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Banking on Buffers: Balance Sheet Responses to Household Demand, Macroeconomic Conditions, and Monetary Policy

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Abstract

This paper examines how banks adapt to tightening regulations, evolving macroeconomic conditions, and changes in household demand. Unlike most analyses of banking regulation, we develop a general equilibrium model in which banks both borrow from and lend to households, allowing us to assess the impact of regulations in conjunction with other macroeconomic factors. The model features an often overlooked interplay between household portfolio choices and bank financial decisions, emphasizing the contribution of household preferences to the precipitous climb in cash ratios that accompanied reductions in bank leverage following the 2008 global financial crisis. Through counterfactual analysis, we find that in the absence of heightened household demand for deposits, decline in bank leverage would have been twice as steep, and the proportion of mortgage loans within total assets would have contracted by more than twice the actual post-crisis change. Our empirical analysis confirms the increase in household demand for deposits and explores how this expansion interacts with banks' capital buffers. The empirical results support our comparative static implications that banks with larger capital buffers accumulate less cash and more mortgages as a share of total assets than banks with smaller capital buffers in response to growing deposits. The mechanisms discussed in this study are pertinent for policymakers, particularly as central banks worldwide consider further interest rate reductions and U.S. regulators finalize the implementation of Basel III requirements.

Keywords: banks · deposits · monetary policy · mortgages

JEL Classification: C58 · D14 · D53 · E44 · E58 · G21 · G28 · G51 · R21

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1 Introduction

The regulatory landscape has evolved significantly since the 2008 global financial crisis (GFC), with increased oversight and new frameworks, like the Basel III Accords, designed to enhance bank resiliency. More recently, the global pandemic introduced new challenges, intensifying liquidity pressures on banks as households and businesses sought safer financial positions. In response, regulators temporarily relaxed certain rules to accommodate the surge in deposits and liquidity needs, further emphasizing the complex relationship between regulatory policy, household behavior, and banks' balance sheet decisions.

This paper examines how three key factors—tightening regulations, evolving macroeconomic conditions, and shifts in household demand —have shaped balance sheets of U.S. banks in the post-crisis period. To the best of our knowledge, this is the first study on banking regulation to combine cross-disciplinary ideas from household finance, general equilibrium modeling, and monetary policy literatures.[1] While existing literature has focused on regulatory changes or monetary policy in isolation, few studies have explored how these forces intersect with household deposit behavior to influence banks' balance sheets. We present a model that captures these dynamics and quantifies their impact on banks' portfolios, particularly the rise in cash holdings and contraction in mortgage lending. Our counterfactual analysis suggests that without the increase in household demand for deposits, decline in bank leverage would have been twice as steep, and the proportion of mortgage loans within total assets would have contracted by more than twice the actual post-crisis change.

Economic disruptions from the pandemic complicated the macroeconomic environment by perpetuating post-crisis trends. Elevated household deposit demand, adjustments in monetary policy rates, and delayed implementation of Basel III regulatory requirements in the U.S. are remnants of the pandemic that still have lingering effects. This paper's findings are especially timely as policymakers face the challenge of pursuing further monetary easing amid pending enactment of stricter regulatory constraints. Our empirical analysis supports the model's predictions, demonstrating a strong relationship between rising household de-

[1] The approach is valuable because it allows us to explore how household portfolio choices influence bank financial decisions and vice versa. The theoretical framework highlights the interaction between household and bank balance sheets, unlike existing models that focus solely on either banks or households. As a result, our discussion is two-sided, which contrasts with conventional discussions about regulation that often present a one-sided view where banks either lend or create deposits (or not) and the financial landscape is shaped primarily by these choices.

posit demand and increased cash ratios on bank balance sheets. Additionally, we investigate how changes in capital requirements, liquidity coverage ratios, and interest rates influence banks' incentives to hold cash and extend credit. Understanding how banks adapt to the combination of regulatory changes and shifting household preferences is crucial as central banks once again lower interest rates in an era of tighter liquidity and capital requirements.

Through the lens of the model, this paper provides an important perspective on how regulatory constraints, monetary easing, and household portfolios coalesce to attenuate or magnify their individual effects on bank portfolios. Section 2 provides an overview of the regulatory environment, explaining the need for a more robust model to capture the interplay among international macroprudential standards, monetary policy, and household behavior. Section 3 describes the general equilibrium model used to assess how banks' balance sheets respond to these different factors. Section 4 presents a calibration of the model, using aggregated balance sheet data to quantify the effects of interest rates, capital requirements, and liquidity coverage ratios on banks' cash holdings and lending behavior. Section 5 covers the comparative statics of key model parameters, while Section 6 explores the empirical results, validating the model's predictions on household deposit demand and its relationship to bank cash ratios with data. Finally, Section 7 concludes by offering insights on the channels through which implementation of stricter regulatory controls may induce balance sheet movements that clash with the aims of an international shift toward accommodative monetary policy, highlighting potential tensions between short-term economic stimulus and long-term financial stability and the role of household demand as a mitigating force.

2 The Regulatory Landscape and Market Dynamics

A common dictum of financial regulation is that stricter rules reduce bank leverage and encourage prudent lending. However, the controversy surrounding international requirements beginning after the 2008 financial crisis and continuing through the Basel III Endgame discourse suggests that U.S. banks may not agree with this principle. Moreover, it remains unclear how macroprudential capital rules affect bank behavior or how the rules factor into lending decisions in general and in an economic setting with persistently low interest rates.[2]

[2]Some studies indicate that increasing the required quantity of safe assets held against risky assets generally decreases loan growth and produces less risky balance sheets. Aiyar, Calomiris, and Wieladek (2014) explain how capital requirements raise costs of issuing loans, causing banks to reduce lending and pass on the costs to borrowers in the form of higher interest rates. Corbae and D'Erasmo (2019) and Giordana and Schumacher (2013) both model a complex banking sector within a general equilibrium framework to affirm that aggregate loan supply falls in response to a rise in capital requirements. Bridges et al. (2014), using

The financial crisis fundamentally altered the regulatory environment, with new rules introduced to strengthen the banking sector. Endorsed in the U.S. in September 2010, Basel III substantially increased capital buffer requirements, imposed the Supplementary Leverage Ratio (SLR) to mitigate risk, and introduced the Liquidity Coverage Ratio (LCR). The capital requirements dictate that banks must hold a minimum amount of capital against their risk-weighted assets.[3] The SLR, established in the U.S. in 2014, adds an additional layer of protection by requiring systemically important banks to meet a stricter non-risk-weighted capital to assets ratio. SLR rules dictate a minimum ratio of 3%, with U.S. implementation of the rules setting the minimum at 5% for systemically important banks. The LCR ensures that banks maintain sufficient high-quality liquid assets to survive a 30-day stress scenario.[4] Although the LCR did not come into full effect until 2017, there is general consensus that large banks began to accumulate reserve balances and reduce lending several years prior, in anticipation of the rule.[5]

These regulatory changes coincided with ongoing macroeconomic shifts, such as sustained low interest rates and evolving household balance sheets. The Federal Reserve reduced the

a 1990-2011 sample of UK banks, supplies evidence for banks cutting a large portion of commercial real estate loans, a slightly smaller portion of corporate lending, and a minimal fraction of household secured finance. Juelsrud and Wold (2020) present evidence from Norway that banks raise capital ratios in reaction to Basel III rules by reducing risk-weighted assets, supplying more credit to the corporate sector relative to the household sector. Noss and Toffano (2014), using aggregate data on UK banks, estimate that banking lending may contract by as much as 4.5% to a 1% increase in macroprudential capital requirements during an economic boom. Francis and Osborne (2009) place the drop at around 0.8%, while the Macroeconomic Assessment Group (MAG) attached to Basel and the Financial Stability Board (FSB) estimate a range of 0.7% to 2.1% if the 1% increase in capital requirements is phased in over a two years. Other research suggest stricter capital-based rules may not prevent crises and could exacerbate risk-taking. Jordà et al. (2021) show empirically that higher capital buffers do not prevent financial crises in advanced economies. Gale (2001) discusses how, in theory, feedback effects can lead banks to reach for yield and take on more risk given higher capital requirements and Cohen and Scatigna (2016) document this behavior among banks in emerging markets.

[3]Specifically, a capital conservation buffer of 2.5% of risk-weighted assets plus a countercyclical buffer of 2.5% during credit booms on top of a new minimum capital requirement of 6% of risk-weighted assets. In sum, banks need a higher quantity and quality of capital at hand.

[4]A significant stress scenario could include any combination of the following: a run on deposits, loss of unsecured wholesale funding capacity, loss of short-term financing, outflows from the bank due to downgrades in the bank's credit rating, market events that induce large collateral haircuts and increased liquidity needs, unscheduled drawdown of committed credit facilities provided to clients, and the potential need to buy back debt or honor non-contractual obligations to mitigate reputational risk. For additional details, please see `http://www.bis.org/publ/bcbs238.pdf`.

[5]Ihrig et al. (2019) document that large banks accumulated reserve balances beginning in 2014 to comply with the requirement, then shifted towards holding more Treasuries and government-sponsored entity (GSE)-backed MBS.

federal funds rate to unprecedented levels following the financial crisis, and interest rates remained low for a prolonged period after the crisis. With the Federal Reserve embarking on a new easing cycle and the finalization of the Basel III Endgame underway, it is useful to revisit the historical experience of the last cycle when similar forces were at play to understand how policies targeted at banks can influence the broader economy. Post-crisis, the concurrent implementation of stricter regulatory controls with expansionary monetary policy raised questions about how these combined forces reshaped banks' balance sheets.[6] Additionally, heightened demand for deposits from households, driven by post-pandemic increases in savings and a flight to quality, has exerted upward pressure on banks' cash holdings, making households an important element to consider when thinking about the current economic situation.

After 2008, banks significantly increased their cash holdings. Figure 1 illustrates the steady rise of cash as a percentage of total assets among U.S.-insured depository institutions, coupled with a decline in residential mortgage lending and leverage. What forces underlie these trends? How large of a role does banking regulation play in explaining the changes?

A general equilibrium model is necessary to disentangle the effects of capital and liquidity-based regulations from movements in macroeconomic factors and investigate their effects on banks. We propose a model to analyze bank balance sheet choices in the context of new regulatory rules and macroeconomic factors to isolate the mechanisms driving bank behavior post-crisis, drawing on lessons from diverse genres of research to capture important features of households, banks, and regulation in our framework.

There is extensive theoretical work on how housing affects investment and consumption decisions of consumers. Portfolio selection models outline how investors choose different asset mixes when they own a house and are subject to pricing risks.[7] General equilibrium models describe how house prices drive fluctuations in aggregate consumption.[8] While the models

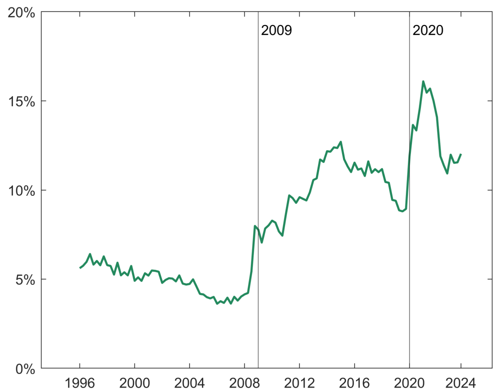
[6] Popoyan (2020) provides a detailed discussion and overview of the literature on macroprudential policy and monetary policy interactions.

[7] Grossman and Laroque (1990) introduce an illiquid durable good into a standard consumption-based asset pricing model to show that transaction costs associated with buying and selling homes can change investors' degree of risk aversion. Flavin and Yamashita (2002) examine how demand for housing and mortgage finance imposes a constraint on the consumer's optimal mean-variance efficient portfolio. Cocco (2005) and Yao and Zhang (2005) study how home ownership reduces stock market participation among lower financial net worth individuals and relative to individuals renting housing.

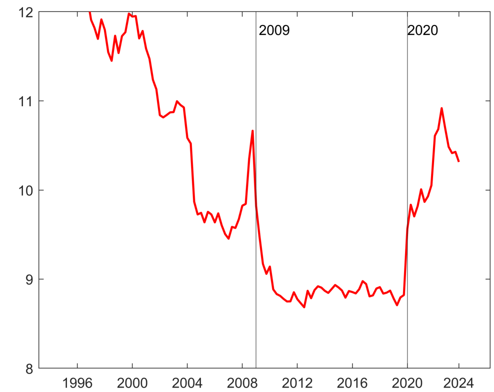
[8] Iacoviello (2004) provides a structural model explaining consumption dynamics as a function of utility

Figure 1: Selected Bank Balance Sheet Ratios

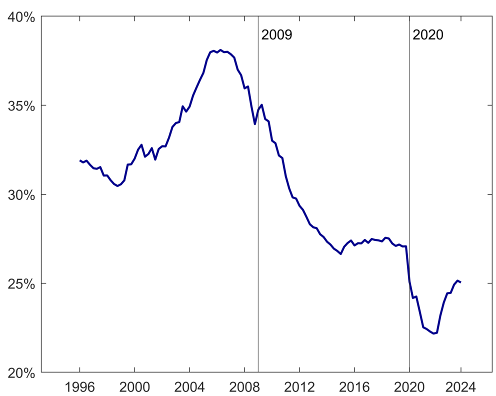
(a) Cash of Depository Institutions



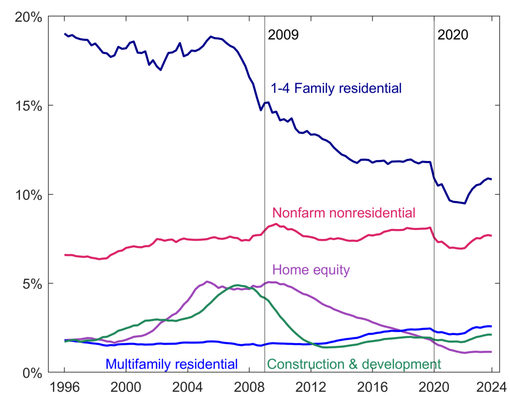
(b) Leverage of Depository Institutions



(c) Loans Secured by Real Estate



(d) Loans Secured by Real Estate



Notes: The percentages displayed in panels a, c, and d are shares of total assets, while panel b displays assets as a multiple of total equity. **Source:** Federal Deposit Insurance Corporation (FDIC) Quarterly Banking Profile. Aggregated data from all FDIC-insured institutions from 1996 through 2023.

examine the household optimization problem in detail, they contain little to no treatment of banks' balance sheet choices. Like household portfolio models, we incorporate home ownership, mortgages, and house prices into our model, but allow the bank's choices about capital structure and asset holdings to influence its lending relationship with households.

In a similar vein, we include insights from the household portfolio literature into the theoretical structure commonly used in banking and macroprudential analyses. Most general

derived from housing, housing prices, and borrowing constraints tied to home collateral values. Aoki, Proudman, and Vlieghe (2004) explains in their model how transmission of monetary policy shocks to consumption is determined by the relative ease with which households can borrow against their home equity.

equilibrium models separate lenders from borrowers, with banks channeling deposits from households to firms.[9] In contrast, within our model setup, households are both debtors and savers, which is consistent with household portfolio data.[10] This allows us to analyze interactions between household and bank balance sheets. Understanding how household savings affect regulatory constraints is particularly interesting given policymakers' re-examination of bank leverage limits because of large deposit inflows during the COVID-19 pandemic.[11] Liquidity and capital rules were designed to address funding outflows from banks, so most analyses do not explore implications of deposit demand by households in their models.

As a general overview, our model considers the bank's portfolio problem in the face of household decisions and regulatory constraints. The bank receives deposits from households and can lend or hold cash as reserves at the central bank.[12] Given house prices, the household chooses whether to move to a new home, how much to save at the bank, and the size of the mortgage to take out from the bank. Regulatory constraints on the bank consist of a minimum ratio of equity to risk-weighted assets and a liquidity coverage ratio.[13] Changes in bank regulation and the economic environment are captured by separate parameters to represent different elements that can affect the bank's optimization choice.

[9] Dynamic general equilibrium models used to study macroprudential rules, such as Covas and Driscoll (2014), have workers as savers and entrepreneurs as borrowers. Traditional business cycle models, like that used in Begenau (2020) to analyze the effects of capital requirements on bank lending, also have households as suppliers of savings and firms as loan takers.

[10] For example, Telyukova (2013) discusses how households hold low-return cash despite having outstanding credit card balances with high interest rates (the "credit card debt puzzle") and provides a theoretical model based on households' needs for liquidity as an explanation.

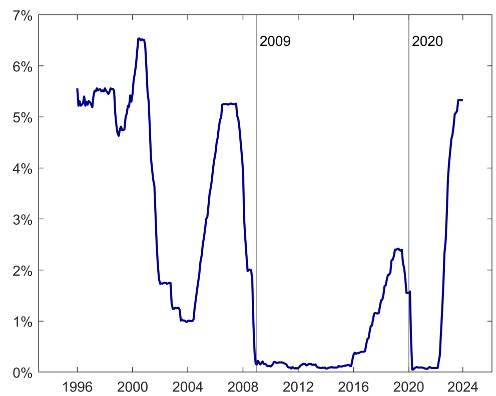
[11] The Supplementary Leverage Ratio Interim Final Rule, approved in May 2020, allows temporary exclusion of U.S. Treasuries and Federal Reserve Bank deposits from the supplementary leverage ratio denominator to accommodate inflows of deposits stemming from flight to liquid assets behavior which expanded balance sheets and pushed up leverage ratios at banks. See `https://www.occ.gov/news-issuances/federal-register/2020/85fr32980.pdf` for further details.

[12] Two types of lending occur. First, mortgages are made to households that yield a return dependent on the probability of default and the value of the home used as collateral. In each period, the household experiences a shock to preferences that changes their demand for housing and determines the price of houses. Second, banks make other loans to the household which pay a constant return. For simplicity, we assume that other loans are exogenous, while mortgages are endogenous and determined in the general equilibrium.

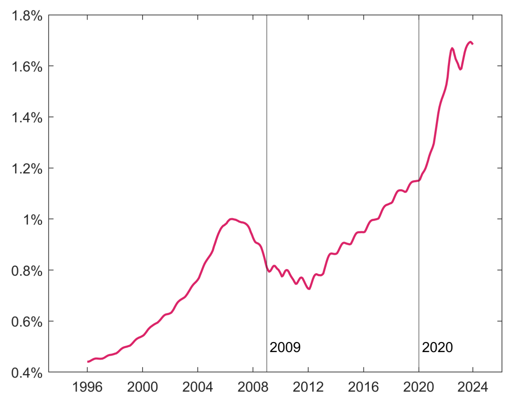
[13] Reserves help fulfill the requirements, but earn little return. Mortgages earn a higher return, but count against regulatory ratios. When regulatory ratios approach minimum stipulated levels, the bank increases the likelihood of incurring a shortfall and facing penalties imposed by the regulator and investors. Thus, the bank faces a trade-off between compliance risk and return. To maximize shareholder value, the bank wants to hold all assets as higher paying mortgages rather than cash. Yet, if it holds too little cash, the bank may realize large regulatory costs.

Figure 2: The Interest Rate Environment and Residential Real Estate Prices

(a) Effective Fed Funds Rate



(b) Residential Real Estate Price Index



Source: In panel (a), the effective federal funds rate comes from the Federal Reserve. In panel (b), the S&P CoreLogic Case-Shiller residential real estate price index comes from S&P Dow Jones Indices LLC. Index value equals 100% in July 2006. All panels show monthly data from 1996 through 2023.

We focus on four major changes that occurred following the GFC in our theoretical analysis. First, regulators raised bank capital requirements starting in 2013 as part of a new Basel III framework to mitigate risk. Second, the LCR was introduced in 2015 to make banks resilient to sudden cash outflows. Third, the Federal Reserve lowered interest rates precipitously from around five percent in 2007 to less than half of a percent in 2009 and kept rates low until early 2016 (see panel (a) in Figure 2). Lastly, housing prices rose over the early 2000s to a peak in July 2006 and then fell until early 2012 when they began to rise on a consistent year-over-year basis until briefly ratcheting up during the pandemic (see panel b in Figure 2), so we consider changes in household demand. Using aggregated balance sheet data on FDIC-insured depository institutions, model parameters are calibrated to pre-crisis (2000-2007) and post-crisis (2009-2016) conditions.[14] To explore potential drivers of the fundamental shift in bank balance sheets away from real estate loans to a larger share of cash in total assets, we analyze changes in parameters over the two periods.[15] Through counterfactual analyses, we

[14]We symmetrically divide the time series into pre-crisis (2000-2007) and post-crisis (2009-2016) periods as two different relatively-steady economic states. The pandemic period from 2020 through 2021 was a time filled with economic uncertainty and cannot be characterized as a stable equilibrium period. Immediately following the pandemic, in 2022, the Federal Reserve began aggressive monetary tightening in reaction to inflation which began its rapid ascent during the pandemic. In contrast, the periods 2000-2007 and 2009-2016 had relatively low and stable levels of inflation near two percent on average. The pre-crisis period could conceptually be extended to 2019, but we chose to end in 2016 to balance the number of quarters considered on either side of 2008.

[15]Standard analyses of macroprudential policy focus on equity and do not study the share of cash in total assets. Zhu (2008) and De Nicolò, Gamba, and Lucchetta (2012) are two prominent models cited in the

quantify how important each of the four major factors is in shaping bank behavior.

