side effects on banks’ profitability.

6.3 Heterogeneous Transmission across Banks

We next examine heterogeneity in monetary transmission across large and small banks, motivated by the finding in Kashyap and Stein (1995) that the impact of monetary policy on lending is stronger for small banks. They suggest that small banks cannot replace deposits with frictionless access to wholesale funding, so shocks to deposits from monetary tightening are more likely to be transmitted to the supply of loans from small banks. However, one limitation of the data used in Kashyap and Stein (1995) is the absence of a measure of the actual cost of external financing. While they proxy for this cost with the size of the bank, size is correlated with many other bank attributes, whose presence compromises the interpretation of their results. For instance, small banks tend to lend to small firms, whose credit demand is more cyclical. Therefore, the higher sensitivity of smaller bank lending can be driven by the demand side rather than by financing friction on the supply side.

We can use our dynamic model to shed light on this issue via subsample estimation, where we split our sample at the 10th percentile of bank size distribution, estimating a subset of the model parameters separately for the large and small banks. For these estimations, we fix the parameters that govern the preference of the household and the macroeconomic conditions.
We also fix the discount rate for banks.\textsuperscript{27} We re-estimate the remaining parameters that govern banks’ operating efficiency and financing frictions.

The results are in Table 8. We find that there are two notable differences between large and small banks—their external financing costs and the fixed operating costs. This result is particularly interesting because we do not use bank size in our vector of identifying moments. Instead, the external financing cost is identified from the fraction of assets financed by nonreservables; the fixed operating cost is identified from the banks’ net non-interest expense and leverage ratio. These two differences jointly imply that loans issued by small banks are 37% more sensitive to the Federal Funds rate (the sensitivity is -1.758 among smaller banks and -1.103 among larger banks). Next, we decompose the two frictions and find that the difference in external financing costs explains 61\% of the heterogeneity in monetary transmission. Reducing the quadratic financing cost among small banks to 0.006 will decrease the loan-to-Federal Funds rate sensitivity to -1.364 among these banks. Because we allow only four parameters to differ for large and small banks, we effectively hold loan demand constant, thus isolating the effect of financial frictions. This result is consistent with the hypothesis proposed by Kashyap and Stein (1995) that large and small banks differ significantly along the dimension of external financing costs, and that this difference leads to heterogeneous transmission of monetary policy to the credit supply. In addition, the variation in fixed operating costs explains most of the remaining variation in monetary transmission. Small banks have relatively few sources from which they can earn non-interest income, which translates into a higher net operating costs and slower accumulation of equity buffers. As a result, when the Fed adjusts the interest rate, the shocks to bank net worth as a result of the maturity mismatch will influence small banks to a greater extent, which also leads to a stronger reaction in their ability to extend loans.

\textsuperscript{27}This is because a relatively small fraction of the small banks have dividend records, which prevents us from identifying these banks’ discount rates using their dividend yields. Because most small banks are not publicly listed, we also cannot calculate their market-to-book ratios.
6.4 Heterogeneous Transmission across Time

In this section, we examine the impact of monetary policy on bank lending over time. Over the past few decades, we have witnessed substantial changes in both the macroeconomic environment and the structure of the banking industry. The average interest rate has declined substantially, which may affect banks’ profitability. The banking industry itself has experienced a large volume of mergers, leading to increased concentration and potentially higher operating efficiency.

To understand how the effect of monetary policy on bank lending has changed over time, we split our sample into two sub-periods—early (1994-2005) and late (2006-2017). We reestimate all model parameters using data in the two sub-periods following the strategy described in Section 5.1. The estimation results are reported in Tables 9 and 10. With the estimated parameters, our model shows that the impact of a 1% Federal Funds rate cut on aggregate bank lending has declined from 1.727% in the early sample period to 0.987% in the late sample period. This result is consistent with the existing evidence in the literature that monetary policy seems to have had more muted effects on real activity and inflation in recent decades (Boivin, Kiley, and Mishkin 2010).