By developing a unique general equilibrium model with interlinkages between bank and household balance sheets, we can examine post-crisis regulations, monetary policy, and changes in household preferences. These factors are becoming increasingly relevant as the U.S. tries to forestall a recession in the aftermath of the pandemic. Our model demonstrates that heightened household demand for bank deposits has been a major contributor to the growth in cash holdings and evolution of bank leverage following the financial crisis.[16] The empirical analysis supports the model's predictions, documenting the rise in household demand for deposits post-crisis and tracing out the positive relationship between demand for bank deposits and cash ratios through panel data analysis.[17] Our results indicate that increasing deposit demand contributes significantly to the rise in cash holdings as bank regulatory buffers are eroded, confirming that liquidity demand can remain elevated even in the presence of accommodative monetary policy. This outcome highlights that, while regulatory reforms aimed to enhance the stability of the financial system, they also created trade-offs that may lead banks to prioritize liquidity over lending. Our model captures how tighter capital and liquidity requirements constrained banks' ability to extend credit, particularly in residential mortgage markets, even when deposits were abundant.[18] We offer a new macro-

literature on capital regulation and bank financial decisions. Zhu employs a model where the balance sheet consists of loans, deposits, and equity, where equity serves as the main tool to meet capital requirements. De Nicolò et al similarly only consider loans, bonds, deposits, and equity in the bank's balance sheet. Work by Mankart, Michaelides, and Pagratis (2020) incorporates a liquid asset into the balance sheet that functions like cash in my model to meet regulatory constraints. However, the focus of Mankart and co-authors is to evaluate how different regulations influence aggregate loan supply and bank failures, not balance sheet composition.

[16]During the post-GFC period, stricter regulatory controls were implemented alongside expansionary monetary policy. Theoretical work by Acharya and Rajan (2024) suggests that expansionary policy, coupled with rising deposit liabilities, can exacerbate liquidity hoarding by banks during periods of stress, leading to higher funding costs and reduced term lending to firms. The effects of financial regulations are partly captured in their model by the illiquid nature of reserves in stress states, and the authors consider the interplay between deposit demand of savers and funding needs of banks through the interbank market. Our modeled and empirical results, which examine the relationship between monetary policy and regulation through the lens of the household balance sheet, confirm that household deposit demand can lead to a sharp rise in cash as a share of banks' total assets and a decline in residential mortgage lending.

[17]Lopez-Salido and Vissing-Jorgensen (2023) also note the rise in deposit demand by households. They use time series regressions to explore the drivers of the growth in log deposits and liquid deposits from 2009 to 2022 as a function of log reserves, household financial assets, and the interest rate on reserves. They find little role for reserves driving the growth in deposits when drivers of household demand for deposits are included and argue against quantitative easing as the main driver of increased deposits, which have grown steadily since 2000.

[18]On the lending side, Gete and Reher (2018) show that tighter lending standards induced by higher liquidity and capital requirements on large banks have led to increased mortgage application denial rates,

financial view: household deposit demand has been instrumental in increasing banks' cash reserves post-crisis, indicating that reducing the federal funds rate might not boost lending but could, instead, support elevated cash ratios depending on banks' regulatory cushions.[19]

The Basel III framework and other macroprudential measures provide essential safeguards, but understanding how they interact with macroeconomic conditions and household preferences is critical. As we explore further in the paper, our model demonstrates that these forces, particularly the interplay between liquidity regulation and interest rates, shape banks' incentives and their balance sheet decisions in distinct ways. This interaction helps explain why some banks hold substantial cash reserves despite low returns, while others reduce leverage to avoid the costs associated with regulatory compliance.[20]

3 Model

There are three sectors in the economy: the household sector, the bank sector, and a combined government central bank. First, we describe the household sector and the bank sector along with the regulatory rules considered in the model. Second, we introduce the role of the government central bank. Then we define the equilibrium and solve for the non-stochastic steady state with some baseline parameters to characterize how the optimal choices of households and banks jointly determine the composition of bank balance sheets.

3.1 Household Sector

Time is discrete and the horizon infinite. A representative household receives utility from consumption, C_t, the size of the house they own, H_t, and savings, S_t:

$$log(C_t) + \psi_t log(H_t) + \rho_t log(S_t) \tag{1}$$

particularly among low income and minority borrowers.

[19]Previous studies have explored how deposit growth impacts bank balance sheets. Diamond, Jiang, and Ma (2024) examine a similar period, showing that increased deposits from higher reserve holdings can crowd out bank lending, particularly in corporate loans. In their model, banks operate in imperfectly competitive deposit markets, with regulatory constraints not explicitly modeled as costs. Our approach differs by treating banks as price takers in the deposit market and focusing on the interaction between household savings preferences and bank balance sheet decisions, with particular emphasis on capital and liquidity requirements. While we find a crowding-out effect, the mechanism differs, being more reliant on regulatory constraints.

[20]Uluc and Wieladek (2017) provide evidence from the UK that rising capital requirements may lead banks to shift risk towards higher-risk mortgage borrowers, illustrating how banks adjust to regulatory constraints in unexpected ways that can sometimes exacerbate risk-taking.

Household income consists of a fixed wage, W_t, and dividends from bank equity, D_t. Income not spent is saved at the bank in the form of deposits, so savings, S_t, earn interest r_t^s. Households derive utility from deposits because of their liquidity properties. As discussed in Begenau (2020), this gives rise to a convenience yield on deposits whereby households want to hold deposits even with little to no return on their investment (when r_t^s is close to zero). Households not only value deposits as an asset for consumption smoothing, but also appreciate the short term nature of deposits that allows them to withdraw funds at any time. The parameter ρ_t captures the degree of liquidity preference and thus the size of the convenience yield. In comparison, housing is illiquid savings that only becomes accessible when the household takes out a mortgage, M_t, with interest rate r_t^m from the bank.[21]

The household has preference shock, ψ_t, which changes their demand for housing.[22] Total housing supply in the economy is fixed, at H, so changes in the household's demand for housing affects the price of the house, P_t, exposing them to house price risk.[23] Maintenance costs that must be paid each period also fluctuate with the house price, $\mu P_t H_t$.

Timing is as follows. First, the household enters the period with the house they own (H_t), a mortgage (of size M_t), and savings (S_t) from the previous period. Second, housing preference shock (ψ_t) and degree of liquidity preference (ρ_t) are realized, price (P_t) is revealed, wages (W_t) and dividends (D_t) are received. Third, the household chooses current consumption (C_t), next period housing (H_{t+1}), mortgage (M_{t+1}), and savings (S_{t+1}). If the household moves to a new house, they must pay the difference in the value of the houses or $P_t(H_{t+1}-H_t)$. Households also have other loans from the bank each period, L_t, with interest r_t^l.[24] To keep

[21] As a simplification, mortgages, M_t, encapsulate all loans backed back real estate on the bank balance sheet. Included are loans backed by single family and multi-family residential properties, farmland, nonfarm nonresidential property, home equity loans, and loans for construction and development. Additionally, we abstract from the heterogeneity of loan terms for different real estate collateral by having a single loan type that is the simple fixed-rate mortgage loan for a house. Changes in household demand for residential housing will drive changes in M_t, which captures the essence of the fourth panel in Figure 1.

[22] The form of the utility function with a housing demand shock is similar to that found in Liu, Wang, and Zha (2013). As the authors explain, the housing demand shock can be thought of as a reduced form representation of shocks not captured in the model, like idiosyncratic liquidity shocks or collateral constraints on borrowing that influence housing demand. Since the household here is subject to a collateral constraint, the house demand shock is meant to capture changes in home services production technology, like that suggested by Iacoviello and Neri (2010). The housing preference shock relies on an underlying assumption that utility depends on the services households receive from housing and there are time-varying shocks to the technology needed to produce services from housing stock.

[23] Essentially, prices adjust indirectly via ψ_t to allow the housing market to clear and match demand for housing with supply in equilibrium.

[24] This simplification of the household's portfolio is used to capture the non-mortgage related assets on

the model tractable, these loans are assumed to be exogenously chosen.

3.1.1 Budget Constraint

The household's budget constraint is

$$W_t+D_t+M_{t+1}+L_{t+1}+S_t = C_t+T_t+\frac{S_{t+1}}{(1+r_t^s)}+(1+r_t^m)M_t+(1+r_t^l)L_t+P_t(H_{t+1}-H_t)+\mu P_t H_t \tag{2}$$

where the left-hand side has sources of funds from current income, next period borrowing, and current savings. The right-hand side has uses of funds for consumption, tax payments to the government, next period savings, current borrowing, and housing costs.

3.1.2 Collateral Constraint

Because the household can potentially default on the mortgage loan, the house serves as collateral for the loan. The bank imposes a loan-to-value limit on the size of the mortgage given to the household based on the value of the house.

$$M_{t+1} \leq \bar{\theta} E_t(P_{t+1})H_{t+1} \tag{3}$$

Since the loan size is based on the expected future value of the house (the house price is not known when the mortgage is made), the mortgage can be interpreted as the culmination of a first lien mortgage and any equity loans or lines of credit.[25]

3.1.3 The Household's Problem

The household maximizes lifetime utility derived from consumption, savings, and the house they own, subject to its budget constraint (equation 2) and the collateral constraint (equation 3). Define the value function as

$$U(S_t, H_t, M_t) = \max_{C_t, S_{t+1}, M_{t+1}, H_{t+1}} \{log(C_t)+\psi_t log(H_t)+\rho_t log(S_t)+\beta_h E_t\left[U(S_{t+1}, H_{t+1}, M_{t+1})\right]\} \tag{4}$$

bank balance sheets, including commercial and industrial loans, loans to individuals, securities, other loans, Fed funds sold, and reverse repurchase agreements. Fed funds purchased and repurchase agreements are subtracted from L_t because interbank borrowing is not considered in the model.

[25] As in Cocco (2005), we assume the household can costlessly renegotiate their desired level of debt to keep the model simple.

which is used, in recursive form, for the household to solve the Lagrangian function

$$\begin{aligned}\mathcal{L}(S_t, H_t, M_t) = U(S_t, H_t, M_t) &+ \eta_{1,t}\left(W_t + D_t + M_{t+1} + L_{t+1} + S_t\right) \\ &- \eta_{1,t}\left(C_t + T_t + \frac{S_{t+1}}{(1+r_t^s)} + (1+r_t^m)M_t + (1+r_t^l)L_t + P_t(H_{t+1} - H_t) + \mu P_t H_t\right) \\ &+ \eta_{2,t}\left(\bar{\theta}P_{t+1}H_{t+1} - M_{t+1}\right) \qquad (5)\end{aligned}$$

3.1.4 Optimal Choices

The household faces tradeoffs when deciding how much to borrow, how much to save, and how to allocate spending between consumption and housing. The intertemporal dimension presents a decision to consume now or save to have more resources to spend in the future. In the intratemporal dimension, the household must choose between utility gained from consumption, enjoyment of a bigger home, or the benefits of having liquid savings at hand. Taking the derivative with respect to consumption (C_t), savings (S_{t+1}), size of the mortgage (M_{t+1}), and housing (H_{t+1}), the first-order conditions capture the optimal household choices.

Consumption. The household's choice of consumption is described by

$$\eta_{1,t} = \frac{1}{C_t} \qquad (6)$$

where consumption is chosen so that the marginal utility gained from an additional unit is equal to the value of an additional dollar in the household's budget that must be given up.

Savings. When deciding how much to save, household savings is determined by

$$\beta_h E_t\left(\frac{\rho_{t+1}}{S_{t+1}} + \frac{1}{C_{t+1}}\right)(1+r_t^s) = \frac{1}{C_t} \qquad (7)$$

which the household weighs as the expected discounted marginal utility of future savings and consumption against the incremental loss in utility from foregone consumption today.

Mortgage. The decision about borrowing to buy a house depends on the value of an additional dollar in home equity, expressed as

$$\eta_{2,t} = \frac{1}{C_t} - \beta_h E_t\left(\frac{(1+r_{t+1}^m)}{C_{t+1}}\right) \qquad (8)$$

Home equity is equal to the difference in the value of the house less the value of the mortgage, $(\bar{\theta}P_{t+1}H_{t+1} - M_{t+1})$. For a given house worth $P_{t+1}H_{t+1}$, when the household increases the size of their mortgage loan, they reduce home equity and their potential to borrow more against the value of their home in the future. Equation 8 links the cost of reducing home equity by an additional dollar today to the difference in the marginal utility gained from one unit of borrowing today and the discounted expected loss in marginal utility from forgone consumption tomorrow. Additional borrowing becomes more valuable as the gap grows between the marginal utility from borrowing today and the utility cost of repayment tomorrow.[26]

Housing. The choice to move and buy a new home is characterized by

$$\eta_{2,t}\bar{\theta}P_{t+1} + \beta_h E_t\left(\frac{\psi_{t+1}}{H_{t+1}} + \frac{P_{t+1}}{C_{t+1}}\right) = \frac{P_t}{C_t} + \beta_h E_t\left(\mu\frac{P_{t+1}}{C_{t+1}}\right) \tag{9}$$

The left-hand side has the household's marginal benefits, consisting of utility from additional equity available to borrow from today and the expected increase in utility from owning the new home and extra consumption tomorrow. The right-hand side contains marginal costs associated with acquiring a new house plus utility from expected future maintenance costs.

3.2 Bank Sector

3.2.1 Setup

A representative bank takes deposits, S_t, from households and can invest in mortgages, M_{bt}, and other loans, L_t, to households or hold the deposits in the form of reserves at the central bank.[27] The price of deposits is $q_t^s = \frac{1}{(1+r_t^s+\phi)}$.[28] The portion of deposits held in other loans to households, L_t, earns interest rate r_t^l. Income from mortgages is characterized by $y_t = z_t M_{bt}$, where z_t is the gross return on investment and M_{bt} is the amount of investment. Letting π denote the probability of household default[29], ν the recovery rate on the value of

[26]Slackness conditions apply, so $\eta_{2,t}(\bar{\theta}P_{t+1}H_{t+1} - M_{t+1}) = 0$. Either $\eta_{2,t} = 0$ and $\bar{\theta}P_{t+1}H_{t+1} > M_{t+1}$, or $\eta_{2,t} > 0$ and $\bar{\theta}P_{t+1}H_{t+1} = M_{t+1}$. Additional equity is only valuable when the loan-to-value limit is binding.

[27]To match the asset side of the balance sheet, deposits here include subordinated debt, other borrowed money, and other liabilities. Fed funds purchased and repurchase agreements are not included, as there is no interbank market in the model. In the data, deposits drive most of the change in the non-equity portion of total liabilities (less Fed funds purchases and repurchase agreements) from 2000 to 2018. Thus, we treat the entirety of non-equity as if they are deposits in the model and only consider the decisions behind changes in deposits in the bank and household's problem.

[28]ϕ is the unit cost of intermediation as proposed by Philippon (2015). The constant per unit cost is akin to overhead costs associated with provision of deposit services that are not paid to the depositors.

[29]We do not explicitly modeling the strategic default choice of the household and instead use π to capture the costs of default in reduced form. Default can be interpreted as a price wedge that causes banks to charge

the foreclosed home, and M_t the total mortgages demanded by households, then z_t equals

$$\frac{\pi\nu\frac{M_{bt}}{M_t}P_tH_t + (1-\pi)(1+r_t^m)M_{bt}}{M_{bt}} \tag{10}$$

Central bank reserves, F_t, earn a gross return of $(1+r_t^f)$, and act as a buffer against potential liquidity shocks. The bank pays dividends of D_t each period. For simplicity, we assume other loans, L_t, are exogenous while mortgages, M_{bt}, are endogenously determined.

3.2.2 Potential Regulatory Costs

The bank is subject to a capital constraint and a Liquidity Coverage Ratio (LCR). When the bank's capital ratio or LCR approaches the minimum regulatory benchmark, the bank increases its risks of potentially incurring a shortfall, whether in stress tests scenarios or in actual liquidity crises. Given that the bank's capital condition is public knowledge, the larger the distance between the bank's regulatory ratios and minimum required levels, the lower is the expected regulatory burden and negative market reaction faced by the bank. Furthermore, buffers are always positive.[30] These dynamics are captured parsimoniously by a convex cost that increases as the bank's regulatory ratio falls.[31]

Figure 3 illustrates such potential costs and equilibrium conditions. Panel (a) shows the general shape of potential regulatory costs as a function of the bank's distance from the minimum requirement, using the capital ratio as an example. Panel (b) depicts a mortgage market equilibrium between the bank sector and government central bank. The conditions

higher interest rates for mortgage provision. Alternatively, π can also capture the provisions for mortgage related loan and lease losses banks must deduct from assets, which is like a cost for mortgage lending.

[30]During September 2019, after an overnight repo market freeze, banks revealed that incurring daylight overdrafts would entail immeasurable costs.

[31]The potential costs we have in mind include direct costs of heightened regulatory scrutiny or intervention in bank operations, cuts in dividend payouts imposed as penalties by regulators, reductions in the market evaluation of the firm, and increases in the price of additional external funding. Banks that fail the Dodd-Frank Act Stress Tests (DFAST) or the Comprehensive Capital Analysis and Review (CCAR) conducted by the Federal Reserve are barred from increasing shareholder payouts through dividends or share buybacks. Under Basel III, banks that experience a shortfall in their LCR are subject to enhanced reporting commensurate with the size and duration of the shortfall and regulatory supervisors could also require a bank to reduce its exposure to liquidity risk, strengthen its overall liquidity risk management, or improve its contingency funding plan. Sahin, de Haan, and Neretina (2020) provide evidence that DFAST and CCARs affect the CDS spreads of banks. Flannery, Hirtle, and Kovner (2017) and Fernandes, Igan, and Pinheiro (2020) suggest that investors are attentive to bank stress tests and trade based on the results, which impacts banks' average returns. The formulation of regulation as a convex adjustment cost mirrors the setup in Furfine (2001), Darracq Pariès, Sørensen, and Rodriguez-Palenzuela (2011) and Roger and Vlček (2011) though the functional form is different.

are built up over the next series of equations and subsections.

Capital Requirement. The capital requirement is a Tier 1 RWA ratio calculated as shareholder's equity divided by risk-weighted assets:

$$\frac{F_{t+1} + M_{bt+1} + L_{t+1} - S_{t+1}}{\omega_{mt} M_{bt+1} + \omega_{lt} L_{t+1}} \tag{11}$$

Taking the required capital ratio to be equal to φ_t, the potential regulatory cost is:

$$\begin{cases} \lambda \left(\frac{F_{t+1}+M_{bt+1}+L_{t+1}-S_{t+1}}{\omega_m M_{bt+1}+\omega_{lt} L_{t+1}} - \varphi_t \right)^{-2} & \text{if} \quad \frac{F_{t+1}+M_{bt+1}+L_{t+1}-S_{t+1}}{\omega_{mt} M_{bt+1}+\omega_{lt} L_{t+1}} > \varphi_t \\ \infty & \text{if} \quad \text{otherwise} \end{cases} \tag{12}$$

Liquidity Coverage Ratio. The mandated liquidity coverage ratio must be met each period. Regulators assign runoff rates to the bank's deposits, δ_t, and outstanding unused credit lines, ζ_t, to calculate potential cash outflows due to negative shocks, taking into account potential offsetting cash inflows from mortgage payments.[32] High quality liquid assets in the bank's possession, comprised of reserves (F_{t+1}) and a portion of other loans ($\tau_{lt} L_{t+1}$), must be equal or greater than some multiple of net cash outflows ($\gamma_t \geq 1$). Thus, the potential regulatory costs associated with LCR are:

$$\begin{cases} \alpha \left(\frac{F_{t+1}+\tau_{lt} L_{t+1}+\frac{1}{2} r^m_{t+1} M_{bt+1}}{\delta_t S_{t+1}+\zeta_t M_{bt+1}} - \gamma_t \right)^{-2} & \text{if} \quad \frac{F_{t+1}+\tau_{lt} L_{t+1}+\frac{1}{2} r^m_{t+1} M_{bt+1}}{\delta_t S_{t+1}+\zeta_t M_{bt+1}} > \gamma_t \\ \infty & \text{if} \quad \text{otherwise} \end{cases} \tag{13}$$

To simplify notation, let

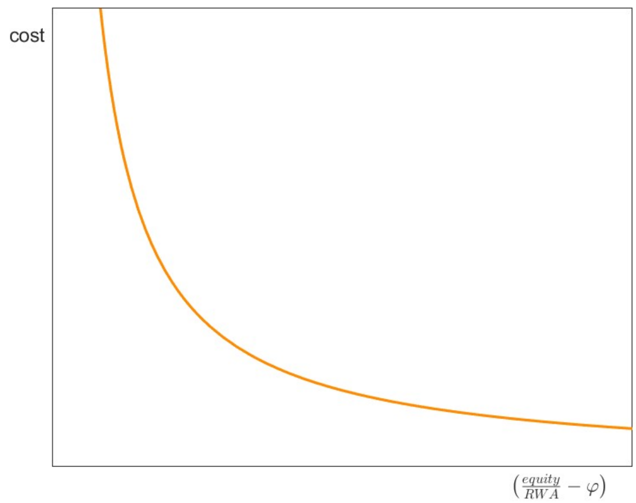
$$\Omega_{t+1} = \lambda \left(\frac{F_{t+1} + M_{bt+1} + L_{t+1} - S_{t+1}}{\omega_{mt} M_{bt+1} + \omega_{lt} L_{t+1}} - \varphi_t \right)^{-2} + \alpha \left(\frac{F_{t+1} + \tau_{lt} L_{t+1} + \frac{1}{2} r^m_{t+1} M_{bt+1}}{\delta_t S_{t+1} + \zeta_t M_{bt+1}} - \gamma_t \right)^{-2} \tag{14}$$

Derivatives taken with respect to variable i are denoted as $\Omega_{i,t+1}$. Reserves reduce regulatory costs ($\Omega_{F,t+1} < 0$), while deposits increase regulatory costs ($\Omega_{S,t+1} > 0$). The effect of mortgages is less clear, since mortgages both add to capital requirements and partially offset liquidity outflows, but they generally reduce regulatory costs ($\Omega_{Mb,t+1} < 0$).

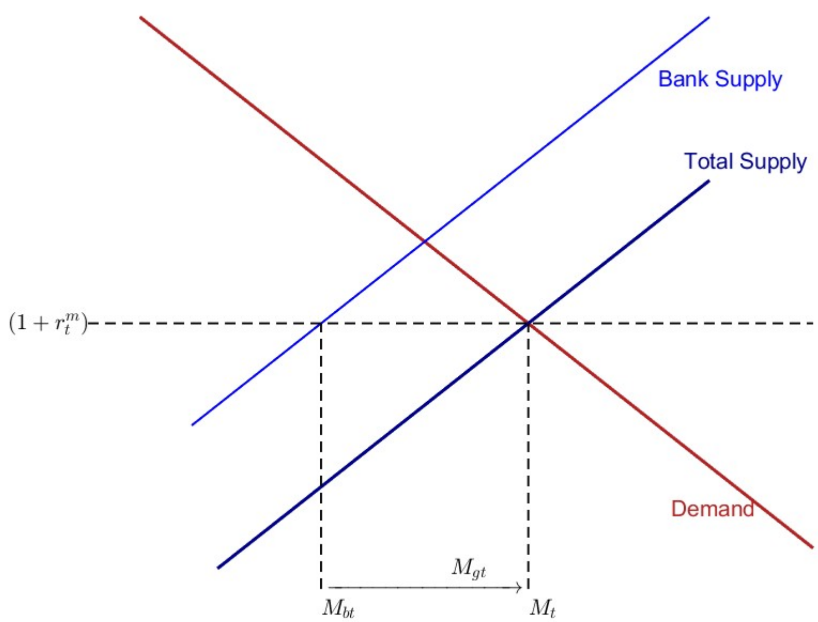
[32] Deposits that can be withdrawn quickly have a minimum runoff rate of 10%. Commitments for mortgages primarily secured by a first or subsequent lien on a one-to-four family property that can be drawn upon within 30 calendar days have a runoff rate of 10% applied to the undrawn portion. Committed credit and liquidity facilities to retail and small business customers are assigned a runoff of 5% of undrawn portions. Retail and business customer inflows equal to 50% of contracted amounts can offset cash outflows.

Figure 3: Modeling Costs and Equilibrium Conditions

(a) Potential Costs Associated with Capital Regulation



(b) Mortgage Market Equilibrium



Note: RWA is risk-weighted assets. In the mortgage market, total supply M_t, is the sum of bank supply M_{bt} and government central bank supply M_{gt}.

3.2.3 Budget Constraint

The bank's budget constraint is

$$z_t M_{bt} + (1 + r_t^l)L_t + q_t^s S_{t+1} + F_t = S_t + D_t + \Omega_{t+1} + M_{bt+1} + L_{t+1} + q_t^f F_{t+1} \tag{15}$$

where $q_t^f = \frac{1}{(1+r_t^f)}$ is the price of reserves. On the left-hand side is the bank's source of funds, comprised of revenue from investment, $z_t M_{bt} + (1 + r_t^l)L_t$, the value of deposits issued next period, $q_t^s S_{t+1}$, and reserves, F_t. Funds are used to repay deposits, S_t, pay dividends, D_t, pay expected regulatory costs, Ω_{t+1}, to lend, $M_{bt+1} + L_{t+1}$, or are allocated to reserves next period (adjusted for the rate of return), $q_t^f F_{t+1}$.

3.2.4 The Bank's Optimization Problem

The goal of the bank is to maximize its value, which is the present value of dividend payments to households. The problem of the bank in recursive form is

$$V(z_t, P_t, S_t, M_{bt}, F_t) = \max_{S_{t+1}, M_{bt+1}, F_{t+1}} \{D_t + \beta_b E_t V(z_{t+1}, P_{t+1}, S_{t+1}, M_{bt+1}, F_{t+1})\} \tag{16}$$
$$\text{s.t. } \Omega_{t+1}$$

The bank's problem mirrors a firm's equity value maximization problem, with constant returns to scale production technology, convex regulatory costs, and a borrowing constraint.

3.2.5 Optimal Balance Sheet Choices

When deciding the relative amounts of deposits, reserves, and mortgages to hold, the bank faces a tradeoff between risk and return. Assets with higher returns are more desirable for generating dividends, but the gains must be weighed against the risks of experiencing costly regulatory shortfalls. Taking the first-order conditions from the optimization problem for deposits, S_{t+1}, reserves, F_{t+1}, and mortgages, M_{bt+1}, we obtain the conditions that characterize the optimal decisions of the bank.

Deposits. Because deposits are a liability for the bank, deposits are equivalent to borrowing. When deciding how much to borrow, the bank considers the marginal benefit of an additional unit of borrowing versus the marginal cost, expressed as

$$q_t^s = \beta_b + \Omega_{S,t+1} \tag{17}$$

The bank's marginal benefit is the value of one dollar today, weighted by the rate of return paid to depositors, q_t^s. Marginal costs of borrowing (shown on the right-hand side of equation 17) include the discounted value of the one dollar the bank must return to the depositor tomorrow plus the cost of additional capital the bank must hold to meet regulatory liquidity and capital rules for one additional unit of borrowing. Deposits reduce the liquidity coverage ratio, $\frac{F_{t+1}+M_{bt+1}+L_{t+1}-S_{t+1}}{\omega_{mt}M_{bt+1}+\omega_{lt}L_{t+1}}$, and capital ratio, $\frac{F_{t+1}+\tau_{lt}L_{t+1}+\frac{1}{2}r_{t+1}^m M_{bt+1}}{\delta_t S_{t+1}+\zeta_t M_{bt+1}}$, which increases the bank's risk of incurring a shortfall and facing penalties, so the bank must consider the capital costs of borrowing when deciding on the optimal share of deposits on its balance sheet.

Reserves. The bank's choice about reserves is characterized by

$$\beta_b - \Omega_{F,t+1} = q_t^f \tag{18}$$

Reserves are chosen so that the marginal benefits of additional funds tomorrow and reduction in potential regulatory costs (since reserves increase regulatory liquidity and capital ratios) are equal to the marginal cost of reserves.

Mortgages. Mortgages are determined by

$$\beta_b E_t\left[(1-\pi)(1+r_{t+1}^m) + \pi\nu\frac{P_{t+1}H_{t+1}}{M_{t+1}}\right] - \Omega_{Mb,t+1} = 1 \tag{19}$$

An additional dollar made in mortgages brings the bank an expected return based on the probability of default, π, the interest rate charged, r_{t+1}^m, and the value of the home used as collateral adjusted for the size of the total mortgage taken against the home, $\frac{P_{t+1}H_{t+1}}{M_{t+1}}$.

Mortgages partially reduce the bank's required regulatory ratios and increase the potential regulatory costs faced by the bank. The second term in equation 19 is the net marginal benefit from one unit of mortgages in terms of regulatory liquidity and capital costs. For each extra unit of mortgages, the bank can use its net interest revenue to raise additional deposits, which relax constraints placed on borrowing by the liquidity ratio requirement. However, for one extra unit of mortgages, the bank reduces its liquidity ratio by the risk weight in the denominator of the required ratio, which it must offset by holding additional reserves. The net marginal benefit of one unit of mortgages in terms of regulatory capital costs is $\frac{F_{t+1}+M_{pt+1}+L_{t+1}-S_{t+1}}{\omega_{mt}M_{bt+1}+\omega_{lt}L_{t+1}}$. Increasing mortgages by one unit raises bank equity, $(F_{t+1} + M_{pt+1} + L_{t+1} - S_{t+1})$, and enables the bank to raise additional deposits. At the same time, the capital ratio is reduced by ω_{mt}, so the bank needs to hold extra reserves to offset the increase in mortgages, leading to a net marginal benefit of $\omega_{mt}(S_{t+1} - F_{t+1} - L_{t+1})$. Marginal benefits must be equal to the price of one unit of mortgages made, which is one.

3.3 Combined Government Central Bank

The government central bank collects taxes from households, intervenes in the mortgage market, and issues reserves to the banking sector.

Let the total value of mortgages extended to households be M_t, equal to the sum of mortgages intermediated by the bank sector, M_{bt}, and by the government, M_{gt} (see panel (b) in Figure 3). The government intervenes in the mortgage market by supplying mortgages, M_{gt}, to achieve an equilibrium price of $(1 + r_t^m)$.[33]

For a set interest rate level, r_t^f, the central bank issues reserves, F_t.[34] The chosen level of reserves must satisfy the budget constraint:

$$(1 + r_t^m)M_{gt+1} + F_t = T_t + q_t^f F_{t+1} + z_t M_{gt} \tag{20}$$

where $z_t = [\pi\nu \frac{M_{gt}}{M_t} P_t H_t + (1 - \pi)(1 + r_t^m)M_{gt}]/M_{gt}$. The government central bank does not maximize an objective function, but maintains a balanced budget embodied in equation 20.

3.4 Equilibrium

3.4.1 Definition

Let X be a vector of state variables containing housing preference parameter, ψ_t, the weight of deposits in household utility, ρ_t, house size, H_t, government mortgage supply, M_{gt}, the central bank's interest rate on reserves, r_t^f, amount of other loans, L_t, and interest on other loans, r_t^l. Let K be a vector containing variables describing the regulatory environment: minimum capital ratio, φ_t, risk-weights on mortgages and other loans, ω_{mt} and ω_{lt}, minimum LCR, γ_t, outflow rates on deposits and mortgages, δ_t and ζ_t, and other loans qualifying as high quality liquid assets, τ_{lt}.

[33] We use this assumption to capture, in a simple way, how U.S. government-sponsored enterprises, like the Federal Home Loan Banks, Freddie Mae, and Fannie Mac, reduce the cost of mortgage-financing for households through the purchase and securitization of mortgages.

[34] The interest rate on reserves, r^f is determined by many factors, like unemployment and inflation, that are outside of the model. We incorporate interest rate policy in a reduce-form way by defining r_t^f as an exogenous variable.

Denote the set of policy functions for the household, bank, and government central bank as

$$f_H : \left\{ \begin{array}{cc} C(X,W_t) & \text{consumption} \\ S^H(X,W_t) & \text{savings demand} \\ M^H(X,W_t) & \text{mortgage demand} \\ H^H(X,W_t) & \text{housing demand} \end{array} \right\} \quad f_B : \left\{ \begin{array}{cc} S^B(X,K,z_t) & \text{deposit supply} \\ M^B(X,K,z_t) & \text{mortgage supply} \\ F^B(X,K,z_t) & \text{reserves demand} \end{array} \right\} \quad f_G : \left\{ \begin{array}{cc} F^G(X,z_t) & \text{reserves supply} \end{array} \right\}$$

An equilibrium consists of f_H, f_B, f_G, a dynamic process for ψ_t, house price (P_t), interest rates (r_t^s and r_t^m) such that household policy functions f_H satisfy equations 6, 7, and 8 given P_t, r_t^s, and r_t^m; bank policy functions f_B satisfy equations 17, 21, and 19 given P_t, r_t^s, and r_t^m; and government central bank policy functions f_G satisfy its budget constraint of $(1+r_t^m)M_{gt+1} + F_t = T_t + q_t^f F_{t+1} + z_t M_{gt}$. Markets clear for mortgages if $M^B + M^G = M^H$, for reserves if $F^B = F^G = F$, for housing if $H^H = H$, and for savings if $S^H = S^B = S$.

3.4.2 Nonstochastic Steady State

Setting the housing preference shock $\psi_t = \bar{\psi}$, we solve for the nonstochastic steady state of the model. The set of equations describing the steady state can be found in the Appendix.

4 Quantitative Exercises

We calibrate model parameters to reflect the macroeconomic and regulatory environment, household characteristics, interest rates, and the structure of the housing market before and after the financial crisis. To focus on the main channels of interest, we specifically try to match balance sheet and regulatory ratios in the data with model moments determined by capital and liquidity regulation, monetary policy, and household preference parameters. We then examine the evolution of model parameters implied by the change in moments from pre- to post-crisis to understand which channels are more important.

4.1 Target Moments

The two time periods considered are pre-crisis defined as 2000 to 2007 and post-crisis from 2009 to 2016. We choose years relatively close to the peak of the financial crisis and use six year periods on either side just to balance the observations.

Because we want to explain the drop in leverage and accumulation of cash holdings by banks after the financial crisis, our first two targets are the cash to total assets ratio and book leverage. To quantify the perceived costs of regulatory noncompliance, λ and α, we include banks' actual liquidity coverage and Tier 1 RWA ratios as targets. Given the large movements in interest rates and housing prices that occurred from 2000 to 2012, we also want to match the interest rate on deposits and the price per square foot for housing to estimate housing preferences, ψ, and utility from deposits, ρ. To pin down the discount factor, β_b, which affects the range of interest rates on deposits, r^s, that the model can accommodate, our last target is the return on bank equity.

The top panel of Table 1 summarizes target moments and corresponding model moments. Balance sheet data are from the FDIC Quarterly Banking Profile (QBP). The QBP provides aggregated financial results of all FDIC-insured institutions, encompassing national and state banks, federal savings associations, and thrifts (all subject to Basel III capital rules).[35] The cash ratio, row one in Table 1, is calculated as "cash and due from depository institutions" divided by total assets.[36] Leverage, row two in Table 1, is total assets divided by equity.

Regulatory ratios are taken from FDIC QBP data and Basel III assessment reports. The Tier1 RWA ratio is line item "Tier 1 risk based capital ratio (PCA definition)" for all institutions in FDIC QBP bank ratios data. The liquidity coverage ratio comes from two different sources. For the period 2000 to 2007, in lieu of an actual liquidity coverage ratio, we use the average LCR calculated for Group 1 banks (internationally active banks with Tier 1 capital greater than three billion Euros) based on December 31, 2009 data as reported in the Basel Committee on Banking Supervision (BCBS) December 2010 Comprehensive Quantitative Impact Study.[37] Group 1 banks in the Study totaled 91 banks, including 13 U.S. banks, and had an average LCR of 83%. For the period of 2009 to 2016, we use a measure of the LCR for U.S. banks from the BCBS July 2017 Assessment of Basel III LCR regulations report. The average LCR for all internationally active bank holding companies in the U.S. was estimated at 110.5% based on September 30, 2016 data.[38]

To obtain the average price per square foot of houses sold in the U.S., we rely on the

[35] A weekly or monthly series is also available from the Federal Reserve H.8 "Assets and Liabilities of Commercial Banks in the United States" report, but it is based on a smaller core sample of 875 domestically chartered banks and foreign-related institutions, so it is not used.

[36] Cash is line item RCFD0010 or RCON0010 from Schedule RC-A in the FFIEC 031 and 041 Call Reports, which includes cash items in process of collection, unposted debits, currency and coin, balances due from U.S. depository institutions, balances due from banks in foreign countries and foreign central banks, and balances due from Federal Reserve Banks.

[37] See `https://www.bis.org/publ/bcbs186.pdf`.

[38] See `https://www.bis.org/bcbs/publ/d409.pdf`.

Table 1: Summary of Target and Model Moments

Target and Model Moments		
Data Moment	*Data Source*	*Model Moment*
$\frac{\text{cash}}{\text{total assets}}$	FDIC Quarterly Banking Profile	$\frac{F}{F+M^B+L}$
$\frac{\text{assets}}{\text{assets - liabilities}}$	FDIC Quarterly Banking Profile	$\frac{F+M^B+L}{F+M^B+L-S}$
Tier 1 RWA ratio	FDIC Quarterly Banking Profile	$\frac{F+M^B+L-S}{\omega_m M^B+\omega_l L}$
LCR	Basel III assessment reports	$\frac{F+\tau_l L+\frac{1}{2}r^m M^B}{\delta S+\zeta M^B}$
$\frac{\text{average sales price of house sold in U.S.}}{\text{average square footage of house}}$	U.S. Census	P
MZM own rate	Federal Reserve	r^s
return on equity	FDIC banking ratios	$\frac{1}{\beta_b}$

Imputed Parameters Used in Calibration					
Both Periods 2000-2016		Pre-Crisis 2000-2007		Post-Crisis 2009-2016	
Parameter	Value	Parameter	Value	Parameter	Value
W	\$86,000	H	2,377	H	2,550
π	0.010	φ	0.04	φ	0.06
θ	0.800	ζ	0.018	ζ	0.016
μ	0.020	τ_l	0.013	τ_l	0.028
ν	0.650	r^f	0.034	r^f	0.002
β_h	0.935	ϕ	0.032	ϕ	0.029
ω_l	1.000	M^G	\$105,000	M^G	\$148,000
		L	\$152,000	L	\$190,000
		r^l	0.066	r^l	0.043
		α	0.705	γ	1.000

Note: "RWA" stands for risk-weighted asset, "LCR" for liquidity coverage ratio, and "MZM" for money of zero maturity.

Characteristics of New Housing tables from the U.S. Census Survey of Construction (SOC).[39] Average square footage is from the table "Median and Average Square Feet of Floor Area in New Single-Family Houses Completed", which provides annual square footage for the U.S. and broad subregions. Average sales price is the series "Average Sales Price of Houses Sold for the United States" (APSUS) retrieved from FRED, which is derived from new residential sales data from the U.S. Census and Department of Housing and Urban Development.

The MZM own rate is from FRED. MZM is a measure of money stock equal to M2 minus small-denomination time deposits, plus institutional money market mutual funds. M2 consists of savings deposits (including money market deposit accounts), small-denomination time deposits (time deposits of less than $100,000), and balances in retail money market mutual funds. Basically, the MZM own rate captures the return on very liquid, short-term, money holdings of households.

Return on equity is calculated from the FDIC QBP "Annual Income and Expense of FDIC-insured Commercial Banks and Savings Institutions" table. The numerator is net operating income. The denominator is average total equity capital over four quarters of the previous year, from FDIC QBP balance sheet data. We also construct an alternative measure using the last quarter of every year, but it does not materially change the number.

4.2 Calibration Setup

To isolate the mechanisms behind capital and liquidity regulation, monetary policy, and household preferences, we calibrate other parameters of the model by imputing values directly from the data. The lower panel of Table 1 provides the full list of parameters.

In the left side of the lower panel of Table 1 are the parameters set constant for both time periods in the analysis. The first is household wage, W, which we equate to average annual household income in the 2017 U.S. Census, rounded to the nearest thousand, of $86,000 (see row one). The subsequent rows pertain to the housing market structure. We assume that one percent of mortgages are defaulted on with $\pi = 0.01$. Following general lending standards,

[39] The SOC is a national sample survey of new houses selected from building permits and a canvassing of areas not requiring permits. Builders or owners of the houses selected are interviewed for information including start, sale, and completion dates, and more than 40 physical and financial characteristics of the houses. The characteristics are collected throughout the construction process, thus the highest response rate is associated with completed homes. The overall national sampling rate is about 1 in 50 new houses, although this varies considerably by individual survey location based on activity.

the maximum loan-to-value ratio for a mortgage, θ, is 80 percent. Maintenance costs, μ, are two percent of home value, calculated as the sum of 2018 U.S. average annual utility bills, homeowner's insurance, HVAC, and house cleaning costs, from Zillow, divided by the average sales price of a house from 2000 to 2018, from FRED. Foreclosure sale recovery value, ν, is taken from Guren, Krishnamurthy, and McQuade (2021) and equals 65 percent. The household discount factor, β_h, is kept constant at 0.935. To satisfy slackness conditions of the model, β_h must be less than or equal to $\frac{1}{(1+r^m)}$, so we set β_h just below the pre-crisis value of $\frac{1}{(1+r^m)}$, 0.937. The last parameter kept constant is the risk weight assigned to other loans in the calculation of the Tier 1 RWA ratio, ω_l, set to 1. We keep the risk weight on other loans constant so we can solve for the risk weight on mortgages, ω_m, that corresponds to the actual Tier 1 RWA ratio in the data.[40]

We also impute parameters for the size of a house, the regulatory environment, interest rates, other bank assets, and government mortgage supply based on averages for each sub-period (see the middle and right panels of the lower half of Table 1). House size, H, is equal to average square footage from the U.S. Census SOC, aforementioned in Section 4.1. Average house size increases from 2,377 square feet pre-crisis to 2,550 post-crisis. The regulatory environment is described by statutory benchmarks for capital and liquidity ratios, and actual holdings of risk-weighted assets. The capital requirement, an equity to risk-weighted assets ratio, φ, was raised from 0.04 pre-crisis to 0.06 post-crisis under Basel III. The required liquidity coverage ratio (LCR), γ, equals 1 for the post-crisis period (last row in the bottom right panel of Table 1). The portion of mortgage loans that count as outflows for the LCR, ζ, is calculated as ten percent of the ratio of unused credit lines to total loans backed by real estate, taken from FDIC QBP balance sheet data. ζ remains fairly low in both periods, around 0.02. The portion of other loans that count as high quality liquid assets in the LCR, τ_l, is the share of Treasury securities divided by total assets less mortgages and cash, also from FDIC QBP. Banks' holdings of Treasury securities increased over the two periods, with the ratio more than doubling from 0.013 to 0.028. Imputed rates include r^f and ϕ. Interest rate on reserves, r^f, is the Fed funds rate, which falls from 3.4 percent pre-crisis to 0.2 post-crisis. Noninterest cost per unit of deposits, ϕ, is calculated by dividing total annual noninterest expense by the average of previous year's total assets. Noninterest expense comes from annual bank income and expense data from the FDIC QBP, while total assets come

[40] Alternatively, we can keep the risk weight on mortgages constant and solve for the risk weight on other loans. The choice is not crucial to the calibration, since we are interested in finding some weight combination in the model that satisfies the Tier 1 RWA ratio and am not targeting the risk weights themselves.