What factors have been driving the declining impact of monetary policy on bank lending? To answer this question, we first categorize our parameters into three groups. The first group includes changes in macroeconomic conditions, such as the Federal Funds rate process itself, the banks’ loan charge-offs, the regulatory constraints and the deposit/loan market size; the second group consists of measures of bank operating efficiency and financial frictions, including their discount rates, operating costs, and external financing costs; the last group consists of parameters that govern banks’ market power. In our model, banks’ market power is governed by the number of competing banks in the local market, \( \hat{J} \), and the rate sensitivities that banks face in the deposit and loan markets, \( \alpha^d \) and \( \alpha^l \). Over time, the market concentration of banks has increased: the number of competing banks in the local
market has decreased from 7 to 5, which increases banks’ market power. At the same time, however, both depositors and borrowers become more rate-sensitive. In the most recent decade, the adoption of new technology and a surge in internet and mobile banking has lowered the cost of searching, which allows deposits and borrowers to be more reactive to banks’ rate-setting. Holding all else equal, this increased sensitivity decreases banks’ market power.

To gauge the overall effect of bank market power on variations in monetary transmission, we eliminate the differences in bank market power across the two subsamples by setting the late period values to be same as those in the early period. Doing so reduces the gap in monetary transmission by 18%.

We turn next to banks’ operating and external financing costs. As banks have merged to form bigger ones, their fixed operating costs have gone down substantially. This lowers their operating leverage, which consequently reduces their exposure to monetary policy. Furthermore, the cost of accessing the wholesale funding market has declined, which allows banks to better cushion the loss of deposits. If we eliminate the difference in bank operating and financing costs, the gap in monetary transmission further narrows by 16%.

The remaining 66% of the variation is attributable to changes in macro-economic condition. In particular, we find that changes in the Federal Funds rate process itself plays the most important role in explaining the declining trend in monetary policy transmission. Over time, the average Federal Funds rate has decreased substantially. This lower Fed Funds rate implies that the economy spends more time around the reversal-rate region, where monetary policy has a weaker, or even opposite, effect on bank lending decisions.

7. Robustness

In this section, we examine the implications of several ingredients that we have left out of the baseline model but are nevertheless important for describing bank behaviors in reality.
First, instead of requiring dividends to be positive, we allow them to be negative, subject to a linear equity issuance cost, $\phi^e$. We re-estimate our model, with the parameter $\phi^e$ being identified by an additional moment—the ratio of bank equity issuance to total assets. In the data, this moment is 2%; in our model, we find that an equity issuance cost of 10% would yield a predicted equity issuance rate that matches what we observe in the data. The value is comparable to that among industrial firms (Hennessy and Whited 2007).

Second, we introduce time-varying discount rates. More specifically, we assume that banks apply a discount rate of $f + \omega$. In the absence of any intertemporal frictions, banks will discount using the Federal Funds rate, which implies that $\omega = 0$. In our estimation, we identify $\omega$ from banks’ dividend yields, the same moment that we have previously used to identify the constant discount factor in our baseline model. Our results suggest that $\omega = 1.6\%$. As is the case with the baseline estimates, this result indicates that banks do face substantial frictions in their maturity transformation activity. Our results concerning the decomposition of monetary transmission and reversal rate are robust to these alternative model specifications.

Another concern is that our model is set up in a risk-neutral world, while in reality loan spreads contain a risk premium component. To make the model and data moment comparable, we adjust the data moment by subtracting a risk premium. We calibrate the risk premium following Giesecke, Longstaff, Schaefer, and Strebulaev (2011), who show that the credit risk premium in the bond market roughly equals the expected default loss. After adjusting the data moment, we re-estimate the model. Our results suggest that the only notable difference lies in banks’ estimated cost of serving loans, which becomes insignificantly different from zero. This result suggests that banks’ perceived cost on the loan market is driven almost entirely by the default risk. Other than that, banks face zero marginal costs to extend one additional unit of credit. We verify that our main predictions remain robust under this re-estimation.
8. Conclusion

The U.S. banking sector has experienced an enormous amount of consolidation. The market share of the top five banks has increased from less than 15% in the 1990s to over 45% as of 2017. This consolidation begs the question whether bank market power has a quantitatively important effect on the transmission of monetary policy. We study this question by formulating and estimating a dynamic banking model with regulatory constraints, financial frictions, and imperfect competition. This unified framework is useful because it allows us to gauge the relative importance of different monetary policy transmission channels.