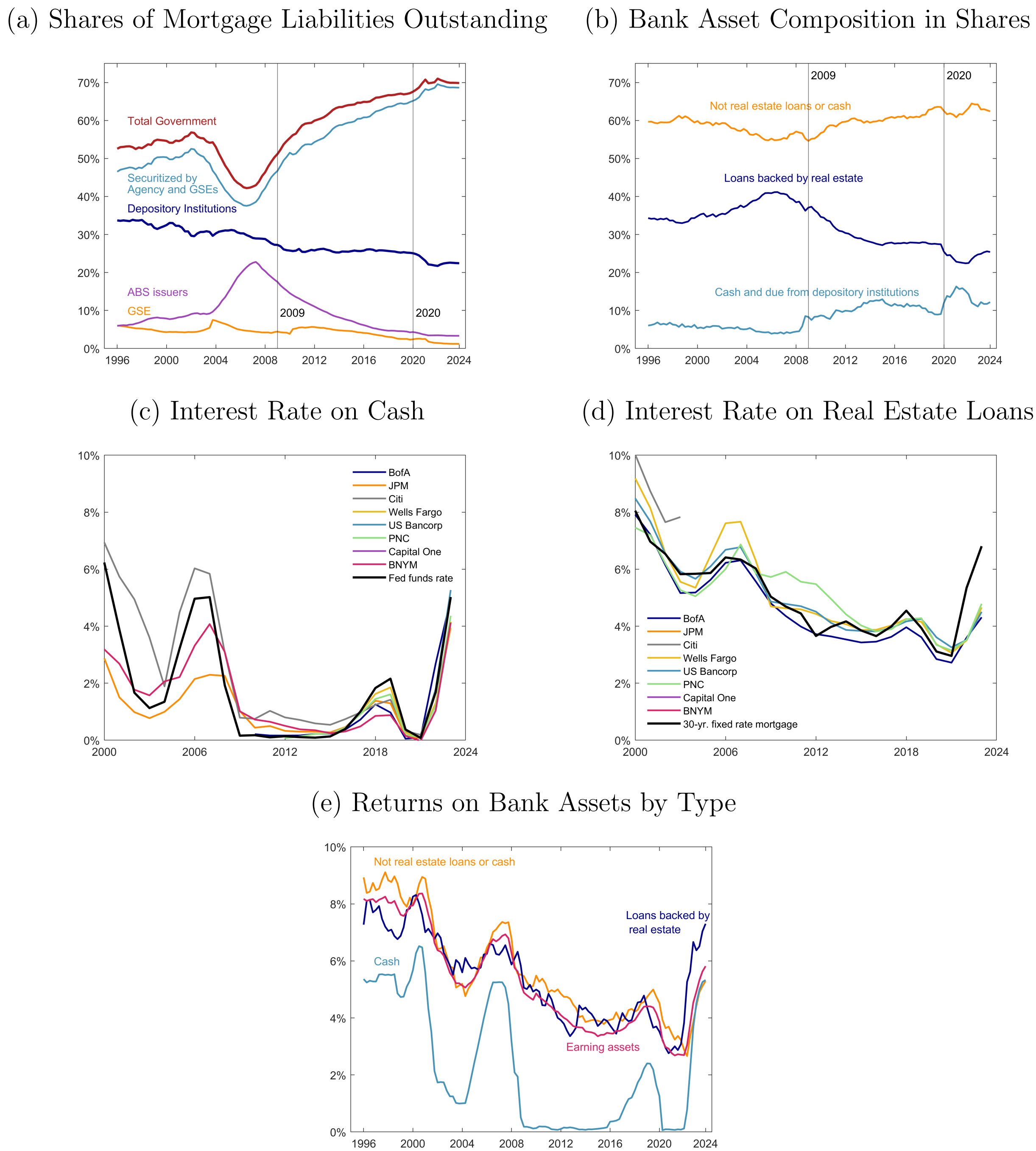
from quarterly balance sheet data. ϕ stays fairly constant around 0.03 in both periods.

Figure 4 compares bank lending liabilities, interest rates, and returns. For government mortgage supply, M^G, we use the share of total outstanding one to four family residential mortgage liabilities held by U.S. government sponsored entities. The data is from the Flow of Funds Table L128 on home mortgage liabilities. Panel (a) of Figure 4 shows the share over time held by government sponsored agencies (Fannie Mae and Freddie Mac) as mortgage loans, securitizations, and in agency- and GSE-backed mortgage pools. The share averages 50 percent pre-crisis and 60 percent post-crisis. Growth in the government share of residential mortgages outstanding stems from restructuring of GSEs under the Housing and Economic Recovery Act (HERA) in September 2008 and subsequent relaxation of qualifying criteria for conforming loans.[41] To reflect the growth in government subsidization of mortgages through direct ownership and securitization (and capture the growth in nonbank lending resulting from government actions) over the two periods, M^G, is set at \$105,000 pre-crisis and then \$148,000 post-crisis, assuming average loan size of around \$200,000 pre-crisis and considering the average size of mortgages in 2017 was about \$247,000 according to National Statistics for New Fixed-Rate Fully Amortizing Residential Mortgages in the U.S. from the Federal Housing Finance Agency (FHFA) National Mortgage Database (NMDB®).

The amount of other loans, L, is based on asset shares in the bank's balance sheet. L is meant to represent other assets not captured by mortgages, M^B, and cash, F, in the model. Empirically, other assets are comprised of total assets less loans backed by real estate and cash. Panel (b) of Figure 4 presents the composition of banks' assets by category, as a share of total assets, excluding Fed funds purchased and repurchase agreements. The teal line, cash and due from depository institutions, grows quickly beginning from the first quarter of 2009. Loans backed by real estate rise over the early-2000s and then gradually decline

[41] HERA permitted Fannie and Freddie to purchase higher balance loans, raising conforming loan limit values up to \$417,000 or 125% LTV beginning on January 1, 2009 (Congressional Budget Office). In 2014 and 2015, Fannie Mae and Freddie Mac began accepting mortgages with only 3% downpayment, and eliminated many borrower income and geographic constraints, which made it easier to issue conforming loans (Shoemaker, 2019). By making government guarantee of GSE obligations explicit, HERA increased investor demand for agency- and GSE-backed mortgages. These government reforms are linked to growth in nonbank activity in the conventional mortgage market. Nonbanks typically follow an originate-to-distribute model, so stand to benefit from improvements in secondary market liquidity (Gete and Reher, 2021). Additionally, expansion of loan eligibility for GSE guarantees and purchases arguably allowed nonbanks in the post-crisis period to operate with looser underwriting standards than depository institutions and expand market share (Shoemaker, 2019).

Figure 4: Bank Lending Liabilities, Interest Rates, and Returns



Source: Panel (a) displays mortgage assets held by each entity, divided by total home mortgage liabilities of households and nonprofit organizations from the Flow of Funds. Panel (b) data come from FDIC QBP. The series are divided by total bank assets less Fed funds liabilities. In panels (c) and (d), interest rates on cash and loans backed by real estate for bank holding companies come from FDIC QBP, FRED, 10-Ks and earnings reports. Data on the interest rate on cash for banks other than Citi, BNYM, and JPM begin in 2010 and may overlap. In panel (e), yields come from FDIC QBP, FRED, and author calculations. Panels (a), (b), and (e) begin in 1996, while panels (c) and (d) start in 2000. All panels end in 2023.

starting in 2006. The share of other assets, shown in red, is comparably more stable around 55 to 60 percent of total assets. To mimic the evolution of other assets, we choose L to constitute 57 percent of total assets pre-crisis and 59 percent of total assets post-crisis (total assets are $F + M^B + L$). The resulting inputs are \$152,000 pre-crisis and \$190,000 post-crisis.

We derive the interest rate on other loans, r^L, using a weighted average calculation. Given the cash to total assets ratio, loans backed by real estate as a share of total assets, and average yield on earning assets from the FDIC QBP, we can extract the interest rate on other loans by making two assumptions. The first assumption is that the average interest rate banks earn on loans backed by real estate is the 30-year fixed rate mortgage rate. The second assumption is that banks, on average, receive the Fed funds rate on cash. Panels (c) and (d) of Figure 4 display interest rates on cash and loans backed by real estate, collected from 10-K's and earnings reports of the largest U.S. bank holding companies (BHCs), whose bank subsidiaries constitute roughly half the banking sector's assets.[42] The black lines in Panels (c) and (d) are the Fed funds rate and 30-year fixed rate mortgage rate, respectively. In both graphs, individual BHC colored lines straddle the black line fairly consistently, suggesting our assumptions about average returns on cash and loans backed by real estate are reasonable. We obtain interest rate on other loans by solving for r^L in this equation:

$$\begin{aligned} \text{average yield on earning assets} &= \left(\frac{\text{cash}}{\text{total assets}}\right) * r^{\text{Fed funds}} + \left(\frac{\text{other loans}}{\text{total assets}}\right) * r^L \\ &+ \left(\frac{\text{loans backed by real estate}}{\text{total assets}}\right) * r^{\text{30 year fixed-rate mortgage}} \end{aligned} \tag{21}$$

Time series for r^L, and other interest rate components of the weighted average equation are plotted in panel (e) of Figure 4. The average for r^L is 0.066 pre-crisis and 0.043 post-crisis.

To implement the calibration, we first solve for parameters of the model that match data moments for the post-crisis period, 2009 to 2016. In addition to the full set of choice variables for the household and bank, market clearing prices and interest rates, we also solve for regulatory factors. Regulatory parameters include perceived costs of the capital requirement, λ, the cost of the liquidity requirement, α, and the outflow rate of deposits during a stress scenario, δ. After we obtain the solution for the post-crisis period, we then solve for model parameters in the pre-crisis period. Assuming perceived costs of noncompliance with liquidity

[42] BHCs operate in many sectors outside of traditional banking, but their bank subsidiaries tend to be the largest sources of interest rate revenue. BHC data serve as a close approximation for bank interest rates.

Table 2: Model Calibration Results

Pre-crisis 2000-2007				Post-crisis 2009-2016			
Parameter		Key Ratios		Parameter		Key Ratios	
γ	0.67	LCR	0.83	γ	1.00	LCR	1.11
φ	0.04	Tier 1	0.10	φ	0.06	Tier 1	0.13
ψ	0.34	P	109	ψ	0.33	P	121
ρ	0.18	r^s	0.02	ρ	0.30	r^s	0.00
		leverage	9.74			leverage	8.63
F	13,144	cash	0.05	F	33,586	cash	0.10
M^B	101,478	mortgage	0.38	M^B	99,140	mortgage	0.31
S	239,240	deposit	0.90	S	285,316	deposit	0.88
C	65,505			C	64,314		
M^H	206,478			M^H	247,140		
$P \cdot H$	258,097			$P \cdot H$	308,925		

rules is the same in both periods, we use α for the post-crisis period, 0.705, as the value for α in the pre-crisis period to solve for the required liquidity coverage ratio, γ.

4.3 Calibration Results

Table 2 summarizes the model parameters obtained from the calibration exercise. Comparing the values for the pre-crisis, on the left-hand side, with values for the post-crisis period, on the right-hand side, we can describe bank behavior that is consistent with the empirical targets. Regulatory changes, macroeconomic movements in prices, and associated adjustments in bank or household balance sheets will be discussed in turn.

The first two rows of Table 2 reflect the implementation of the LCR and the increase in Tier 1 RWA ratios after the crisis. The minimum required LCR ratio, γ, increases from 67 to 100 percent and the stipulated minimum Tier 1 RWA ratio, φ, rises from 4 percent to 6 percent of risk-weighted assets. The bank's actual LCR rises from 83 percent to 111 percent and Tier 1 RWA ratios move from 10 to 13 percent.

To conform to new capital and liquidity requirements, the book leverage of the bank falls sharply from 9.74 to 8.63 times equity (see row one in the lower panel). The bank doubles the share of assets allocated to cash and decreases the share of mortgages by roughly seven percent of total assets (see rows two and three in the lower panel). Additionally, the bank slightly shrinks deposit funding from 90 to 88 percent of total assets. Because the growth in assets is heavily weighted towards cash, F, the bank is able to expand total assets and deposits, S, even while meeting more stringent regulatory ratios.

Turning to macroeconomic factors, house prices, P, rose in the post-crisis period while interest rates on savings, r^s, fell precipitously (see rows three and four in the top panel). Two elements in the model are relevant for the housing price. The first is the value of additional borrowing capacity, η_2, which depends on the difference between the value of borrowed funds today and the household discounted marginal loss in utility tomorrow $(1-\beta_h(1+r^m))$. The second is preference shocks to demand for housing, ψ. From pre- to post-crisis, value of additional borrowing capacity , $(1-\beta_h(1+r^m))$, rises from around 0.003 to 0.024 (see the last row of the third and fourth columns in Table C.1 for more details). Because the value households gain from borrowing a dollar today grows larger compared to the current value of the dollar they pay back tomorrow, households demand more housing. The post-crisis increase in house demand due to changes in relative borrowing costs account for a large portion of the rise in P. As a result, ψ, remains fairly stable across pre and post-crisis periods. Matching the decline in interest rates, r^s, to zero, the utility weight of deposits, ρ, grows by 65 percent as households need to derive greater value from cash holdings in order to supply more deposits to banks despite receiving no return on savings. Consumption, C, falls as households accumulate savings and houses (see row four in the lower panel).

Combining the changes in the household portfolio with those of the bank, we can characterize the housing market. With the interest rate paid on deposits, r^s, at roughly zero, the bank enjoys a significant reduction in the cost of funds in the later period. With lower cost of funds, the bank still extends a large amount of mortgages, M^B, and coupled with stronger household demand for houses, enables households to borrow more against the value of the house (see M^H, total household demand for mortgages, and the value of the house, $P \cdot H$, in the last two rows of Table 2). Thus, even though the bank reduces its exposure to mortgages relative to other assets in response to regulatory rules, the lower interest rate environment and stronger housing demand allows households to increase their mortgage borrowing.

A more detailed discussion of all the model parameters can be found in the Appendix, as well as the full results. There are two potential concerns related to the rise in household savings and larger share of reserves in banks' total assets post-crisis. Given the negative shock from the financial crisis, the buildup of savings by both households and banks could be largely a byproduct of precautionary savings during the onset of the Great Recession from 2007 to 2009. For bank reserves, the post-crisis results could be heavily influenced by the policy change on October 1, 2008, when the Federal Reserve began paying interest on required and excess reserves. Using the Fed funds rate as the return on reserves for the analysis across sub-periods could understate the size of changes in bank's remuneration on reserves and incentives to hold reserves. The general results discussed here are robust to excluding crisis years from the data and removing required reserves from the definition of cash. Calibration results taking into account these considerations are also in the Appendix.

4.4 Counterfactuals

To gauge the relative importance of regulatory changes, interest rate movements, and shifts in household preferences, we perform counterfactual exercises to elucidate the mechanisms behind changes in bank balance sheets since 2009.

Our analysis starts with the model solution for the pre-crisis period. Using parameter values obtained in the calibration for the pre-crisis period, we solve the model for household and bank choice variables (consumption, savings, mortgages, reserves), taxes, per unit price of housing, and interest rates (for deposits and mortgages). From the solution, we calculate key balance sheet ratios, such as the bank's LCR, capital ratio, leverage, deposits as a share of total assets, cash ratio, reserves to deposits, and the share of mortgages in total assets. We do the same using post-crisis parameter values and obtain a benchmark for comparison. Then, we test four counterfactual scenarios. First, we consider what happens when all post-crisis changes occur except for the interest rate decline. Second, we look at how the post-crisis solution changes if we remove increases in household demand for deposits and houses. Third, we exclude the regulatory changes to stipulated capital ratios and the LCR in the post-crisis period. Lastly, we remove the expansion of government subsidies for mortgages.

Table 3 presents the results of the counterfactual experiments. In the first two columns are the benchmark model solutions for the pre- and post-crisis period, which we refer to as "actuals". In the next four columns are the solutions for each of the counterfactual exercises.

For the first scenario, we hold the interest rate on reserves constant at its pre-crisis level while setting all other parameters to their post-crisis values. Comparing the post-crisis values in

Table 3: Results of Counterfactual Exercises

	Actuals		Post-Crisis Counterfactuals			
	Pre-crisis 2000-2007	Post-crisis 2009-2016	No interest rate decline	No HH pref. change	No reg. ratio hikes	No gov. supply rise
LCR ratio	0.830	1.105	1.459	1.095	0.780	1.096
Capital Ratio	0.105	0.127	0.126	0.154	0.105	0.129
Equity/Total Assets	0.103	0.116	0.110	0.141	0.100	0.118
Leverage	9.737	8.627	9.101	7.099	9.973	8.465
S/(F+M+L)	0.897	0.884	0.890	0.859	0.900	0.882
F/(F+M+L)	0.049	0.104	0.147	0.095	0.068	0.103
F/S	0.055	0.118	0.165	0.111	0.076	0.117
M/(F+M+L)	0.381	0.307	0.294	0.226	0.335	0.366
% L/(F+M+L)	0.570	0.589	0.559	0.678	0.597	0.531
r^s	0.019	0.002	0.006	0.020	0.002	0.007
r^m	0.067	0.044	0.043	0.062	0.042	0.049
C	65,505	64,314	64,027	64,221	64,429	65,181
S	239,240	285,316	302,423	240,645	286,124	315,561
M^B	101,478	99,140	99,870	63,399	106,383	130,931
F	13,144	33,586	49,886	26,704	21,629	36,900
T	703	397	1,997	413	374	308
D	4,750	3,506	3,519	574	3,489	3,043
P	109	121	122	104	125	116

Note:"LCR" stands for liquidity coverage ratio, "RWA" for risk-weighted asset, and "TA" for total assets.

column two of Table 3 with the values in the third column, the model still replicates many of the post-crisis changes. In particular, the model is able to match the interest rate on mortgages, r^m, and reproduce elevated regulatory ratios and reserves. The LCR of 1.459 overshoots the actual of 1.105, but the capital ratio is very close to 0.127. Ratios of reserves to total assets, F/(F+M^B+L), and reserves to deposits, F/S, are quite high, in the range of 0.14 while actual post-crisis ratios are closer to 0.10. However, without the change in interest rates, the share of mortgages in total assets, M^B/(F+M^B+L), declines a bit too much while growing deposits (S) keep leverage high. The exercise suggests that a sharp drop in interest rates is necessary to induce the bank to shift assets shares away from reserves towards mortgages to reduce reserve ratios and increase the risk profile of its balance sheet.

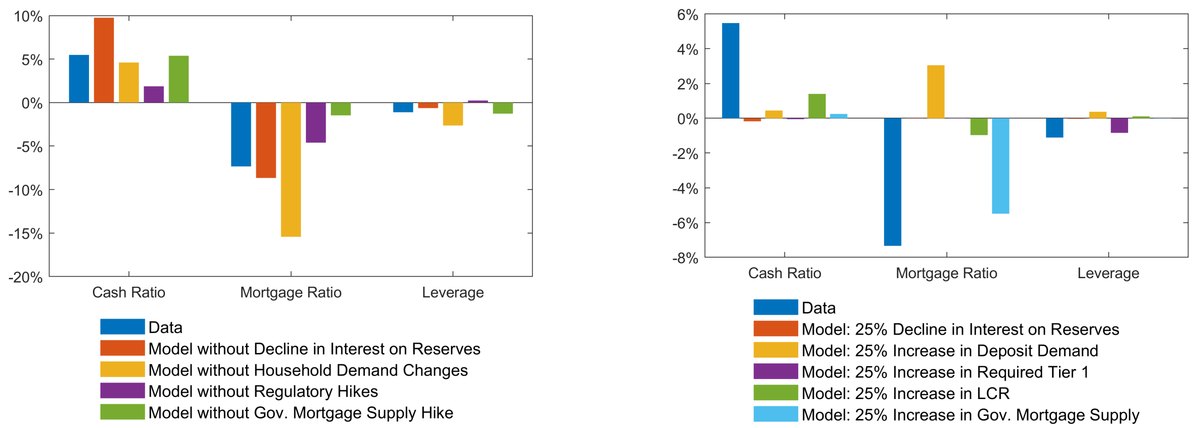
For the second scenario, we keep parameters for housing preference shock, ψ, and weight of deposits in household utility, ρ, at pre-crisis values (see column four of Table C.2 for details) so that regulatory and interest rate changes occur without changes in household demand for deposits and houses. As the fourth column of Table 3 highlights, the combination of interest rate declines and increased regulation can achieve levels of LCR, capital, equity, savings to total assets, and reserves ratios that move in the same direction as actuals. However, capital ratios are too high and the decline in leverage and mortgage share, M^B/(F+M^B+L), is too steep and r^m does not fall enough. There is muted growth in deposits, S, so deposit interest rates, r^s, remain elevated. The second counterfactual points to a need for greater household demand for deposits (since ψ barely changes) to expand the bank balance sheet and counteract the contraction of mortgage share in total assets due to stricter regulation.

The third scenario examines how the balance sheet evolves when interest rates fall and household demand increases, but there are no hikes in required regulatory ratios. We estimate the model using all post-crisis parameter values excluding those corresponding to the LCR, γ, and the Tier 1 RWA ratio, φ, which we keep at pre-crisis values of 0.674 and 0.04 respectively (colored in blue in column five of Table C.2). Comparing the fifth column in Table 3 with the second column, regulatory ratios are too low and leverage is too high. Two key balance sheet components also move in the wrong direction. Mortgages, M^B, and deposits to total assets, S/(F+M^B+L), increase relative to the pre-crisis baseline when they should fall. This emphasizes how heightened regulation forces the bank to reduce deposit liabilities, accumulate reserves, and dampen the growth of mortgages on the balance sheet.

In the last scenario, we keep the government supply of mortgages, M^G, constant to simulate what bank balance sheets would look like without greater government involvement in the mortgage market post-crisis. Almost all balance sheet ratios obtained without the increased government mortgage supply (in the last column of Table 3) are within a hundredth of a decimal point of the actuals (in column two). Only leverage and the share of mortgages in total assets are noticeably different. Without greater government involvement, interest rates on mortgages, r^m, do not decrease as sharply compared to pre-crisis levels, so the bank has greater incentive to hold mortgages relative to other assets. Indeed, the level of mortgages, M^B, obtained in the counterfactual, is 130,931, rising from pre-crisis levels of 101,478 rather than declining to below 100,000 as in actuals. To fund the mortgages, there is accompanying growth in deposits, S. The bank's greater demand for deposits drives interest rates on deposits, r^s, up relative to the actual post-crisis rate. Thus, expanded government presence in mortgage markets functions primarily to drive down mortgage rates and reduce the share of bank total assets allocated to mortgages.

Figure 5: Comparing Results of Key Ratios

(a) Counterfactuals (b) Comparative Statics



Note: Bars show percentage point changes for each key ratio. Author calculations.

Figure 5 summarizes the changes in key balance sheet ratios from pre- to post-crisis periods. In panel (a), the results are obtained through the counterfactual exercises. For comparison, actual changes in the data are shown in blue. Orange bars represents results from the counterfactual where interest rates are held constant, yellow are outcomes without household demand changes, purple bars are the model without regulatory ratio hikes, and green bars are results without the government mortgage supply increase. The first set of bars in panel (a) illustrate that even in the absence of stricter banking regulation, cash ratios rise in the post-crisis period with changes in interest rates and household demand factors (the purple bar). Comparing outcomes in mortgages to total assets ratios across counterfactual scenarios (second set of bars in panel (a)), the importance of heightened regulation or government supply in dampening growth of mortgage shares and countervailing forces of interest rates and household demand is evident. The last set of results in panel (a) emphasizes the role of regulatory hikes in reducing bank leverage.

5 Comparative Statics

A comparative statics exercise provides further insights about the importance of different factors for the bank's equilibrium choice of reserves, F, deposits, S, and mortgages, M. The exercise illustrates how regulatory ratios and leverage change with the bank's balance sheet composition. We consider the major changes that occurred over the period before and after the financial crisis highlighted by the counterfactual exercise: a rise in capital requirements,

Table 4: Balance Sheet Responses to Regulatory and Macroeconomic Forces

Parameter	Description	Leverage ratio	Cash ratio	Capital ratio	LCR	Mortgage share
φ	Required capital ratio increase	fall	fall	rise	rise	fall
λ	Costs of capital shortfall increase	fall	fall	rise	rise	fall
γ	Required LCR increase	rise	rise	rise	rise	fall
α	Costs of LCR shortfall increase	rise	rise	rise	rise	fall
r^f	Interest rate on reserves decrease	fall	fall	rise	fall	fall
$\rho \leq 0.285$	Deposit demand increase	rise	rise	fall	rise	rise
$\rho > 0.285$	Deposit demand increase	rise	rise	rise	rise	fall

implementation of the liquidity coverage ratio, a drop in interest rates, and increased demand for deposits. To understand how each change influences the bank's behavior, we separately vary parameters associated with regulatory costs, interest rates, and household preferences to see how the bank's balance sheet differs from the pre-crisis calibration of the model.

5.1 Results

The comparative statics exercise confirms the general channels outlined by the counterfactual scenarios and also reveals nuances in the effects of the forces considered in the model. First, increases in all regulatory parameters (φ, λ, γ, α) induce build up of capital and reduction in mortgage shares (see the first four rows of Table 4). However, the effect on the cash ratio and leverage is not as uniform. Tightening required Tier 1 RWA ratios (φ) triggers deleveraging but also reductions in the share of cash in total assets, as the bank raises equity by shrinking the entire balance sheet. On the other hand, as rows three and four illustrate, raising liquidity requirements (through γ or α) leads the bank to bolster cash ratios, which are funded by expanding deposit liabilities. The amount of mortgages is falling at the same time that cash is growing, and on net, total assets grow slightly slower than total liabilities, so leverage rises. Essentially, capital requirements encourage banks to replace deposit funding with equity, while the LCR rule instills a preference for holding cash assets over mortgages but does not inhibit the bank's ability to leverage.

Second, reductions in the interest rate on reserves, r^f, are linked to lower cash ratios and a smaller share of mortgages in total assets (see row five of Table 4). With lower interest rates on reserves, the bank reduces the share of assets held in reserves, lowering its capacity to accumulate deposits and risk-weighted assets. Leverage falls, the LCR buffer shrinks, and the fall in deposit funding slightly outpaces the shrinkage of assets. Compared to regulatory forces, however, the impact of interest rates on the balance sheet is relatively small.

Third, the evolution of mortgage shares in total assets and capital ratios due to a change in household demand for deposits, unlike cases discussed so far, is not monotonic. For values of ρ less than or equal to 0.285, greater demand for deposits is associated with a falling capital ratio and a rise in the share of mortgages in total assets (see row six of Table 4). Further increases in ρ beyond 0.285 yield a rising capital ratio and falling mortgage share (relative to levels seen when ρ equals 0.285). From Table 2, ρ grows from around 0.18 pre-crisis to 0.30 post-crisis, so greater demand for deposits pushes the bank to increase both mortgage assets and deposit funding.[43]

Lastly, by varying parameter values equally in percentage terms, we highlight the relative magnitudes of effects on key balance sheet ratios. In panel (b) of Figure 5, comparative statics communicate the results of reducing interest rates on reserves, increasing deposits demand, raising required Tier 1 RWA, LCR, and government mortgage supply from pre-crisis values by 25 percent in turn. General effects of the parameters mirror those discussed above, but the graphs indicate a striking implication of the model. The effect of greater deposit demand on the cash ratio is noticeably stronger than changes derived from other parameters, only second to regulation (see first panel). Additionally, deposit demand is the strongest force counteracting the fall in mortgage shares due to greater government supply and stricter LCR requirements. Further analysis of the deposit demand parameter, ρ, in the Appendix, suggests that interaction between deposit demand by households and the bank's desire to maintain a capital buffer is crucial in determining key balance sheet ratios. Thus, we conduct an empirical analysis of household demand for deposits in the next section.

6 Deposit Demand

The model suggests greater deposit demand by households is a key element facilitating the rise in cash on bank balance sheets. Additionally, a bank's desire to maintain a capital buffer determines its reaction to stronger deposit demand. More demand for deposits reduces the cost of funds, so the bank expands the share of mortgages in its total assets to capitalize on higher returns and the capital buffer begins to erode. If the capital buffer drops too much, potential regulatory costs skyrocket, forcing the bank to cut mortgages and accumulate

[43] A detailed discussion of the effects of ρ on mortgage and deposits shares is presented in the Appendix.

relatively more cash. To test the mechanism outlined by the model, we first document the rise in deposit demand, then provide evidence for a positive relationship between deposits and cash ratios, and illustrate how household demand interacts with capital regulation to shape banks' balance sheets. A caveat of the analysis in this section is that empirical tests are conducted at the BHC level, rather than at the banking sector level addressed by the model. In the discussion that follows, we assume relationships between deposits, cash ratios, and capital ratios that hold for the aggregate banking sector also hold at the BHC level.

6.1 A Shift in Demand for Deposits

One implication of the calibration results is that households have an increased appetite for deposits in the period following the financial crisis. Anecdotal evidence suggests greater household demand for deposits may stem from precautionary savings motives due to reduced access to credit post-crisis. Historical trends outlined in the 2016 Survey of Consumer Finance (SCF) roughly support such a story. Survey results summarized in the top panel of Table 5 point to a general reduction in real values of mortgage loans, home equity lines of credit, credit card balances, and other residential debt of households from pre- to post-2009. The financial press likewise paints a picture of banks limiting credit to households around the time of the crisis.[44] Research by Gilchrist and Zakrajšek (2012) show that unused loan commitments were cut immediately at the onset of the crisis in 2007 as banks became concerned about credit risk. Consumer credit panel data from the Federal Reserve Bank of New York illustrate shrinkage of credit card and HELOC limits from 2009 through at least 2013 even as credit card balances stayed constant or grew over the same period, corroborating the story described above.[45]

An additional explanation for greater demand for deposits is heightened risk perception by households after the crisis. The SCF reports a rise in the mean value of transactional accounts accompanied with heightened importance placed on liquidity needs by households

[44] A New York Times article published in October 2008 notes how major banks and credit card companies cut inactive accounts, reduced credit limits for consumers across all credit scores, tightened lending standards for cards, and dramatically curtailed marketing of new credit cards upon realizing large consumer loan losses in 2008 and in anticipation of more delinquencies related to the economic downtown (Dash 2008).

[45] Lopez-Salido and Vissing-Jorgensen (2023) highlight that household deposits have been growing since around 2000 and that the growth is concentrated in demand and other liquid deposits rather than time deposits, which indicates this increase in deposits may be more related to lockdowns (limiting spending), fiscal stimulus, and increased risk aversion due to COVID-19 than to banks enticing customers with attractive deposits rates to fund their reserve holdings.

Table 5: Households Shifted toward Deposits for Liquidity after the GFC

	2001	2004	2007	2010	2013	2016	2019	2022
Mean Value of Holdings for Families with Debt (Thousands of 2022 dollars)								
Mortgages	153.1	191.5	213.9	207.3	199.1	196.8	214	215.2
HELOC	43.6	62.5	56.1	74.4	61	61.5	58.1	44.3
Other residential debt	124	261.9	253.7	245.2	198.7	198.1	238.7	242.5
Lines of credit not secured by real estate	30.2	57.5	35.5	67.1	44.8	68.7	46.8	126.7
Credit card balances	6.9	8.1	10.5	9.7	7.3	7	7.3	6.1
Education loans	22.9	26.2	30.7	35	36.8	42.2	46.8	46.6
Vehicle loans	18.8	21.2	20.9	19.4	18.5	21.2	20.4	21.2
Other installment loans	18.1	29.4	21.1	20.3	20.3	19	23.9	10.3
Other	29.6	26.8	22.1	22.9	18.6	33.1	28.6	45.7
Mean Value of Holdings for Families with Assets (Thousands of 2022 dollars)								
Transaction accounts	39.7	42.7	37.8	44.3	46.2	49.6	48.3	62.5
Certificates of deposit	62.7	86.2	79.6	99.2	82.1	93.3	118.2	99.2
Bonds	487.6	859.5	821.8	840	740.4	950.9	757.6	961.2
Stocks	321.9	251.9	316	286.4	374.6	404.3	404	403.9
Pooled investment funds	218.9	289.1	443.1	530.7	589.2	957	990.3	960.9
Retirement accounts	175.3	193.4	210.9	233.8	256.2	282.4	295.8	334
Reasons Respondents Gave as Most Important for Their Families' Saving								
Education	10.9	11.6	8.4	8.2	8.6	7.2	5.5	2.9
For the family	5.1	4.7	5.5	5.7	6.3	6.9	6.1	5.7
Buying own home	4.2	5	4.2	3.2	3.1	4.1	5.1	4.8
Purchases	9.5	7.7	10	11.5	9.1	12.1	11.2	10.7
Retirement	32.1	34.7	34	30.1	30.5	30.3	28.4	26.6
Liquidity	31.2	30	32	35.2	35.8	36.2	38.1	43.4
Investments	1	1.5	1.6	1.2	1.4	1.8	1.8	1.4
No particular reason	1.1	0.7	1.1	1.4	1.2	0.6	0.8	1.5
Reported do not save	4.9	4	3.3	3.5	4.1	0.8	3	2.9

Note: Pooled investment funds exclude money market funds. **Source:** Federal Reserve Board Survey of Consumer Finances, Table "Alternate 13. Family holdings of debt, by selected characteristics of families and type of debt, 1989-2022 surveys", Table "6. Family holdings of financial assets, by selected characteristics of families and type of asset, 1989-2022 surveys", and Table "3. Reasons respondents gave as most important for their families' saving, distributed by type of reason, 1989–2022 surveys" from historical real tables based on internal data.

after 2009 (see middle and bottom panel of Table 5).[46] Bayer et al. (2019) document that demand for liquidity increases when uncertainty increases. Households faced greater income risk following the Great Recession, fueling a flight to liquidity.

In reduced form, ρ incorporates the effects of both the credit access and risk perception

[46]Transactional accounts include savings, checking, and money market deposit accounts, money market funds, and call or cash accounts at brokerages and prepaid debit cards.

channels discussed above. From a modeling perspective, the rise in ρ captures an exogenous shift in household's demand for deposits that is unaccounted by interest rate movements, house price fluctuations, or mortgage market developments considered in the model. A conventional money demand framework quantifies the shift in household demand for deposits.

Money demand models propose a long run relationship between real money balances, income, and interest rates. A typical money demand equation is described by:

$$(m-p)_t = \delta_0 + \delta_1 y_t + \delta_2 w_t + \delta_3 R_t + \delta_4 r_t + \delta_5 own_t + \delta_6 \pi_t \tag{22}$$

where $(m-p)_t$ is log real money balances, y_t is log real income, w_t is log real wealth, R_t is a nominal long term interest rate, r_t is a nominal short term interest rate, own_t is the return on money balances, and π_t is the nominal annualized inflation rate (see Dreger and Wolters (2015) for a discussion of the standard model and variants). Higher real income, y, is associated with higher real money balances, while higher returns on alternative assets, R or r, tend to reduce money demand.

Drawing on Nagel (2016), we modify Equation 22 to instead consider the relative return differentials between similarly liquid assets over deposits given close substitutability between Treasuries and deposits. Additionally, because houses are an alternative form of savings for households in the model, we use house value as a measure of wealth rather than a broader measure of financial wealth. The basic deposit demand relationship we want to estimate is

$$(m-p)_t = \delta_0 + \delta_1 y_t + \delta_2 \text{ real house wealth}_t + \delta_3 (R_t - own_t) + \delta_4 (r_t - own_t) + \delta_5 \pi_t \tag{23}$$

where $(m-p)_t$ is log real deposits.

6.1.1 Data

Because the demand for deposits is affected by income and wealth, variation along these two dimensions should be accounted for when estimating the long term relationship outlined by Equation 23. In the absence of individual level data that allows me to control for individual-specific characteristics, we use county level data and assume that household wealth and income differs primarily based on the county of residence.

Deposit data comes from the FDIC Summary of Deposits (SOD), which contains information on U.S. branch level deposits for all FDIC institutions at an annual frequency from 1998 to 2016. Data are aggregated to the county level by adding together deposits for each bank in a given county. Table 6 provides a comparison of coverage between the SOD used here and the FDIC QBP used in the calibration of the model. All 960 non-domestic branches are dropped. The resulting level of SOD deposits in the panel regression contains information on roughly 80 percent of all deposits at FDIC-insured institutions.[47]

Measures of income and house wealth are from the BEA and Zillow. Log real income, y_{it}, is the natural log of county level nominal gross domestic product (GDP) less the natural log of the GDP deflator calculated from the BEA's county and metropolitan area statistical tables, which begin from 2001. Real house wealth, w_{it}, is the natural log of median home value in a county measured by Zillow's home value index for all homes less the natural log of the GDP deflator. Interest rate data is from RateWatch and FRED. For each year, own_{it} is the average interest rate paid on deposits in county i, with all branches taking equal weight in the calculation. Ratewatch county-level interest rate data are from 1998 to 2015. The long term interest rate, R_t, is the Treasury 10-year constant maturity yield and the short term interest rate, r_t, is the effective Fed funds rate downloaded from FRED. Inflation, π_{it}, is measured by the growth rate of the county-level GDP deflator from the BEA's county and metropolitan area statistical tables.

Table 7 summarizes the variables used in the analysis. The resulting panel contains 37,263 total county-quarter observations for deposits. Raw SOD data at the branch level from 1998 to 2015 contains roughly 1.6 million observations. Merging in RateWatch data, which is missing interest rates for a number of counties across all years, reduces the number of observations by 96,181 and total deposits of 3,920 billion. On average, deposits are reduced by around 215 billion each year relative to the original SOD data. After merging in Zillow home values and BEA county level statistics, we aggregate the branch level data to the county level and arrive at a total of 44,794 observations. Since Arellano-Bond requires at least three years of data, we drop counties with less than three years of data for the full set of deposits, real income, house wealth, inflation, and interest differential variables. This

[47]The main reason for this difference is because total deposits taken from FDIC QBP includes foreign (non-US) office deposits, while SOD considers domestic (US) office deposits, including insured U.S. branches of foreign banks. Additionally, during the cleaning process, counties for which there was no RateWatch data were dropped and counties with less than 3 years of data for RHS variables in equation (15) were removed (see discussion in the last paragraph). For comparison, in 2015, total deposits in the raw SOD data is 10,629 billion, which is fairly close to FDIC QBP second quarter domestic office deposits of 10,589 billion.

Table 6: Deposits Coverage in Summary of Deposits (SOD) versus Quarterly Banking Profiles (QBP)

	Total deposits		Panel coverage
	SOD	QBP	(% of QBP total)
2000	3,670	4,690	78
2001	4,031	5,020	80
2002	4,296	5,254	82
2003	4,796	5,850	82
2004	5,118	6,290	81
2005	5,561	6,821	82
2006	6,069	7,505	81
2007	6,314	8,036	79
2008	6,625	8,573	77
2009	7,163	9,021	79
2010	7,316	9,141	80
2011	7,861	9,766	80
2012	8,531	10,323	83
2013	9,042	10,781	84
2014	9,700	11,490	84
2015	10,191	11,932	85

Note: Total deposits are in billions of U.S. dollars.
Source: FDIC.

Table 7: Summary Statistics for Full Sample Used in Arellano-Bond Estimation

	Type	Mean	Std. Dev.	Min	Max	N
Deposits	$	3,033	17,120	16.183	919,943	37,263
GDP	$	6,426	23,629	3.060	689,496	31,253
Real GDP	$	6,914	24,990	40.065	653,885	31,253
ln(Real deposits)	$	8.95	1.37	5.10	15.94	31,253
ln(Real income)	$	14.33	1.48	10.60	20.30	31,253
ln(Real house wealth)	$	7.16	0.52	5.33	9.23	25,707
Inflation	%	2.30	3.70	-54.76	52.02	29,190
Fed Funds – Return on deposits	%	0.09	0.78	-3.34	4.09	37,263
10-year Treasury – Return on deposits	%	1.75	0.77	-0.83	3.92	37,263
Return on deposits	%	2.14	1.69	0.00	6.59	37,263

Note: Counties with extreme levels of inflation include counties like those in Texas (De Witt, Dimmit, Karnes, Martin, Reagan) and Doddridge, WV for 2015 and Brooks, TX for 2003, which are fairly small counties with large contributions from oil and gas extraction to GDP. Deposits, GDP, and real GDP are expressed in millions of U.S. dollars. Inflation, Fed funds, 10-year Treasury, and Return on deposits are expressed as a percentage.
Sources: FDIC SOD, BEA, Zillow, RateWatch, and FRED.

reduces the total observations by 7,531 and an average of roughly 150 billion deposits per year, for a total reduction in deposits of 2,779 billion.

6.1.2 Empirical Approach

The deposit demand relationship to estimate at the county level is

$$\begin{aligned}(m-p)_{it} =& \delta_0 D_{\text{post-2008}} + \delta_1 (m-p)_{it-1} + \delta_2 y_{it} + \delta_3 w_{it} \\ &+ \delta_4 (R_t - own_{it}) + \delta_5 (r_t - own_{it}) + \delta_6 \pi_{it} + \eta_i + \nu_{it}\end{aligned} \tag{24}$$

A lag of real deposits, $(m-p)_{t-1}$, captures persistence in the time series. $D_{\text{post-2008}}$ is a dummy variable equal to 1 for post-crisis years and 0 otherwise. The coefficient $\hat{\delta}_0$ should be positive if there is an exogenous shift in deposit demand post-crisis, given the long term relationship between deposits, interest rates, income, and housing wealth.

Because we have a short panel with a maximum time period of 15 years, the county-level fixed effect is imprecisely measured using OLS. If a fixed effects model is used, the disturbance term $\eta_i + \nu_{it}$ will be correlated with the lagged value of real deposit demand, $(m-p)_{it-1}$, leading to biased estimates of the county fixed effect. The Arellano and Bond (1991) approach estimates Equation 24 in first differences using GMM and instruments for terms that may be correlated with the disturbances:

$$\begin{aligned}\Delta(m-p)_{it} =& \alpha_0 + \alpha_1 \Delta(m-p)_{it-1} + \alpha_2 \Delta y_{it} + \alpha_3 \Delta w_{it} \\ &+ \alpha_4 \Delta(R_t - own_{it}) + \alpha_5 \Delta(r_t - own_{it}) + \alpha_6 \Delta\pi_{it} + \Delta\nu_{it}\end{aligned} \tag{25}$$

6.1.3 Results

To establish reasonable bounds for the coefficient estimates of the model, we first run OLS and a fixed effects estimation of Equation 25, with a time trend, year fixed effects, and robust standard errors clustered by county.[48] Generally, the OLS estimate of $(m-p)_{it-1}$ is likely to be biased upwards, while the fixed effects estimate tends to be biased downward, so from Table 8, we have an upper bound of 0.96 and a lower bound of 0.73 for $(m-p)_{it-1}$ to compare Arellano Bond estimates against. Of note, the coefficient on the post-2008 dummy is around 0.03 (see second row) and is significant even in the presence of a time trend (*year* in the last row). These estimates suggest there is a shift in demand for deposits post-2008

[48] One lag of each RHS variable is included as control variables.

Table 8: Naïve OLS and Fixed-Effects Regressions

	Dependent Variable: $(m-p)$	
	OLS	FE
$(m-p)_{t-1}$	0.96028***	0.73319***
	(0.041)	(0.044)
$D_{post-2008}$	0.02888***	0.03336***
	(0.004)	(0.004)
y	0.13146***	0.11564***
	(0.016)	(0.015)
y_{t-1}	-0.11420***	-0.00456
	(0.016)	(0.011)
w	0.23463***	0.21312***
	(0.014)	(0.015)
w_{t-1}	-0.22505***	-0.12524***
	(0.013)	(0.016)
Fed funds	-0.00736***	-0.00459***
	(0.001)	(0.001)
Fed funds$_{t-1}$	0.00819***	0.00349*
	(0.002)	(0.002)
10-year Treasury	-0.01379***	-0.01159***
	(0.001)	(0.001)
10-year Treasury$_{t-1}$	0.00139	0.00087
	(0.001)	(0.001)
Inflation	-0.00783***	-0.00734***
	(0.000)	(0.000)
	(0.000)	(0.000)
Year	-0.00577***	-0.00395***
	(0.000)	(0.000)
N	22,074	22,074

Note: Regressions are performed on county level data from 2000 to 2015. Coefficients are listed in the table and standard errors are below in parentheses. Robust standard errors are clustered at the county level (2,209 groups). Statistical significance is denoted as * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$.