In our counterfactuals, we show that the channel related to reserve requirements has limited quantitative importance. In contrast, we find that channels related to bank capital requirements and market power are very important. We also find an interesting interaction between the market power channel and the bank capital channel. If the Federal Funds rate is low, depressing it further can actually contract bank lending, as reduced profits in the deposit market impact bank capital negatively. Lastly, we show that accounting for bank market power and its interaction with regulatory constraints is key to understanding cross-sectional and time-series variations in monetary transmission.
References


Table 1: Summary Statistics

In this table, we report summary statistics for the sample. The sample period is 1994-2017. We use national market as the market definition. The total size of the deposit market is defined as the sum of deposits, cash, and Treasury bills held by all U.S. households and non-financial corporations. The total size of the loan market is defined as the sum of U.S. corporate and household debt. Deposit and loan rates are calculated using interest expenses and income. Expenses of fixed assets and salaries are scaled by total assets. Deposit shares, loan shares, deposit rates, loan rates, expenses of fixed assets, salaries, and net noninterest expenses are reported in percentages. Asset maturity is reported in years. Mean(vw) is calculated using banks’ asset values in each year as the weight. The data sources are Call reports and the FDIC Summary of Deposits.

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<td>0.001</td>
<td>0.002</td>
<td>0.004</td>
<td>0.009</td>
<td>0.034</td>
</tr>
<tr>
<td>Deposit rates</td>
<td>1.706</td>
<td>2.032</td>
<td>1.292</td>
<td>0.166</td>
<td>0.873</td>
<td>2.085</td>
<td>3.150</td>
<td>3.714</td>
</tr>
<tr>
<td>No. of branches</td>
<td>1778</td>
<td>69.753</td>
<td>315.678</td>
<td>7.000</td>
<td>11.000</td>
<td>17.000</td>
<td>34.000</td>
<td>94.000</td>
</tr>
<tr>
<td>Expenses of fixed assets</td>
<td>0.454</td>
<td>0.480</td>
<td>0.165</td>
<td>0.270</td>
<td>0.347</td>
<td>0.448</td>
<td>0.584</td>
<td>0.798</td>
</tr>
<tr>
<td>Salaries</td>
<td>1.590</td>
<td>1.725</td>
<td>0.486</td>
<td>1.061</td>
<td>1.348</td>
<td>1.650</td>
<td>2.036</td>
<td>2.646</td>
</tr>
<tr>
<td>Net noninterest expenses</td>
<td>1.230</td>
<td>2.778</td>
<td>0.830</td>
<td>1.904</td>
<td>2.246</td>
<td>2.653</td>
<td>3.142</td>
<td>3.743</td>
</tr>
<tr>
<td>Loan-to-deposit ratio</td>
<td>0.816</td>
<td>0.815</td>
<td>0.170</td>
<td>0.598</td>
<td>0.710</td>
<td>0.821</td>
<td>0.925</td>
<td>1.022</td>
</tr>
<tr>
<td>Borrowing-to-deposit ratio</td>
<td>0.699</td>
<td>0.136</td>
<td>0.138</td>
<td>0.013</td>
<td>0.041</td>
<td>0.096</td>
<td>0.181</td>
<td>0.308</td>
</tr>
<tr>
<td>Deposit-to-asset ratio</td>
<td>0.707</td>
<td>0.805</td>
<td>0.082</td>
<td>0.691</td>
<td>0.763</td>
<td>0.822</td>
<td>0.866</td>
<td>0.895</td>
</tr>
</tbody>
</table>
Table 2: The Bank Balance Sheet

This table illustrates the balance sheet of a typical bank at the beginning of the period. The bank’s assets consist of existing plus new loans, reserves, and holdings of government securities; its liabilities consist of deposits and non-reservable borrowings.

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing loans</td>
<td>$L_t$</td>
</tr>
<tr>
<td>New loans</td>
<td>$B_t$</td>
</tr>
<tr>
<td>Reserves</td>
<td>$R_t$</td>
</tr>
<tr>
<td>Government securities</td>
<td>$G_t$</td>
</tr>
<tr>
<td><strong>Total Assets</strong></td>
<td>$L_t + B_t + R_t + G_t$</td>
</tr>
<tr>
<td><strong>Deposits</strong></td>
<td>$D_t$</td>
</tr>
<tr>
<td><strong>Non-reservable borrowings</strong></td>
<td>$N_t$</td>
</tr>
<tr>
<td><strong>Equity</strong></td>
<td>$E_t$</td>
</tr>
<tr>
<td><strong>Total Liabilities and Equity</strong></td>
<td>$D_t + N_t + E_t$</td>
</tr>
</tbody>
</table>
Table 3: Parameter Estimates

In this table we report the model parameter estimates. Panel A presents values for parameters that represent statutory rates. Panel B presents values for parameters that can be calculated as simple averages or by simple regression methods. Panel C presents results for parameters estimated via BLP. Panel D presents results for parameters estimated via SMM. Standard errors for the estimated parameters are clustered at the firm level and reported in parentheses.