Table 9: Arellano-Bond Estimation of Deposit Demand

	Dependent Variable: $(m-p)$ Two-Step, Specific GMM-Instruments for Lagged RHS				
for Fed funds	3+	3-11	3-9	3-7	3-6
for y	4+	4-11	4-9	4-7	4-6
other RHS	2+	2-11	2-9	2-7	2-6
$(m-p)_{t-1}$	0.8283***	0.8215***	0.8099***	0.8153***	0.8454***
	(0.0332)	(0.0347)	(0.0350)	(0.0360)	(0.0349)
$D_{post-2008}$	0.0439***	0.0406***	0.0407***	0.0414***	0.0430***
	(0.0063)	(0.0060)	(0.0063)	(0.0054)	(0.0052)
w	0.2567***	0.2580***	0.2662***	0.2495***	0.2905***
	(0.0358)	(0.0362)	(0.0368)	(0.0350)	(0.0338)
10-year Treasury	-0.0129***	-0.0131***	-0.0131***	-0.0110***	-0.0121***
	(0.0018)	(0.0018)	(0.0019)	(0.0020)	(0.0018)
Inflation	-0.0066***	-0.0065***	-0.0065***	-0.0065***	-0.0062***
	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)
Fed funds	-0.0084***	-0.0089***	-0.0086***	-0.0075***	-0.0070**
	(0.0018)	(0.0021)	(0.0023)	(0.0019)	(0.0024)
y	0.1236***	0.1301**	0.1194**	0.1277***	0.0868
	(0.0345)	(0.0398)	(0.0422)	(0.0286)	(0.0465)
Year	-0.0038***	-0.0037***	-0.0038***	-0.0034***	-0.0028**
	(0.0007)	(0.0008)	(0.0008)	(0.0008)	(0.0009)
Lags of y	3	3	3	3	3
N	18,565	18,565	18,565	18,565	18,565
Instruments	500	454	397	312	259

Note: Regressions are performed on a county level panel from 2000 to 2015. Windmeijer corrected robust standard errors are listed in parentheses. Assumed inflation is exogenous. Statistical significance is denoted as * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$. "RHS" stands for right-hand side variables.

and, in analyses to follow, we will focus on whether this result holds.

The results of the Arellano-Bond estimation are in Table 9. Column 1 is the baseline model estimating equation 25 with an additional one lag of each RHS variable and three lags of log real income, y, to control for autocorrelation. Coefficients are reported for the level variables and subsequent columns contain results for the baseline model with different instruments used in the GMM differenced equation. For the baseline, we assume that inflation is exogenous while all other explanatory variables are endogenous. To estimate coefficients for endogenous RHS variables, the second and later lags of the variable are used as instruments in the differenced equation. As an example, to estimate the coefficient for $\Delta(R_t - own_{it})$ in Equation 25, observations $(R_{t-2^+} - own_{it-2^+})$ serve as instruments. The third lag and later were used for the Fed funds spread because coefficient estimates were more within the bounds of values in Table 8 compared to using second lags and later. Lags four and onward are used as instruments for y in the differenced equation because three lags of y are included in the baseline. As a check, the coefficient estimate for $(m-p)_{it-1}$ of 0.828 in row one column one of Table 9 is between 0.960 (for OLS) and 0.733 (fixed-effects) estimates in Table 8. The coefficient for the post-2008 dummy is around 0.04 (second to last row in Table 9), slightly outside the bounds found in Table 8, but not wildly off.

Due to the proliferation of instruments, it is important to to check the robustness of results to different numbers of instruments used. The total time period for the sample is 15 years, so the maximum lag length is around 13 if we start from the second lag. Moving to the left from column two to column five in Table 9, we reduce the maximum lag length. The number of instruments shrinks from 500 in the baseline to 259 in the last model variant. Movement of coefficient estimates across the columns is fairly minimal, except for the last column, where estimates for y, w, and the time trend ($year$) are noticeably different. However, in all specifications, the coefficient attached to $D_{\text{post-2008}}$ is positive and significant, indicating support for a post-crisis shift in demand for deposits as suggested by the theoretical results in Sections 4 and 5.

6.2 Greater Deposit Demand and Key Bank Ratios

The comparative statics results point to a positive relationship between more demand for deposits from households and higher cash to total asset ratios for banks. To characterize the relationship between deposit demand and bank cash ratios, we look at the relationship between changes in the ratios of deposits and cash to total assets on bank balance sheets. The results here are purely suggestive, as changes in deposit ratios may not be a good proxy for changes in demand for deposits and all variables in the regressions are endogenous.

6.2.1 Data

For the analysis, we use FR Y-9C, Call Report data consolidated at the BHC-level. The quarterly data span from 2000 to 2018, with a total of around 89,000 observations. Cash is total cash and due from depository institutions, Schedule HC, line 1 (the sum of BHCK0081, BHCK0395, and BHCK0397). Deposits correspond to Schedule HC, line 13, the sum of BHDM6636, BHDM6631, BHDM6636, and BHDM6631. Mortgages are loans backed by real estate from Schedule HC-C, line 1 (BHCK1410). The cash, deposits, and mortgage ratios are just their levels divided by total assets from Schedule HC, line 12 (BHCK2170). To calculate capital buffers, we consider banks' Tier 1 risk-weighted assets ratio (RWA). The Tier 1 RWA ratio is from Part 1 of Schedule HC-R, line 26, Tier 1 capital (BHCK8274 prior to 2015 and BHCA8274 from 2015 onward) divided by line 46, risk-weighted assets (BHCKA223 prior to 2015 and BHCAA223 from 2015 onward). Buffers are equal to the Tier 1 RWA ratio less 0.04 for years up through 2009 and the Tier 1 RWA ratio less 0.06 from 2010.

To minimize the influence of outliers, we winsorize the data at the one percent level based on the cross-sectional distribution of capital buffers. Because the analysis is conducted using growth rates, we also confine our analysis to banks with four consecutive quarters of available data. Table F.1 summarizes the resulting sample and variables considered in the regressions.

6.2.2 Empirical Approach and Results

We run the following set of panel regressions to examine the link between cash and deposits:

$$\Delta\text{cash ratio}_{it} = \alpha_i + \beta_1 \Delta\text{deposit ratio}_{it} + \delta QTR_t + \epsilon_{it} \tag{26}$$

$$\Delta\text{cash ratio} = \alpha_i + \beta_1 \Delta\text{deposit ratio} + \beta_2 \boldsymbol{\Delta}\textbf{capital buffer} + \delta QTR_t + \epsilon_{it} \tag{27}$$

$$\begin{aligned}\Delta\text{cash ratio} = {} & \alpha_i + \beta_1 \Delta\text{deposit ratio} + \beta_2 \Delta\text{capital buffer} \\ & + \beta_3 \boldsymbol{\Delta}\textbf{capital buffer} \cdot \boldsymbol{\Delta}\textbf{deposit ratio} + \delta QTR_t + \epsilon_{it}\end{aligned} \tag{28}$$

where variables that are added successively are in bolded font. The baseline, Equation 26 considers the change in the cash ratio related to changes in the deposit ratio at the BHC level, controlling for BHC fixed effects (α_i) and quarter fixed effects (QTR_t). We then add in the change in capital buffers (Equation 27) and interaction term for changes in deposits and buffers (Equation 28) to gauge how capital buffers influence the deposits-cash relationship. Table 10 presents the results of the panel regression with bank and time fixed effects for Equations 26 through 28. The first row highlights that the change in banks' cash ratio and the change in the deposit to total assets ratio exhibit a positive relationship. The positive relationship holds even when controlling for changes in the capital buffer. In the last row, for Equation 28, the interaction term is negative, suggesting larger capital buffers lead to smaller increases in the cash ratio given increases in deposits.

Based on the mechanism outlined by the theoretical model, the size of a bank's capital buffer determines whether the bank responds to greater deposit demand by accumulating

Table 10: The Relationship between Cash and Deposits Ratio

	Dependent Variable: Δcash ratio			
	(18)	(18) robust	(19)	(20)
Δdeposit ratio	0.091***	0.091***	0.097***	0.097***
Δcapital buffer			0.160***	0.160***
Δcapital buffer · Δdeposit ratio				-0.518
N	72,997	72,997	72,929	72,929
Bank FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
R^2	0.042	0.042	0.049	0.049
adjusted R^2	0.012	0.041	0.048	0.048

Note: Panel regressions are performed at the bank holding company level using FR Y-9C quarterly data from 2000 to 2018. Data are winsorized at the one percent level based on the cross-sectional distribution of capital buffers. Statistical significance is denoted as * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$.

cash (and reducing mortgages) or by increasing mortgages (and cutting cash) as a share of total assets. To test the channel, we sort banks into quartile and decile buckets based on the size of their capital buffer and examine how cash ratios and mortgage ratios of the least and most capitalized banks respond to changes in deposit ratios.

Following the setup in Kashyap and Stein (2000), we add four lags of the growth in cash, the contemporaneous capital buffer, and lagged capital buffer to Equation 26. Banks are sorted into quartile and decile buckets based on the cross sectional distribution of capital buffers in the entire sample. The top panel of Table 11 summarizes the results obtained by estimating banks in the first and last quartile or decile buckets separately. Comparing the size of the coefficient for Δdeposit ratio between the left and right columns, there is a positive response of changes in cash ratios for banks in the bottom and top of the capital buffer distribution. The effect on cash ratios is slightly weaker for the last decile bucket compared to the first decile bucket. The left panel of Table 12 elaborates on the difference, with the coefficient on the interaction term of (Δdeposit ratio · quartile or decile rank) indicating a generally weaker response in the growth rate of cash for banks in higher quartiles versus the first quartile (and decile).[49] The regression results are consistent with banks building up less

[49] Sorting banks into quartile and decile buckets based on the cross-sectional distribution of capital buffers each year (instead of based on the entire sample) produces similar regression results.

Table 11: The Cash Ratio, Mortgage Ratio, Deposits Ratio, and the Role of Capital Buffers

	Cash Ratio			
	First Decile (0-10%)	First Quartile (0-25%)	Last Quartile (75-100%)	Last Decile (90-100%)
Δcash ratio$_{t-1}$	-0.386*** (0.031)	-0.386*** (0.023)	-0.361*** (0.024)	-0.412*** (0.030)
Δcash ratio$_{t-2}$	-0.318*** (0.030)	-0.287*** (0.021)	-0.216*** (0.032)	-0.229*** (0.049)
Δcash ratio$_{t-3}$	-0.269*** (0.026)	-0.231*** (0.016)	-0.147*** (0.021)	-0.116*** (0.032)
Δcash ratio$_{t-4}$	0.006 (0.032)	-0.007 (0.019)	0.058** (0.020)	0.064 (0.037)
Δdeposit ratio	0.107*** (0.018)	0.086*** (0.012)	0.099*** (0.015)	0.104*** (0.027)
capital buffer	0.100 (0.066)	0.113** (0.037)	0.268*** (0.035)	-0.276*** (0.049)
capital buffer$_{t-1}$	-0.146** (0.051)	-0.183*** (0.032)	-0.260*** (0.034)	0.104*** (0.027)
N	5,772	14,864	14,867	5,755
Bank FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
R^2	0.24	0.21	0.20	0.25
adj. R^2	0.23	0.20	0.20	0.24
	Mortgage Ratio			
	First Decile (0-10%)	First Quartile (0-25%)	Last Quartile (75-100%)	Last Decile (90-100%)
Δmortgage ratio$_{t-1}$	-0.183*** (0.032)	-0.131*** (0.019)	-0.063*** (0.014)	-0.092*** (0.025)
Δmortgage ratio$_{t-2}$	-0.115*** (0.019)	-0.075*** (0.013)	-0.039** (0.014)	-0.028 (0.018)
Δmortgage ratio$_{t-3}$	-0.123*** (0.028)	-0.075*** (0.015)	-0.045*** (0.013)	-0.035 (0.019)
Δmortgage ratio$_{t-4}$	0.061* (0.024)	0.053*** (0.015)	0.100*** (0.017)	0.111*** (0.022)
Δdeposit ratio	-0.062** (0.020)	-0.051*** (0.015)	0.040 (0.024)	0.049 (0.028)
capital buffer	-0.146 (0.077)	-0.147*** (0.044)	-0.202*** (0.021)	-0.182*** (0.026)
capital buffer$_{t-1}$	0.164* (0.066)	0.189*** (0.040)	0.196*** (0.021)	0.178*** (0.025)
N	5,950	15,257	15,168	5,917
Bank FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
R^2	0.10	0.07	0.08	0
adj. R^2	0.08	0.06	0.07	0.09

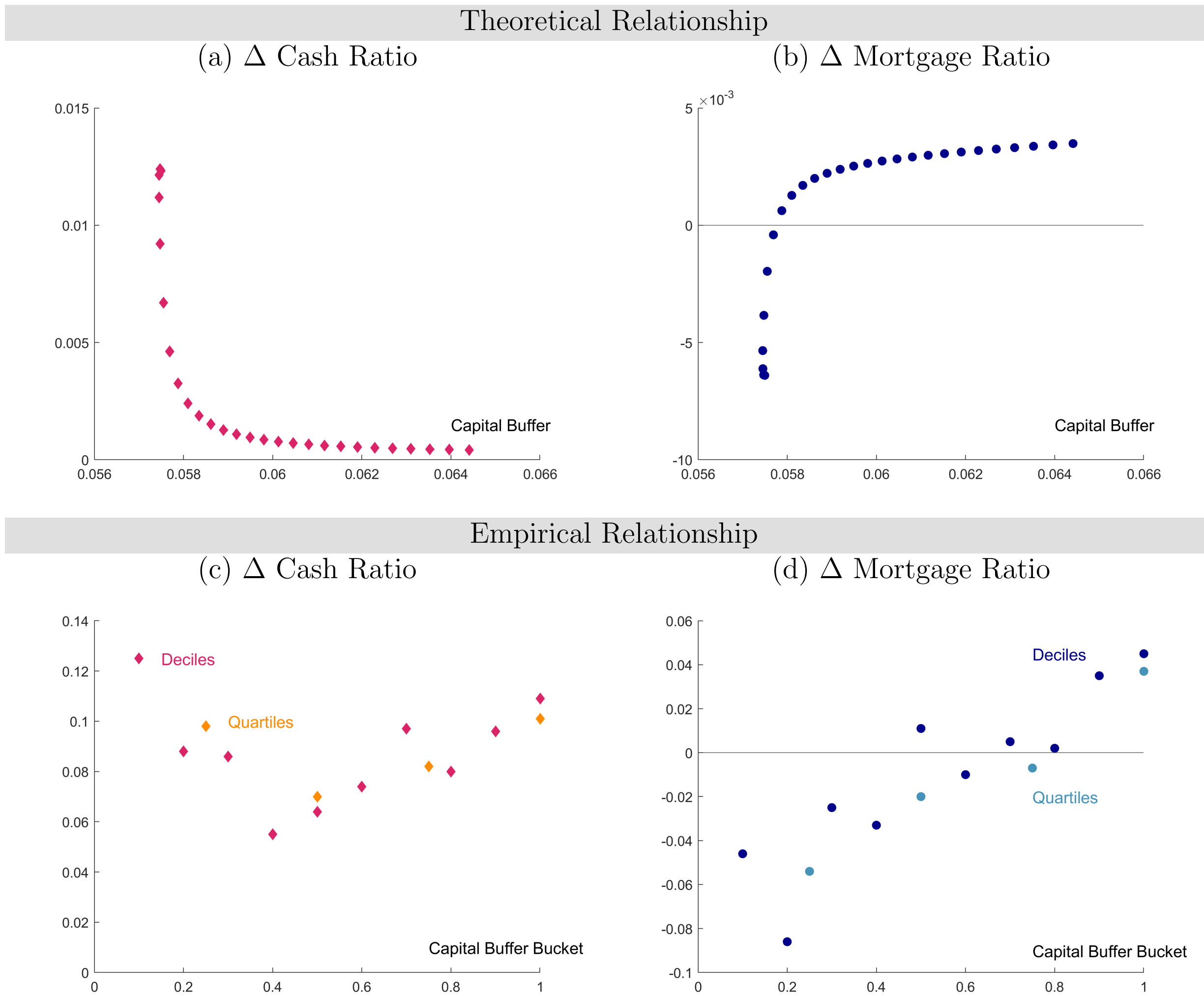
Note: Panel regressions are performed at the bank holding company level using FR Y-9C quarterly data from 2000 to 2018. Data are winsorized at the one percent level and sorted into decile or quartile buckets based on the cross-sectional distribution of capital buffers. Each column is a separate panel regression performed on bank holding companies in the designated bucket. Cluster-robust standard errors are in parentheses. Statistical significance is denoted as * $p < 0.05$, ** $p < 0.01$, ***$p < 0.001$.

Table 12: The Response of Banks' Cash Ratio and Mortgage Ratio to Changes in the Deposit Ratio as Capital Buffers Increase

	Cash Ratio		Mortgage Ratio	
	Quartiles	Deciles	Quartiles	Deciles
Δcash ratio$_{t-1}$	-0.355*** (0.013)	-0.355*** (0.013)		
Δcash ratio$_{t-2}$	-0.216*** (0.014)	-0.216*** (0.014)		
Δcash ratio$_{t-3}$	-0.153*** (0.010)	-0.153*** (0.010)		
Δcash ratio$_{t-4}$	0.050*** (0.011)	0.050*** (0.011)		
Δmortgage ratio$_{t-1}$			-0.075*** (0.008)	-0.075*** (0.008)
Δmortgage ratio$_{t-2}$			-0.035*** (0.006)	-0.035*** (0.006)
Δmortgage ratio$_{t-3}$			-0.034*** (0.007)	-0.034*** (0.007)
Δmortgage ratio$_{t-4}$			0.084*** (0.008)	0.084*** (0.008)
capital buffer	0.202*** (0.018)	0.203*** (0.018)	-0.224*** (0.017)	-0.223*** (0.017)
capital buffer$_{t-1}$	-0.216*** (0.018)	-0.217*** (0.018)	0.216*** (0.017)	0.215*** (0.017)
Δdeposit ratio	0.098*** (0.011)	0.125*** (0.017)	-0.054*** (0.015)	-0.046* (0.019)
Δdeposit ratio $\cdot$ quartile 25-50%	-0.028* (0.013)		0.034* (0.016)	
Δdeposit ratio $\cdot$ quartile 50-75%	-0.016 (0.015)		0.047 (0.024)	
Δdeposit ratio $\cdot$ quartile 75-100%	0.003 (0.018)		0.091*** (0.027)	
Δdeposit ratio $\cdot$ decile 10-20%		-0.037 (0.021)		-0.040 (0.027)
Δdeposit ratio $\cdot$ decile 20-30%		-0.039 (0.023)		0.021 (0.025)
Δdeposit ratio $\cdot$ decile 30-40%		-0.070*** (0.021)		0.013 (0.026)
Δdeposit ratio $\cdot$ decile 40-50%		-0.061** (0.021)		0.057* (0.026)
Δdeposit ratio $\cdot$ decile 50-60%		-0.051* (0.022)		0.035 (0.031)
Δdeposit ratio $\cdot$ decile 60-70%		-0.028 (0.022)		0.051 (0.038)
Δdeposit ratio $\cdot$ decile 70-80%		-0.045 (0.027)		0.048 (0.052)
Δdeposit ratio $\cdot$ decile 80-90%		-0.029 (0.026)		0.081** (0.030)
Δdeposit ratio $\cdot$ decile 90-100%		-0.016 (0.030)		0.091** (0.033)
N	60,733	60,733	62,085	62,085
Bank FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
R^2	0.18	0.18	0.06	0.06
adj. R^2	0.18	0.18	0.03	0.03

Note: Panel regressions are performed at the bank holding company level using FR Y-9C quarterly data from 2000 to 2018. Data are winsorized at the one percent level and sorted into decile or quartile buckets based on the cross-sectional distribution of capital buffers. Each column is a separate panel regression performed with all capital buffer bucket dummies interacted with changes in the deposit ratio using deciles or quartiles, as indicated in the heading, with the first decile (0-10%) or first quartile (0-25%) left out. Cluster-robust standard errors are in parentheses. Statistical significance is denoted as * $p < 0.05$, ** $p < 0.01$, $^{***}p < 0.001$.

Figure 6: The Response of Banks' Cash Ratio and Mortgage Ratio to Changes in the Deposit Ratio as Capital Buffers Increase



Note: Panels (a) and (b) display the decimal changes in the cash ratio and mortgage ratio plotted against values of the bank's capital buffer obtained from the model's comparative statics for the household liquidity preference parameter, ρ. Panels (c) and (d) present the change in deposit ratio for each capital buffer bucket obtained from regression results in Table 12. Results corresponding to regressions run using quartile buckets are shown in a lighter shade than results using decile buckets.

cash in total assets when capital buffers are high than when their buffers are low.

We conduct a similar exercise to analyze the relationship between capital buffers and movements in the mortgage to total assets ratio due to growth in deposit ratios. The bottom panel of Table 11 highlights how banks with the smallest buffers reduce the share of mortgage loans in total assets, while banks with the largest buffers will instead grow the mortgage share. The right panel of Table 12 shows that, as the theoretical model claims, when deposit ratios climb, banks accumulate more mortgages when capital buffers are high compared to when buffers are low. Figure 6 visually represents the parallels of the theoretical results and empirical results from Table 11. The downward sloping relationship between changes in the cash ratio and higher capital buffers produced from the theoretical model in panel (a) is roughly mirrored by the movement of regression coefficients plotted in panel (c). However, the empirical relationship differs in its U-shaped curve as higher capital buffer buckets are reached. The upward sloping relationship between changes in the mortgage ratio and higher capital buffers from the model in panel (b) closely matches the upward trend outlined in panel (d), with the coefficients flipping signs from negative to positive as capital buffer buckets increase. Thus, reduced form associations between deposit growth and changes in cash or mortgage ratios lend support to the mechanisms laid out by the theoretical analysis.

7 Conclusion

Using a general equilibrium model where a bank makes balance sheet decisions subject to regulatory constraints and household choices, we illustrate how monetary policy combines with changes in household demand and stricter regulation to explain the post-crisis composition of bank assets. Falling interest rates on reserves induce the bank to reduce the share of liquid assets on its balance sheets and dampens the bank's demand for deposits. Higher capital and liquidity requirements also reduce the bank's appetite for accumulating deposit liabilities, but push the bank in the opposite direction for assets, stimulating its demand for reserves at the expense of mortgages. Growth in household demand for savings, meanwhile, stymie the sharp contraction of mortgage shares in total assets stemming from stricter bank regulation. Together, these four forces cause bank leverage to flatline and cash ratios to continue their precipitous climb in the post-crisis period.

The model further implies that monetary policy, capital rules, and the LCR work through different channels. Capital rules constrain expansion of the balance sheet by restricting growth of deposit liabilities. The LCR prompts banks to reshuffle assets towards greater cash holdings. Larger cash holdings should decrease the risk profile of the bank, however, compliance with the LCR does not preclude increases in leverage. Monetary policy functions mainly by changing the bank's willingness to amass reserves. Looser policy tends to counteract stronger bank regulation, while tighter policy complements stricter bank rules.

Comparative statics exercises emphasize the importance of rising household demand for deposits for post-crisis changes in bank balance sheets. The model suggests growth in household demand for deposits interacts with the banks' incentives to maintain capital buffers to allow the balance sheet to expand even as leverage falls. Reduced form regressions suggest a positive link between household deposit demand and larger shares of cash in the bank's total assets, providing support for the model's finding that stricter regulation is not the sole driver of the rise in cash holdings post-crisis.

Because the empirical analysis of mechanisms outlined by the model are not causal, conclusions drawn from the regression results should be done heedfully. Exploiting the cross-sectional variation of banks' exposure to deposit shocks and heterogeneity in capital buffers to illustrate how changes in household demand interact with capital regulation to shape banks' balance sheets is the aim of future work.

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A Bank Balance Sheet Developments, by Asset Size

In the introduction, movements in cash as a share of total assets, leverage, and loans backed by real estate were highlighted as examples of balance sheet ratios that have changed dramatically between pre-2009 and post-2009 periods. The data presented in Figure 1 were aggregates. For the cash ratio, total cash and due was summed up across all FDIC-insured depository institutions and divided by the sum of total assets of all banks. Leverage and mortgage ratios were also calculated in a similar manner. This method of calculation places more weight on the balance sheets of larger banks, so reflect the activity of the banks with the largest assets in the sector more than banks of smaller asset sizes.

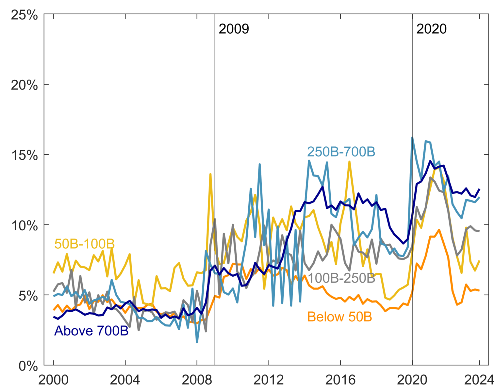
Since small, medium, and large banks tend to have different business models and sometimes very different customers, the aggregation of balance sheets may mask heterogeneity in how banks have changed in reaction to the post-2009 environment. The variation in post-crisis regulatory rules across size thresholds is another important reason to compare balance sheet changes across banks of different sizes. Notably, banks with total assets under $50 billion are not subject to a LCR, while bank with assets between $100 to $250 billion are subject to modified LCR requirements, and those above $250 billion are subject to a full LCR. Capital requirements also vary depending on whether banks are Category II, III, or IV banks, which correspond roughly to assets sizes of over $700 billion, between $250 and 700 billion, $100 to 250 billion, between $50 to 100 billion. The Category size thresholds serve as cutoffs to examine trends in balance sheets from 2000 to 2016 among the different groups. Figure A.1 presents bank balance sheet developments by asset size using the FR Y-9C Consolidated Financial Statements for Bank Holding Companies. Each panel is described below.

Panel (a) of Figure A.1 conveys the evolution of cash as a share of total assets. Here, cash and due is summed up among all banks in each size category and divided by the sum of total assets at those same banks. For banks between $50 to 100 billion assets in gold, banks between $100 to 250 billion in gray, $250 to 700 billion in turquoise, and above $700 billion in dark blue all, cash as a share of deposits rose from around 3 to 8 percent in 2000 to between 8 to 12 percent after 2009. Meanwhile, for banks below $50 billion, in orange, rose only to slightly, from 4 percent in 2000 to slightly above 4 to 6 percent after 2009. Nonetheless, banks in all asset classes increased the share of cash in total assets from 2010 to 2016.

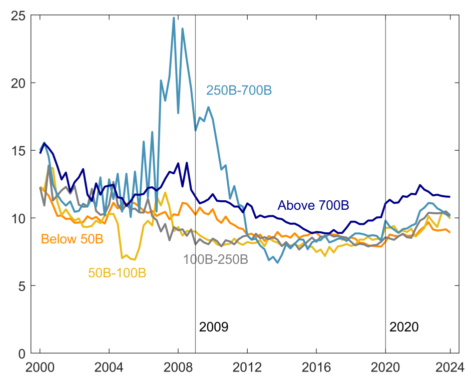
Leverage, measured as total assets divided by equity within each size category, displays a

Figure A.1: Bank Balance Sheet Developments by Asset Size

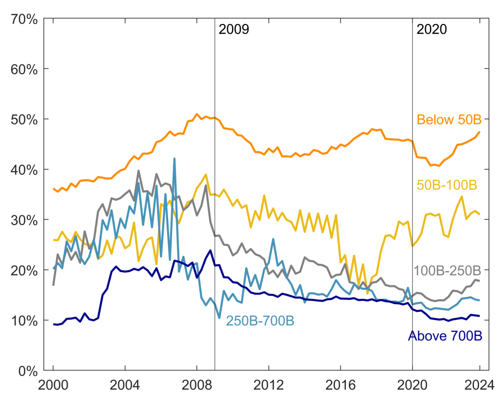
(a) Cash as Share of Total Assets



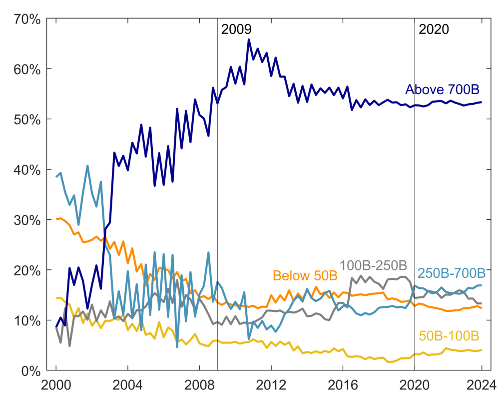
(b) Leverage



(c) Loans Backed by Real Estate as Share of Total Assets



(d) Share of Total Industry Assets



Note: Data come from the FR Y-9C Consolidated Financial Statements for Holding Companies. Leverage in panel (b) is total assets divided by equity. Author calculations.

similar pattern across banks. Panel (b) of Figure A.1 highlights, leverage fell from a range between 10 to 15 times equity in 2000 to between 5 and 9 times equity in 2016. During the run-up to the crisis, in 2006 and 2007, the sector made up of banks with $250 to 700 billion in total assets (in turquoise) accumulated the most leverage, reaching almost 25 times equity, while the leverage of all other asset size groups remained below 15 times equity. From 2010 to 2016, leverage of banks in the between $250 to 700 billion group fell quite precipitously to converge to lower levels of leverage along with other size categories.

Unlike cash in total assets and leverage, the change in loans backed by real estate as a share of total assets was not uniform across all banks. Panel (c) of Figure A.1 illustrates, in contrast to other asset size groups, the share of loans backed by real estate rose for banks with assets below \$50 billion, in orange, and banks with assets above \$700 billion, in dark blue. For banks with assets between \$50 to 100 billion (in gold) and \$250 to 700 billion (in turquoise), the share of loans backed by real estate followed a similar pattern, rising from around 20 percent in 2000 to around 35 percent in 2006 and then falling to slightly under 20 percent in 2016. For banks with between \$100 to 250 billion, in gray, the ratio remained almost stable at around 20 percent.

Thus, aggregate trends from 2000 to 2016 that are consistent across all size groups are the fall in leverage and rise in cash as a share of total assets. To place the differences in growth of loans backed by real estate in total assets in perspective, it is useful to consider the changes in shares of total industry assets occupied by each asset size category over the same period. Panel (d) of Figure A.1 shows how the share of banks above \$700 billion in total assets (in dark blue) has been rising since 2002, comprising a little over 50 percent of total assets in the banking sector in 2016. Meanwhile, the share of total industry assets held among banks below \$50 billion (in orange) and between \$50 to 100 billion in total assets (in gold) has been declining. In the paper, discussion of aggregate trends in the banking sector will mainly reflect changes in banks larger than \$100 billion in assets, with movements in banks below \$100 billion in assets playing a lesser role given their diminishing share of the industry. Given the focus of the paper is on understand the role of post-crisis regulatory rules which disproportionately affect the larger banks, the emphasis placed on balance sheet changes among banks larger than \$100 billion in aggregated data is not an issue. However, the empirical section of the paper explores the influence of changes in demand for deposits on bank balance sheets distinctly because the analysis is generalizable to all banks.

B Equations

B.1 Derivatives for Potential Regulatory Costs

Ω_{t+1} denotes the combined regulatory costs the bank faces from capital and liquidity rules:

$$\lambda\left(\frac{F_{t+1}+M_{bt+1}+L_{t+1}-S_{t+1}}{\omega_{mt}M_{bt+1}+\omega_{lt}L_{t+1}}-\varphi_t\right)^{-2}+\alpha\left(\frac{F_{t+1}+\tau_l L_{t+1}+\frac{1}{2}r^m_{t+1}M_{bt+1}}{\delta_t S_{t+1}+\zeta_t M_{bt+1}}-\gamma_t\right)^{-2} \tag{29}$$

The derivative with respect to deposits, S_{t+1}, is

$$\begin{aligned}\Omega_{S,t+1} =& 2\lambda\left(\frac{(\omega_{mt}M_{bt+1}+\omega_{lt}L_{t+1})^2}{(F_{t+1}+(1-\varphi_t\omega_{mt})M_{bt+1}+(1-\varphi_t\omega_{lt})L_{t+1}-S_{t+1})^3}\right)\\ &+2\delta_t\alpha\left(\frac{(\delta_t S_{t+1}+\zeta_t M_{bt+1})(F_{t+1}+\tau_{lt}L_{t+1}+\frac{1}{2}r^m_{t+1}M_{bt+1})}{(F_{t+1}+\tau_{lt}L_{t+1}+(\frac{1}{2}r^m_{t+1}-\gamma_t\zeta_t)M_{bt+1}-\gamma_t\delta_t S_{t+1})^3}\right)\end{aligned} \tag{30}$$

The first term is the increase in capital burden from an additional unit of deposits. By increasing deposit funding, the bank reduces equity $(F_{t+1}+M_{t+1}+L_{t+1}-S_{t+1})$ and lowers the capital ratio. This increases regulatory costs by $(\omega_{mt}M_{bt+1}+\omega_{lt}L_{t+1})$ because of the weighting structure. The second term is the marginal increase in liquidity costs. Each dollar increase in deposits adds to the denominator of the LCR $\left(\frac{F_{t+1}+\tau_{lt}L_{t+1}+\frac{1}{2}r^m_{t+1}M_{bt+1}}{\delta_t S_{t+1}+\zeta_t M_{bt+1}}\right)$, which brings the bank closer to its minimum requirements. To counteract the decline, the bank must raise high quality liquid assets, through reserves, F_{t+1}, Treasuries, $\tau_{lt}L_{t+1}$, or additional mortgage interest revenue, $r^m_{t+1}M_{t+1}$. The derivative with respect to reserves, F_{t+1}, is

$$\begin{aligned}\Omega_{F,t+1} =& -2\lambda\left(\frac{(\omega_{mt}M_{bt+1}+\omega_{lt}L_{t+1})^2}{(F_{t+1}+(1-\varphi_t\omega_{mt})M_{bt+1}+(1-\varphi_t\omega_{lt})L_{t+1}-S_{t+1})^3}\right)\\ &-2\alpha\left(\frac{(\delta_t S_{t+1}+\zeta_t M_{bt+1})^2}{(F_{t+1}+\tau_{lt}L_{t+1}+(\frac{1}{2}r^m_{t+1}-\gamma_t\zeta_t)M_{bt+1}-\gamma_t\delta_t S_{t+1})^3}\right)\end{aligned} \tag{31}$$

Reserves add to equity, so an additional unit of reserves reduces capital costs by an amount equal to the risk-weighted assets equity is held against, $(\omega_{mt}M_{bt+1}+\omega_{lt}L_{t+1})$ in the numerator of the first term. Similarly, reserves reduce liquidity costs, so the marginal reduction in regulatory costs associated with an additional unit of reserves is the amount of liability outflows one unit of high quality liquid asset offsets, $(\delta_t S_{t+1}+\zeta_t M_{bt+1})$ in the numerator of the second expression. The derivative with respect to mortgages, M_{bt+1}, is

$$\begin{aligned}\Omega_{Mb,t+1} =& -2\lambda\left(\frac{(\omega_{mt}M_{bt+1}+\omega_{lt}L_{t+1})[\omega_{mt}(S_{t+1}-F_{t+1}-L_{t+1})+\omega_{lt}L_{t+1}]}{(F_{t+1}+(1-\varphi_t\omega_{mt})M_{bt+1}+(1-\varphi_t\omega_{lt})L_{t+1}-S_{t+1})^3}\right)\\ &-2\alpha\left(\frac{(\delta_t S_{t+1}+\zeta_t M_{bt+1})(\frac{1}{2}r^m_{t+1}\delta_t S_{t+1}-\zeta_t F_{t+1}-\zeta_t\tau_{lt}L_{t+1})}{(F_{t+1}+\tau_{lt}L_{t+1}+(\frac{1}{2}r^m_{t+1}-\gamma_t\zeta_t)M_{bt+1}-\gamma_t\delta_t S_{t+1})^3}\right)\end{aligned} \tag{32}$$

The first term is the net marginal reduction in regulatory costs of one unit of mortgages related to the capital ratio, $\frac{F_{t+1}+M_{pt+1}+L_{t+1}-S_{t+1}}{\omega_{mt}M_{bt+1}+\omega_{lt}L_{t+1}}$. Increasing mortgages by one unit raises bank equity, $(F_{t+1}+M_{pt+1}+L_{t+1}-S_{t+1})$, and enables the bank to raise additional deposits. At the same time, the capital ratio is reduced by ω_{mt}, so the bank needs extra reserves to offset the increase in mortgages, leading to a net decrease of $\omega_{mt}(S_{t+1} - F_{t+1} - L_{t+1})$. If the amount of reserves that needs to be raised is greater than the amount of additional deposits that can be raised, $S_{t+1} < F_{t+1} + L_{t+1}$, additional mortgages eat into the bank's equity and net marginal capital costs increase with additional mortgages.

The second term is the net marginal benefit from one unit of mortgages in terms of regulatory liquidity costs. For each extra unit, the bank can use its net interest revenue to raise additional deposits, $\frac{1}{2}r^m_{t+1}\delta_t S_{t+1}$, which relax constraints placed on borrowing by the liquidity ratio requirement. However, for one extra unit of mortgages, the bank reduces its liquidity ratio by ζ in the denominator of the required ratio, $\frac{F_{t+1}+\tau_{lt}L_{t+1}+\frac{1}{2}r^m_{t+1}M_{bt+1}}{\delta_t S_{t+1}+\zeta_t M_{bt+1}}$, which it must offset by holding extra reserves equal to $\zeta_t F_{t+1}$. If the amount of high quality liquid assets that must be raised ($\zeta_t(F_{t+1}+\tau_{lt}L_{t+1})$) is greater than the amount deposits generated from interest revenue ($\frac{1}{2}r^M_{t+1}\delta_t S_{t+1}$), net marginal liquidity costs increase with additional mortgages.

B.2 Nonstochastic Steady State Details

The set of equations describing the steady state when $\eta_2 > 0$ and $\bar{M}^H = \bar{\theta}\bar{P}\bar{H}$ are:

$$\bar{r}^s = \frac{\bar{S}}{\beta_h(\bar{C}\rho + \bar{S})} - 1 \tag{33}$$

$$\bar{P} = \frac{\beta_h \frac{\bar{\psi}}{\bar{H}}\bar{C}}{1 + \beta_h(\mu - 1) - \bar{\theta}\left[1 - \beta_h(1 + \bar{r}^m)\right]} \tag{34}$$

$$\bar{M}^H = \bar{\theta}\bar{P}\bar{H} \tag{35}$$

$$\bar{C} = \bar{W} + \bar{D} - \bar{r}^m\bar{M}^H - \bar{r}^l\bar{L} - \bar{T} + \bar{S}\frac{\bar{r}^s}{1+\bar{r}^s} - \mu\bar{P}\bar{H} \tag{36}$$

$$\begin{aligned}\frac{1}{(1+\bar{r}^s+\phi)} - \beta_b - 2\delta\alpha&\left(\frac{(\delta\bar{S}+\zeta\bar{M}^B)(\bar{F}+\tau_l\bar{L}+\frac{1}{2}\bar{r}^m\bar{M}^B)}{(\bar{F}+\tau_l\bar{L}+(\frac{1}{2}\bar{r}^m-\gamma\zeta)\bar{M}^B-\gamma\delta\bar{S})^3}\right)\\ -2\lambda&\left(\frac{(\omega_m\bar{M}^B+\omega_l\bar{L})^2}{(\bar{F}+(1-\varphi\omega_m)\bar{M}^B+(1-\varphi\omega_l)\bar{L}-\bar{S})^3}\right) = 0\end{aligned} \tag{37}$$

$$\begin{aligned}-\frac{1}{1+\bar{r}^f} + \beta_b + 2\alpha&\left(\frac{(\delta\bar{S}+\zeta\bar{M}^B)^2}{(\bar{F}+\tau_l\bar{L}+(\frac{1}{2}\bar{r}^m-\gamma\zeta)\bar{M}^B-\gamma\delta\bar{S})^3}\right)\\ +2\lambda&\left(\frac{(\omega_m\bar{M}^B+\omega_l\bar{L})^2}{(\bar{F}+(1-\varphi\omega_m)\bar{M}^B+(1-\varphi\omega_l)\bar{L}-\bar{S})^3}\right) = 0\end{aligned} \tag{38}$$

$$\begin{aligned}2\alpha&\left(\frac{(\delta\bar{S}+\zeta\bar{M})(\frac{1}{2}\bar{r}^m\delta\bar{S}-\zeta\bar{F}-\zeta\tau_l\bar{L})}{(\bar{F}+\tau_l\bar{L}+(\frac{1}{2}\bar{r}^m-\gamma\zeta)\bar{M}^B-\gamma\delta\bar{S})^3}\right)\\ +2\lambda&\left(\frac{(\omega_m\bar{M}^B+\omega_l\bar{L})[\omega_m(\bar{S}-\bar{F}-\bar{L})+\omega_l\bar{L}]}{(\bar{F}+(1-\varphi\omega_m)\bar{M}^B+(1-\varphi\omega_l)\bar{L}-\bar{S})^3}\right)\end{aligned}$$

$$+ \beta_b \left[(1-\pi)(1+\bar{r}^m) + \frac{\pi\nu}{\bar{\theta}}\right] - 1 = 0 \tag{39}$$

$$\bar{D} = \frac{\pi\nu}{\bar{\theta}}\bar{M}^B + \bar{r}^l\bar{L} + \left[\bar{r}^m - \pi(1+\bar{r}^m)\right]\bar{M}^B + (\frac{1}{1+\bar{r}^s+\phi} - 1)\bar{S} + (\frac{\bar{r}^f}{1+\bar{r}^f})\bar{F}$$
$$- \lambda\left(\frac{\bar{F}+\bar{M}^B+\bar{L}-\bar{S}}{\omega_m\bar{M}^B+\omega_l\bar{L}} - \varphi\right)^{-2} - \alpha\left(\frac{\bar{F}+\tau_l\bar{L}+\frac{1}{2}\bar{r}^m\bar{M}^B}{\delta\bar{S}+\zeta\bar{M}^B} - \gamma\right)^{-2} \tag{40}$$

$$\bar{T} = \pi(1+\bar{r}^m)\bar{M}^G + \frac{\bar{r}^f}{(1+\bar{r}^f)}\bar{F} - \frac{\pi\nu}{\bar{\theta}}\bar{M}^G \tag{41}$$

$$\bar{M}^G = \bar{M}^H - \bar{M}^B \tag{42}$$

The set of equations describing the steady state when $\eta_2 = 0$ and $\bar{\theta}\bar{P}\bar{H} > \bar{M}^H$ are:

$$\bar{r}^s = \frac{\bar{S}}{\beta_h(\bar{C}\rho+\bar{S})} - 1 \tag{43}$$

$$\bar{P} = \frac{\beta_h\frac{\bar{\psi}}{\bar{H}}\bar{C}}{1+\beta_h(\mu-1)} \tag{44}$$

$$\frac{1}{(1+\bar{r}^m)} = \beta_h \tag{45}$$

$$\bar{C} = \bar{W} + \bar{D} - \bar{r}^m\bar{M}^H - \bar{r}^l\bar{L} - \bar{T} + \bar{S}\frac{\bar{r}^s}{1+\bar{r}^s} - \mu\bar{P}\bar{H} \tag{46}$$

$$\frac{1}{(1+\bar{r}^s+\phi)} - \beta_b - 2\delta\alpha\left(\frac{(\delta\bar{S}+\zeta\bar{M}^B)(\bar{F}+\tau_l\bar{L}+\frac{1}{2}\bar{r}^m\bar{M}^B)}{(\bar{F}+\tau_l\bar{L}+(\frac{1}{2}\bar{r}^m-\gamma\zeta)\bar{M}^B-\gamma\delta\bar{S})^3}\right)$$
$$- 2\lambda\left(\frac{(\omega_m\bar{M}^B+\omega_l\bar{L})^2}{(\bar{F}+(1-\varphi\omega_m)\bar{M}^B+(1-\varphi\omega_l)\bar{L}-\bar{S})^3}\right) = 0 \tag{47}$$