<table>
<thead>
<tr>
<th>Panel A: Statutory Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \tau_c )</td>
</tr>
<tr>
<td>( \theta )</td>
</tr>
<tr>
<td>( \kappa )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel B: Parameters Estimated Separately</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \mu )</td>
</tr>
<tr>
<td>( \bar{f} )</td>
</tr>
<tr>
<td>( \sigma_f )</td>
</tr>
<tr>
<td>( \rho_f )</td>
</tr>
<tr>
<td>( \delta )</td>
</tr>
<tr>
<td>( \sigma_\delta )</td>
</tr>
<tr>
<td>( \rho_\delta )</td>
</tr>
<tr>
<td>( \hat{J} )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel C: Parameters Estimated via BLP</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha^d )</td>
</tr>
<tr>
<td>( \sigma_{\alpha^d} )</td>
</tr>
<tr>
<td>( \alpha^l )</td>
</tr>
<tr>
<td>( q^d )</td>
</tr>
<tr>
<td>( q^c )</td>
</tr>
<tr>
<td>( q^l )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel D: Parameters Estimated via SMM</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \gamma )</td>
</tr>
<tr>
<td>( W/K )</td>
</tr>
<tr>
<td>( q^N )</td>
</tr>
<tr>
<td>( \phi^N )</td>
</tr>
<tr>
<td>( \phi^d )</td>
</tr>
<tr>
<td>( \phi^l )</td>
</tr>
<tr>
<td>( \psi )</td>
</tr>
</tbody>
</table>
Table 4: Moment Conditions

In this table we report the simulated versus the actual moments in the simulated method of moment (SMM) estimation along with the t-statistics for the pairwise differences. Dividend yield is defined as dividends over bank equity value; non-reservable borrowing share is defined as the ratio of non-reservable borrowing to total assets; corporate borrowing-FFR sensitivity is estimated through a vector autoregression.

<table>
<thead>
<tr>
<th></th>
<th>Actual Moment</th>
<th>Simulated Moment</th>
<th>T-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dividend yield</td>
<td>3.38%</td>
<td>3.00%</td>
<td>-0.687</td>
</tr>
<tr>
<td>Non-reservable borrowing share</td>
<td>29.9%</td>
<td>27.0%</td>
<td>-1.782</td>
</tr>
<tr>
<td>Std of non-reservable borrowing</td>
<td>12.6%</td>
<td>14.8%</td>
<td>1.337</td>
</tr>
<tr>
<td>Deposit spread</td>
<td>1.29%</td>
<td>1.28%</td>
<td>-0.113</td>
</tr>
<tr>
<td>Loan spread</td>
<td>2.81%</td>
<td>2.75%</td>
<td>-0.374</td>
</tr>
<tr>
<td>Deposit-to-asset ratio</td>
<td>0.699</td>
<td>0.728</td>
<td>1.022</td>
</tr>
<tr>
<td>Net noninterest expenses</td>
<td>1.23%</td>
<td>1.20%</td>
<td>-0.822</td>
</tr>
<tr>
<td>Leverage</td>
<td>11.20</td>
<td>11.69</td>
<td>2.337</td>
</tr>
<tr>
<td>Market-to-book ratio</td>
<td>2.061</td>
<td>1.814</td>
<td>-1.424</td>
</tr>
<tr>
<td>Total Credit-FFR sensitivity</td>
<td>-0.995</td>
<td>-0.975</td>
<td>0.083</td>
</tr>
</tbody>
</table>
Table 5: Demand Estimation

In this table, we report the estimated parameters of deposit and loan demand. The first column corresponds to parameters of deposit demand. The second column corresponds to parameters of loan demand. Yield sensitivity ($\alpha$) refers to the average sensitivity of depositors (firms) to deposit rates (loan rates). Log No. of Branches ($\beta_1$) refers to the sensitivity of depositors (firms) to the log number of branches that each bank operates. Log No. of Employees ($\beta_2$) refers to the sensitivity of depositors (firms) to the log number of employees per branch. Yield sensitivity dispersion ($\sigma_\alpha$) refers to dispersion in the sensitivity of depositors to deposit rates (the dispersion is set at 0 for firms). The sample includes all U.S. commercial banks from 1994 to 2017. The data sources are the Call report and the Summary of Deposits.

<table>
<thead>
<tr>
<th></th>
<th>Deposit</th>
<th>Loan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield sensitivity ($\alpha$)</td>
<td>0.800*** [0.158]</td>
<td>-0.904*** [0.163]</td>
</tr>
<tr>
<td>Log number of branches ($\beta_1$)</td>
<td>0.868*** [0.009]</td>
<td>1.117*** [0.000]</td>
</tr>
<tr>
<td>Log number of employees ($\beta_2$)</td>
<td>0.587*** [0.016]</td>
<td>0.694*** [0.031]</td>
</tr>
<tr>
<td>Yield sensitivity dispersion ($\sigma_\alpha$)</td>
<td>1.579*** [0.439]</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Deposit</th>
<th>Loan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sector F.E.</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Time F.E.</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Observations</td>
<td>15575</td>
<td>15575</td>
</tr>
<tr>
<td>Adj. Rsq</td>
<td>0.982</td>
<td>0.867</td>
</tr>
</tbody>
</table>

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Table 6: Determinants of Monetary Policy Transmission

This table presents the results of a series of counterfactual experiments in which we examine the effects of removing frictions from our model. The first column lists the frictions that are removed from the model. The second column presents the sensitivity of loans to the Federal Funds rate (FFR) when the corresponding frictions are removed. The third column presents the contributions of the corresponding frictions. All model solutions are under the same set of parameters reported in Table 3.

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity of Loans to FFR ( \frac{\Delta \ln l}{\Delta f} )</th>
<th>Contribution %</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) All frictions are present</td>
<td>-1.548%</td>
<td>/</td>
</tr>
<tr>
<td>(2) Reserve Regulation</td>
<td>-1.426%</td>
<td>7.88%</td>
</tr>
<tr>
<td>(3) Capital Regulation</td>
<td>-1.120%</td>
<td>27.65%</td>
</tr>
<tr>
<td>(4) Deposit Market Power</td>
<td>-0.992%</td>
<td>35.91%</td>
</tr>
<tr>
<td>(5) Loan Market Power</td>
<td>-1.910%</td>
<td>-23.39%</td>
</tr>
</tbody>
</table>
Table 7: Monetary Policy Shocks and Bank Equity Returns on FOMC Days

In this table, we report the estimates of the relationship between bank equity returns and monetary policy shocks on FOMC Days. Monetary policy shocks are measured by one-day changes in the two-year Treasury yield on FOMC days. HHI is the Herfindahl-Hirschman index for the local deposit market in which a bank operates. A local deposit market is defined as a county. If a bank operates in several counties, the bank-level HHI is the weighted average of the local HHI, weighted by the bank’s deposits in each county. The sample includes all publicly traded U.S. banks from 1994 to 2017. The sample for columns 1 and 3 are dates when the starting level of the Federal Fund rate is above 2%. The sample for columns 2 and 4 are dates when the starting level of the Federal Fund rate is below 2%. We exclude observations during the burst of dot-com bubble (2000-2001) and the subprime financial crisis (2007-2009). Standard errors are clustered by time.

<table>
<thead>
<tr>
<th></th>
<th>(1) High FFR</th>
<th>(2) Low FFR</th>
<th>(3) High FFR</th>
<th>(4) Low FFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy shock</td>
<td>-1.292**</td>
<td>2.202**</td>
<td>-0.639</td>
<td>-1.393</td>
</tr>
<tr>
<td></td>
<td>[0.615]</td>
<td>[0.879]</td>
<td>[0.653]</td>
<td>[0.852]</td>
</tr>
<tr>
<td>HHI*Policy shock</td>
<td></td>
<td></td>
<td>-0.134</td>
<td>0.562***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[0.145]</td>
<td>[0.153]</td>
</tr>
<tr>
<td>Δ Term spread</td>
<td>-0.634</td>
<td>2.336*</td>
<td>-0.667</td>
<td>1.827</td>
</tr>
<tr>
<td></td>
<td>[1.265]</td>
<td>[1.350]</td>
<td>[1.257]</td>
<td>[1.293]</td>
</tr>
<tr>
<td>Market return</td>
<td>0.297***</td>
<td>0.730***</td>
<td>0.295***</td>
<td>0.733***</td>
</tr>
<tr>
<td></td>
<td>[0.072]</td>
<td>[0.070]</td>
<td>[0.071]</td>
<td>[0.070]</td>
</tr>
<tr>
<td>Observations</td>
<td>27,257</td>
<td>33,805</td>
<td>27,257</td>
<td>33,805</td>
</tr>
<tr>
<td>Adj, R-squared</td>
<td>0.015</td>
<td>0.123</td>
<td>0.016</td>
<td>0.125</td>
</tr>
</tbody>
</table>
Table 8: Large versus Small Banks

In this table we report the simulated method of moment estimation results for subsamples of large and small banks. Panel A contains the simulated versus the actual moments the along with the t-statistics for the pairwise differences. In Panel B, we report the parameter estimates—φategories are banks’ marginal costs of intaking deposits and servicing loans, respectively, and φ is the quadratic cost of borrowing non-reservables. The last column presents the sensitivity of loans to the Federal Funds rate, which is a measure of monetary policy transmission. Standard errors clustered at the firm level are in parentheses under the parameter estimates.

### Panel A: Moment conditions

<table>
<thead>
<tr>
<th></th>
<th>Large Banks Actual</th>
<th>Simulated</th>
<th>t-stat</th>
<th>Small Banks Actual</th>
<th>Simulated</th>
<th>t-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dividends</td>
<td>3.60%</td>
<td>2.95%</td>
<td>-1.929</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Non-reservable borrowing share</td>
<td>35.5%</td>
<td>38.8%</td>
<td>2.130</td>
<td>15.3%</td>
<td>15.1%</td>
<td>-0.577</td>
</tr>
<tr>
<td>Std of non-reservable borrowing</td>
<td>19.0%</td>
<td>20.6%</td>
<td>0.726</td>
<td>8.70%</td>
<td>7.58%</td>
<td>-1.992</td>
</tr>
<tr>
<td>Deposit spread</td>
<td>1.32%</td>
<td>1.33%</td>
<td>0.133</td>
<td>1.25%</td>
<td>1.29%</td>
<td>0.915</td>
</tr>
<tr>
<td>Loan spread</td>
<td>2.67%</td>
<td>2.71%</td>
<td>0.280</td>
<td>2.98%</td>
<td>2.83%</td>
<td>-3.193</td>
</tr>
<tr>
<td>Deposit-to-asset ratio</td>
<td>0.666</td>
<td>0.672</td>
<td>0.201</td>
<td>0.784</td>
<td>0.793</td>
<td>0.788</td>
</tr>
<tr>
<td>Net noninterest expense</td>
<td>0.96%</td>
<td>1.01%</td>
<td>0.994</td>
<td>1.70%</td>
<td>1.58%</td>
<td>-3.918</td>
</tr>
<tr>
<td>Leverage</td>
<td>11.36</td>
<td>12.45</td>
<td>2.448</td>
<td>10.78</td>
<td>11.16</td>
<td>2.499</td>
</tr>
<tr>
<td>Market-to-book ratio</td>
<td>2.061</td>
<td>2.009</td>
<td>-0.894</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Total credit-FFR sensitivity</td>
<td>-0.995</td>
<td>-0.898</td>
<td>0.177</td>
<td>-0.995</td>
<td>-0.960</td>
<td>0.064</td>
</tr>
</tbody>
</table>

### Panel B: Parameter Estimates

<table>
<thead>
<tr>
<th></th>
<th>φ^N</th>
<th>φ^d</th>
<th>φ^l</th>
<th>Sensitivity of Loans to FFR (Δln/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Banks</td>
<td>0.006</td>
<td>0.010</td>
<td>0.006</td>
<td>-1.103</td>
</tr>
<tr>
<td>Small Banks</td>
<td>0.016</td>
<td>0.009</td>
<td>0.007</td>
<td>-1.758</td>
</tr>
</tbody>
</table>

Standard errors in parentheses.
Table 9: Subsample Estimates: Early

In this table we report the model parameter estimates for the early subsample (1994–2005). Panel A presents values for parameters that represent statutory rates. Panel B presents values for parameters that can be calculated as simple averages or by simple regression methods. Panel C presents results for parameters estimated via BLP. Panel D presents results for parameters estimated via SMM. Standard errors for the estimated parameters are clustered at the firm level and reported in parentheses.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Estimate</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statutory Parameters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\tau_c$</td>
<td>Corporate tax rate</td>
<td>0.350</td>
<td></td>
</tr>
<tr>
<td>$\theta$</td>
<td>The reserve ratio</td>
<td>0.028</td>
<td></td>
</tr>
<tr>
<td>$\kappa$</td>
<td>The capital ratio</td>
<td>0.060</td>
<td></td>
</tr>
<tr>
<td>Parameters Estimated Separately</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mu$</td>
<td>Average loan maturity</td>
<td>3.178</td>
<td></td>
</tr>
<tr>
<td>$\bar{f}$</td>
<td>Log Federal Funds rate mean</td>
<td>1.245</td>
<td></td>
</tr>
<tr>
<td>$\sigma_f$</td>
<td>Std of log Federal Funds rate innovation</td>
<td>0.552</td>
<td></td>
</tr>
<tr>
<td>$\rho_f$</td>
<td>Log Federal Funds rate persistence</td>
<td>0.700</td>
<td></td>
</tr>
<tr>
<td>$\delta$</td>
<td>Log loan chargeoffs mean</td>
<td>-1.647</td>
<td></td>
</tr>
<tr>
<td>$\sigma_\delta$</td>
<td>Std of log loan chargeoffs innovation</td>
<td>0.863</td>
<td></td>
</tr>
<tr>
<td>$\rho_\delta$</td>
<td>Log loan chargeoffs persistence</td>
<td>0.611</td>
<td></td>
</tr>
<tr>
<td>$\hat{J}$</td>
<td>Number of representative banks</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Parameters Estimated via BLP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha^d$</td>
<td>Depositors’ sensitivity to deposit rates</td>
<td>0.743</td>
<td></td>
</tr>
<tr>
<td>$\sigma_{\alpha^d}$</td>
<td>The dispersion of depositors’ sensitivity to deposit rates</td>
<td>1.467</td>
<td></td>
</tr>
<tr>
<td>$\alpha^l$</td>
<td>Borrowers’ sensitivity to loan rates</td>
<td>-1.017</td>
<td></td>
</tr>
<tr>
<td>$q_d^h$</td>
<td>Convenience of holding deposits</td>
<td>3.465</td>
<td></td>
</tr>
<tr>
<td>$q_c^d$</td>
<td>Convenience of holding cash</td>
<td>1.763</td>
<td></td>
</tr>
<tr>
<td>$q_l^l$</td>
<td>Convenience of borrowing through loans</td>
<td>-0.016</td>
<td></td>
</tr>
<tr>
<td>Parameters Estimated via SMM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Banks’ discount rate</td>
<td>0.046</td>
<td>[0.0124]</td>
</tr>
<tr>
<td>$W/K$</td>
<td>Relative size of the deposit market</td>
<td>0.183</td>
<td>[0.0513]</td>
</tr>
<tr>
<td>$q_n^N$</td>
<td>Value of firms’ outside option</td>
<td>-7.030</td>
<td>[0.5675]</td>
</tr>
<tr>
<td>$\phi^N$</td>
<td>Quadratic cost of non-reservable borrowing</td>
<td>0.010</td>
<td>[0.0042]</td>
</tr>
<tr>
<td>$\phi^d$</td>
<td>Bank’s cost of taking deposits</td>
<td>0.009</td>
<td>[0.0021]</td>
</tr>
<tr>
<td>$\phi^l$</td>
<td>Bank’s cost of servicing loans</td>
<td>0.005</td>
<td>[0.0041]</td>
</tr>
<tr>
<td>$\psi$</td>
<td>Net fixed operating cost</td>
<td>0.039</td>
<td>[0.0001]</td>
</tr>
</tbody>
</table>
Table 10: Subsample Estimates: Late

In this table we report the model parameter estimates for the late subsample (2006–2017). Panel A presents values for parameters that represent statutory rates. Panel B presents values for parameters that can be calculated as simple averages or by simple regression methods. Panel C presents results for parameters estimated via BLP. Panel D presents results for parameters estimated via SMM. Standard errors for the estimated parameters are clustered at the firm level and reported in parentheses.

| Statutory Parameters | | | |
|----------------------|-----------------|-----|
| τ<sub>c</sub>        | Corporate tax rate | 0.350 |
| θ                    | The reserve ratio | 0.022 |
| κ                    | The capital ratio | 0.060 |

| Parameters Estimated Separately | | | |
|---------------------------------|-----------------|-----|
| µ                               | Average loan maturity | 3.195 |
| f                               | Log Federal Funds rate mean | -0.920 |
| σ<sub>f</sub>                   | Std of log Federal Funds rate innovation | 0.951 |
| ρ<sub>f</sub>                   | Log Federal Funds rate persistence | 0.623 |
| δ                               | Log loan chargeoffs mean | -1.221 |
| σ<sub>δ</sub>                   | Std of log loan chargeoffs innovation | 0.935 |
| ρ<sub>δ</sub>                   | Log loan chargeoffs persistence | 0.722 |
| J                               | Number of representative banks | 5 |

| Parameters Estimated via BLP | | | |
|-----------------------------|-----------------|-----|
| α<sup>d</sup>               | Depositors’ sensitivity to deposit rates | 0.925 |
| σ<sub>α<sup>d</sub></sub>   | The dispersion of depositors’ sensitivity to deposit rates | 1.830 |
| α<sup>l</sup>               | Borrowers’ sensitivity to loan rates | -1.454 |
| q<sup>d</sup>               | Convenience of holding deposits | 2.324 |
| q<sup>c</sup>               | Convenience of holding cash | -0.446 |
| q<sup>l</sup>               | Convenience of borrowing through loans | 1.804 |

| Parameters Estimated via SMM | | | |
|-----------------------------|-----------------|-----|
| γ                           | Banks’ discount rate | 0.046 [0.0169] |
| W/K                         | Relative size of the deposit market | 0.283 [0.0221] |
| q<sup>n</sup>               | Value of firms’ outside option | -9.689 [1.0249] |
| φ<sup>N</sup>               | Quadratic cost of non-reservable borrowing | 0.010 [0.0145] |
| φ<sup>d</sup>               | Bank’s cost of taking deposits | 0.009 [0.0002] |
| φ<sup>l</sup>               | Bank’s cost of servicing loans | 0.008 [0.0045] |
| ψ                           | Net fixed operating cost | 0.009 [0.0001] |
Figure 1: Deposit Spread, Loan Spread, and the Federal Funds Rate
This figure plots the non-parametric relationship between the Federal Funds rate and the average deposit spread and loan spread of U.S. banks. The sample period is 1985 through 2017. The data frequency is quarterly. The deposit spread and loan spread are constructed using the Call report and the Federal Funds rate is retrieved from the FRED database of the Federal Reserve Bank of St. Louis.
Figure 2: Timeline within a Period
Figure 3: Relationship between Deposit Rate, Loan Rate, and the Federal Funds Rate
This figure illustrates the relationship between deposit rates, loan rates, and the Federal Funds rates. The Federal Funds rates are plotted on the x-axis; deposit rates and lending rates are plotted on the y-axis.
Figure 4: Model-predicted versus Actual Rates

This figure illustrates how banks’ deposit and loan rates behave as functions of the Fed Funds rate. The grey circles represent the raw data from 1984 through 2017, aggregated at quarterly frequency; the blue lines represent local polynomial smooth plots based on the raw data, and the red lines represent the relationships predicted using the model.
Figure 5: Bank Capital, Bank Lending, and the Federal Funds Rate

This figure illustrates how bank capital and optimal lending vary with the Federal Funds rate. Banks' optimal lending is calculated under two alternative cases: the baseline line case where banks are subject to the capital regulation and an alternative unconstrained case where the capital regulation is removed. The Federal Funds rate is on the x-axis. In Panel A, bank characteristics, scaled by their respective unconditional average values, are on the y-axis; in Panel B, the y-axis measures the impulse response of bank characteristics to a one-percentage-point Federal Funds rate shock.
Figure 6: Impulse Response to Federal Funds Rate Shocks
This figure illustrates banks’ impulse responses to Federal Funds rate shocks. The economy starts at Year 0 when it is in the old steady state with the FFR equal to 0.9%; in Year 1, the FFR either increases to 2% or decreases to 0.2%, and it stays at that level afterwards until the economy reaches the new steady state. Each variable in the graph is scaled by the level in the old steady state (when the FFR = 0.9%).
Figure 7: Monetary Policy Shocks and Bank Equity Returns

This figure provides the scatter plot of bank industry excess returns against monetary policy shocks on FOMC days from 1994 through 2017. The excess returns are defined as the difference between bank industry index returns and market returns. Monetary policy shocks are measured by one-day changes in two-year Treasury yields on FOMC days. The sample for the upper panel corresponds to when the Federal Funds rate is above 2% and the sample for the lower panel is when the Federal Funds rate is below 2%. We exclude observations during the burst of the dot-com bubble (2000-2001) and the subprime financial crisis (2007-2009). Bank industry stock returns are retrieved from Kenneth French’s website and the two-year Treasury yield is retrieved from the FRED database of the Federal Reserve Bank of St. Louis.
Figure 8: Bank Lending During Recoveries
This figure plots bank lending during seven recoveries since the 1960s. The horizontal axis represents months since the start of each recovery. The vertical axis is bank lending normalized by the level at the start of each recovery. The data are retrieved from the FRED database of the Federal Reserve Bank of St. Louis.