$$-\frac{1}{1+\bar{r}^f} + \beta_b + 2\alpha\left(\frac{(\delta\bar{S}+\zeta\bar{M}^B)^2}{(\bar{F}+\tau_l\bar{L}+(\frac{1}{2}\bar{r}^m-\gamma\zeta)\bar{M}^B-\gamma\delta\bar{S})^3}\right)$$
$$+ 2\lambda\left(\frac{(\omega_m\bar{M}^B+\omega_l\bar{L})^2}{(\bar{F}+(1-\varphi\omega_m)\bar{M}^B+(1-\varphi\omega_l)\bar{L}-\bar{S})^3}\right) = 0 \tag{48}$$

$$2\alpha\left(\frac{(\delta\bar{S}+\zeta\bar{M})(\frac{1}{2}\bar{r}^m\delta\bar{S}-\zeta\bar{F}-\zeta\tau_l\bar{L})}{(\bar{F}+\tau_l\bar{L}+(\frac{1}{2}\bar{r}^m-\gamma\zeta)\bar{M}^B-\gamma\delta\bar{S})^3}\right)$$
$$+ 2\lambda\left(\frac{(\omega_m\bar{M}^B+\omega_l\bar{L})[\omega_m(\bar{S}-\bar{F}-\bar{L})+\omega_l\bar{L}]}{(\bar{F}+(1-\varphi\omega_m)\bar{M}^B+(1-\varphi\omega_l)\bar{L}-\bar{S})^3}\right)$$
$$+ \beta_b\left[(1-\pi)(1+\bar{r}^m) + \pi\nu\frac{\bar{P}\bar{H}}{\bar{M}^H}\right] - 1 = 0 \tag{49}$$

$$\bar{D} = \pi\nu\frac{\bar{M}^B}{\bar{M}^H}\bar{P}\bar{H} + \bar{r}^l\bar{L} + \left[\bar{r}^m - \pi(1+\bar{r}^m)\right]\bar{M}^B + (\frac{1}{1+\bar{r}^s+\phi} - 1)\bar{S} + (\frac{\bar{r}^f}{1+\bar{r}^f})\bar{F}$$
$$- \lambda\left(\frac{\bar{F}+\bar{M}^B+\bar{L}-\bar{S}}{\omega_m\bar{M}^B+\omega_l\bar{L}} - \varphi\right)^{-2} - \alpha\left(\frac{\bar{F}+\tau_l\bar{L}+\frac{1}{2}\bar{r}^m\bar{M}^B}{\delta\bar{S}+\zeta\bar{M}^B} - \gamma\right)^{-2} \tag{50}$$

$$\bar{T} = \pi(1+\bar{r}^m)\bar{M}^G + \frac{\bar{r}^f}{(1+\bar{r}^f)}\bar{F} - \pi\nu\frac{\bar{M}^G}{\bar{M}^H}\bar{P}\bar{H} \tag{51}$$

$$\bar{M}^G = \bar{M}^H - \bar{M}^B \tag{52}$$

C Calibration

C.1 Full Model Results and Robustness Checks

Table C.1 presents the full set of parameters obtained from the baseline calibration exercise along with other scenarios that either remove or alter certain periods before recalibrating. Each of the additional scenarios compares both parameters and key ratios for pre-crisis and post-crisis periods. Analyzing the changes in parameters from pre-crisis to post-crisis sheds light on the different forces influencing the bank and household portfolio choices.

The first two columns cover the full model results. Beginning with regulatory changes, in the first row, the required liquidity coverage ratio, γ, rose from 67 percent to 100 percent. The outflow rate assigned to deposits, δ, also increased, from around 9 to 13 percent, incentivizing the bank to reduce deposit liabilities and or raise holding of liquid assets. Required Tier 1 RWA ratios rose form 4 to 6 percent. At the same time, risk weights attached to mortgages for the Tier 1 RWA ratio, ω_m, fell slightly, as did the perceived costs of capital shortfalls, λ. Nevertheless, actual bank LCR and Tier 1 RWA ratios rose to 111 percent and 13 percent. The combined changes in regulatory rules encourage the bank to hold more reserves, reduce the relative share of mortgages in total assets, and cut deposit funding. Indeed, leverage falls, from 9.74 to 8.63 times equity.

To reduce average leverage from 9.7 to around 8.6, the bank cuts the ratio of deposits to total assets by around two percent, decreases the share of mortgages by seven percent, and doubles the share of assets allocated to cash (compare across pre- and post-crisis columns for rows two through four in the Key Ratios section near the bottom of Table C.1). Second, by doubling the ratio of reserves to deposits, F/S, the bank boosts its post-crisis cash and regulatory ratios. This occurs despite interest rates on reserves, r^f, dropping to zero.

On the household side, housing demand rises in the post-crisis period, reflecting the increase in house price (P). To understand the movement of house preferences, ψ, consider the change in interest rates on mortgages, r^m. Given the increase in government supply of mortgages post-crisis, r^m falls from 6.7 percent to 4.4 percent (see row six in the second set of parameter rows in Table C.1). The drop in cost of mortgage loans for households raises the values of borrowed funds today, $\frac{1}{(1+r^m)}$, from 0.938 to 0.958. The current value of a dollar the household must repay tomorrow is $\frac{1}{\beta_h}$, 0.935 in both periods. Because the borrowed funds are worth even more in today's terms than the amount households must repay tomorrow in the post-crisis period (at 0.024 versus 0.003), household demand for borrowing grows. The large magnitude of changes in the incentives to obtain mortgages are enough to account for the rise in P, so housing preferences, ψ, remain relatively stable over both periods as noted by comparing the first two columns in row six of Table C.1).

To match the growth in deposits levels and fall in interest rates on deposits towards zero percent post-crisis, household demand for deposits rises. The weight of deposits in utility, ρ, rises from 0.182 pre-crisis to 0.301 post-crisis, translating into more savings supplied by the household to the bank. With greater supply, the interest rate on deposits, r^s fall. Household consumption, C, falls as a result of the shift towards more housing and savings.

Combining the changes in the household portfolio with the bank, we can characterize the housing market. With a declining interest rate paid on deposits, r^s, from about 1.9 to 0.2 percent, the bank enjoys a hefty reduction in the cost of funds in the later period. At the same time, the reduction in return on mortgages dampens the bank's willingness to increase supply, leaving mortgages, M^B, slightly lower post-crisis. Lower interest rates, coupled with higher house prices, enables households to borrow more against the higher house value (see M^H, total household demand for mortgages, and the value of the house, $P \cdot H$, in the last two rows of Table C.1). In response to regulatory rules, even though the bank reduces its exposure to mortgages relative to other balance sheet assets, the lower interest rate environment and stronger housing demand allows households to increase mortgage borrowing.

Table C.1 presents the full set of model parameters obtained when crisis years (2007 through 2009) are removed from the data in the third and fourth columns under the "Crisis Years" heading. In contrast to the baseline, the housing preference shock, ψ, increases post-crisis because the growth in housing prices is much larger from 106 to 123. Growth in household demand for deposits, ρ, is also larger. All other parameters are roughly unchanged. The changes translate into an increase in the bank's supply of mortgages and stronger deposit growth in levels. This suggests that rising household demand for deposits is driven somewhat

Table C.1: Full Model Calibration Results Versus Different Scenarios

	Full Model		Remove or Alter Attributes and Re-Calibrate to Understand Effects: Crisis Years		Required Reserves		Household Income	
	Pre-crisis 2000-2007	Post-crisis 2009-2016	Pre-crisis 2000-2006	Post-crisis 2010-2016	Pre-crisis 2000-2007	Post-crisis 2009-2016	Pre-crisis 2000-2007	Post-crisis 2009-2016
Parameters								
γ	0.674	1.000	0.676	1.000	0.668	1.000	0.674	1.000
δ	0.085	0.125	0.088	0.130	0.078	0.116	0.085	0.125
α	0.705	0.705	0.731	0.731	0.705	0.634	0.705	0.705
ω_m	1.083	1.057	1.052	1.028	1.069	1.032	1.083	1.057
λ	2.264	1.479	2.411	2.129	2.221	1.457	2.264	1.479
ψ	0.343	0.331	0.333	0.344	0.342	0.328	0.552	0.411
ρ	0.182	0.301	0.183	0.310	0.178	0.292	0.293	0.372
β_b	0.886	0.932	0.881	0.923	0.886	0.932	0.886	0.932
S	239,240	285,316	234,253	290,697	234,287	278,012	239,240	285,316
r^s	0.019	0.002	0.017	0.001	0.019	0.002	0.019	0.002
F	13,144	33,586	13,146	35,302	11,624	30,324	13,144	33,586
r^f	0.034	0.002	0.032	0.002	0.034	0.002	0.034	0.002
M^B	101,478	99,140	95,569	103,663	101,478	99,140	101,478	99,140
r^m	0.067	0.044	0.067	0.045	0.066	0.043	0.067	0.044
β_h	0.935	0.935	0.935	0.935	0.935	0.935	0.935	0.935
P	109	121	106	123	109	121	109	121
C	65,505	64,314	65,694	63,880	65,690	64,600	40,786	51,903
H	2,377	2,550	2,356	2,566	2,377	2,550	2,377	2,550
T	703	397	675	402	652	391	703	397
D	4,750	3,506	4,608	3,741	4,667	3,468	4,750	3,506
M^H	206,478	247,140	200,569	251,663	206,478	247,140	206,478	247,140
$P \cdot H$	258,097	308,925	250,711	314,579	258,097	308,925	258,097	308,925
Key Ratios								
LCR	0.83	1.11	0.83	1.11	0.83	1.11	0.83	1.11
Tier 1	0.10	0.13	0.10	0.13	0.10	0.13	0.10	0.13
Leverage	9.74	8.63	9.85	8.60	9.74	8.63	9.74	8.63
ROE	1.13	1.07	1.14	1.08	1.13	1.07	1.13	1.07
$\frac{S}{(F+M^B+L)}$	0.90	0.88	0.90	0.88	0.90	0.88	0.90	0.88
F/S	0.05	0.12	0.06	0.12	0.05	0.11	0.05	0.12
cash ratio	0.05	0.10	0.05	0.11	0.04	0.10	0.05	0.10
$\frac{M^B}{(F+M^B+L)}$	0.38	0.31	0.37	0.32	0.39	0.32	0.38	0.31
$1-\beta_h(1+r^m)$	0.003	0.024	0.003	0.023	0.003	0.024	0.003	0.024

Note: The first gray shaded panel conveys calibrations of the full model while the next three gray shaded panels show how calibrations might change under different scenarios. Those include removing the crisis years (2007 and 2009) from the full model, removing required reserves from cash, and changing average household income. "ROE" stands for return on equity.

by the Great Recession, but it is also a general post-crisis trend.

Table C.1 highlights that removing required reserves from the definition of cash on bank balance sheets has minimal affect on the baseline calibration results in the fifth and sixth columns under the "Required Reserves" heading. However, removing required reserves from cash addresses the problem of using the Fed funds rate as the interest rate on reserves for both pre- and post-crisis periods. If both required and excess reserves are included in cash, differential rates need to be applied to cash holdings depending on the portion allocated to each. From pre- to post-crisis, the return on required reserves needs to jump from zero to less than one percent, while the return on excess reserves would jump from the Fed funds rate to the interest rate paid on excess reserves. With cash in the model, F, defined as cash and due from depository institutions, less required reserves, the Fed funds rate can be used as the uniform return on cash. For the pre-crisis period, before the Fed began paying interest on reserves, banks with excess reserves would lend the funds out in the overnight interbank market, receiving the Fed funds rate. In the post-crisis period, the Fed funds rate serves as a floor for the interest rate on excess reserves (IOER), so using the Fed funds rate as the return on reserves provides a lower bound for interest earned on excess reserves.

Table C.1 considers how changes in average household income affect household preference parameter estimates in the seventh and eighth columns under the "Household Income" heading. In the original calibration, household income was held flat at \$86,000 for both periods. From the 2017 U.S. Census, Table H.6, average real household income in terms of 2017 CPI-U-RS adjusted dollars, fell about one percent from pre-crisis (\$79,992) to post-crisis (\$78,599). Median real income dropped slightly, averaging \$58,577 from 2000 to 2007 and \$56,377 from 2009 to 2016. On the other hand, nominal incomes rose over the two periods. Given that all values in the model are nominal, we recalibrate to have W, average household income, increased from \$61,281 from 2000 to 2007 to \$73,589 from 2009 to 2016.

Due to the growth in income, household consumption levels rise in the post-crisis period relative to the baseline full model results in Table C.1. Demand for housing is also stronger with more income, which reduces the size of the house preference shock, ψ, in the second period required to match the rise in house prices. Otherwise, bank balance sheet dynamics and other changes mirror the baseline case.

Table C.2: Parameter Inputs for Counterfactual Scenarios

	Actuals		Counterfactuals			
	Pre-crisis 2000-2007	Post-crisis 2009-2016	No interest rate decline	No HH pref. changes	No reg. ratio hikes	No gov. supply rise
ρ	0.182	0.301	0.301	**0.182**	0.301	0.301
ψ	0.343	0.331	0.331	**0.343**	0.331	0.331
β_b	0.886	0.932	0.932	0.932	0.932	0.932
β_h	0.935	0.935	0.935	0.935	0.935	0.935
π	0.010	0.010	0.010	0.010	0.010	0.010
θ	0.800	0.800	0.800	0.800	0.800	0.800
ω_m	1.083	1.057	1.057	1.057	1.057	1.057
ω_l	1.000	1.000	1.000	1.000	1.000	1.000
μ	0.020	0.020	0.020	0.020	0.020	0.020
ν	0.650	0.650	0.650	0.650	0.650	0.650
τ_l	0.013	0.028	0.028	0.028	0.028	0.028
φ	0.040	0.060	0.060	0.060	**0.040**	0.060
λ	2.264	1.479	1.479	1.479	1.479	1.479
γ	0.674	1.000	1.000	1.000	**0.674**	1.000
α	0.705	0.705	0.705	0.705	0.705	0.705
δ	0.085	0.125	0.125	0.125	0.125	0.125
ζ	0.018	0.016	0.016	0.016	0.016	0.016
ϕ	0.032	0.029	0.029	0.029	0.029	0.029
r^f	0.034	0.002	**0.034**	0.002	0.002	0.002
r^l	0.066	0.043	0.043	0.043	0.043	0.043
M^G	105,000	148,000	148,000	148,000	148,000	**105,000**
L	152,000	190,000	190,000	190,000	190,000	190,000
W	86,000	86,000	86,000	86,000	86,000	86,000
H	2,377	2,550	2,550	2,550	2,550	2,550

Note: This table summarizes different parameter values used to obtain solutions for the counterfactual exercises. Values emphasized with bold font and a light gray background cell color indicate parameters that are unchanged from the pre-crisis inputs when solving the model. There are six such instances.

Table C.2 summarizes the different parameter values used to obtain solutions for the counterfactual exercises. Values emphasized with bold font indicate six different instances when parameters are unchanged from their values pre-crisis when solving the model.

D Comparative Statics Details

D.1 Balance Sheet Changes for Each Parameter

Required Capital Ratio (φ) As the top panel of Table D.1 highlights, increasing the required capital ratio primarily shifts the liability structure of the bank towards more equity and less deposit funding. Asset composition is roughly unchanged, with cash constituting 5 percent of assets and mortgages at 38 percent even though total assets shrink. Due to the reduction in deposit shares, the LCR also grows together with the required capital ratio, leading the LCR buffer to rise slightly from 16 percent to 17 percent. Of note, the capital buffer does not change as the required capital ratio increases.

Cost of Capital Shortfall (λ) Increasing the cost of a capital shortfall creates similar adjustments to the bank balance sheet as changing the required capital ratio, albeit at more muted levels. The second panel in Table D.1 shows how there are small reductions in the share of deposits in total assets, and small increases in the capital ratio, equity, LCR, capital and LCR buffers. In model calibration, λ mainly controls the size of the capital buffer, which has indirect effects on the LCR and LCR buffer as well.

Required Liquidity Coverage Ratio (γ) Increasing the required LCR primarily changes the composition of total assets. As columns seven through eight of the third panel of Table D.1 show, the share of cash in total assets rises to about 8 percent while the share of mortgages falls from 38 to 36 percent as we increase the required LCR from 65 to 100 percent. The capital ratio and capital buffer change only slightly, while leverage subtly rises as the LCR reaches 100 percent. The LCR buffer also falls slightly, but is not as noticeable compared to the large reduction in mortgage share.

Costs of LCR Shortfall (α) Increasing the cost of LCR shortfalls primarily increases the LCR bufffer and LCR ratio. As the bottom panel of Table D.1 highlights, capital ratios and balance sheet compositions do not change much in response to larger values of α.

Interest on Reserves (r^f) As the interest rate on reserves rises, the share of cash in total

Table D.1: Modeled Effect of Financial Regulation on Key Bank Balance Sheet Ratios

Parameter Values	Capital Ratio	Capital Buffer	Leverage	LCR	LCR Buffer	$\frac{S}{(TA)}$	$\frac{F}{(TA)}$	$\frac{M}{(TA)}$	TA
Increasing Required Capital Ratio (φ)									
0.04	0.10	0.06	9.74	0.83	0.16	0.90	0.05	0.38	266,622
0.05	0.11	0.06	8.90	0.83	0.16	0.89	0.05	0.38	266,317
0.06	0.12	0.06	8.19	0.84	0.16	0.88	0.05	0.38	266,014
0.07	0.13	0.06	7.59	0.84	0.16	0.87	0.05	0.38	265,710
0.08	0.14	0.06	7.07	0.84	0.17	0.86	0.05	0.38	265,408
0.09	0.15	0.06	6.61	0.84	0.17	0.85	0.05	0.38	265,106
0.10	0.16	0.06	6.21	0.85	0.17	0.84	0.05	0.38	264,805
Increasing Costs of Capital Shortfalls (λ)									
1.45	0.10	0.06	10.63	0.83	0.15	0.91	0.05	0.38	267,115
1.55	0.10	0.06	10.50	0.83	0.15	0.90	0.05	0.38	267,046
1.65	0.10	0.06	10.37	0.83	0.15	0.90	0.05	0.38	266,980
1.75	0.10	0.06	10.25	0.83	0.15	0.90	0.05	0.38	266,916
1.85	0.10	0.06	10.14	0.83	0.16	0.90	0.05	0.38	266,854
1.95	0.10	0.06	10.03	0.83	0.16	0.90	0.05	0.38	266,795
2.05	0.10	0.06	9.93	0.83	0.16	0.90	0.05	0.38	266,738
2.15	0.10	0.06	9.84	0.83	0.16	0.90	0.05	0.38	266,683
2.25	0.10	0.06	9.75	0.83	0.16	0.90	0.05	0.38	266,629
Higher Required Liquidity Coverage Ratio (γ)									
0.65	0.10	0.06	9.72	0.81	0.16	0.90	0.05	0.38	266,337
0.70	0.10	0.06	9.75	0.86	0.16	0.90	0.05	0.38	266,938
0.75	0.10	0.06	9.79	0.91	0.16	0.90	0.06	0.38	267,541
0.80	0.10	0.06	9.82	0.95	0.15	0.90	0.06	0.37	268,147
0.85	0.10	0.06	9.85	1.00	0.15	0.90	0.06	0.37	268,755
0.90	0.11	0.07	9.89	1.05	0.15	0.90	0.07	0.37	269,365
0.95	0.11	0.07	9.92	1.10	0.15	0.90	0.07	0.36	269,977
1.00	0.11	0.07	9.95	1.15	0.15	0.90	0.08	0.36	270,591
1.05	0.11	0.07	9.99	1.20	0.15	0.90	0.08	0.36	271,208
Increasing Costs of LCR Shortfalls (α)									
0.50	0.10	0.06	9.73	0.81	0.14	0.90	0.05	0.38	266,427
0.60	0.10	0.06	9.73	0.82	0.15	0.90	0.05	0.38	266,527
0.70	0.10	0.06	9.74	0.83	0.16	0.90	0.05	0.38	266,617
0.80	0.10	0.06	9.74	0.84	0.16	0.90	0.05	0.38	266,698
0.90	0.10	0.06	9.75	0.84	0.17	0.90	0.05	0.38	266,773

Note: "LCR" stands for liquidity coverage ratio and "TA" for total assets.

Table D.2: Modeled Effect of Monetary Policy (r^f) on Key Bank Balance Sheet Ratios and Households

Parameter Values	Capital Ratio	Capital Buffer	Leverage	LCR	LCR Buffer	$\frac{S}{(TA)}$	$\frac{F}{(TA)}$	$\frac{M}{(TA)}$	TA
0.005	0.105	0.065	9.642	0.785	0.111	0.896	0.045	0.379	263,940
0.010	0.105	0.065	9.656	0.790	0.116	0.896	0.046	0.379	264,341
0.015	0.105	0.065	9.671	0.795	0.121	0.897	0.046	0.380	264,755
0.020	0.105	0.065	9.686	0.801	0.127	0.897	0.047	0.380	265,188
0.025	0.105	0.065	9.702	0.809	0.135	0.897	0.047	0.380	265,647
0.030	0.105	0.065	9.720	0.819	0.145	0.897	0.048	0.381	266,144
0.035	0.105	0.065	9.740	0.832	0.158	0.897	0.049	0.381	266,701
0.040	0.104	0.064	9.765	0.852	0.179	0.898	0.051	0.380	267,371
Parameter Values	**C**	**S**	**M^b**	**F**	**T**	**P**	**r^s**	**r^m**	**Leverage**
0.005	65,515	236,566	99,987	11,953	327	108	0.018	0.067	9.643
0.010	65,514	236,966	100,261	12,080	387	108	0.018	0.067	9.657
0.015	65,514	237,379	100,531	12,225	448	108	0.018	0.067	9.671
0.020	65,513	237,810	100,794	12,394	510	108	0.018	0.067	9.686
0.025	65,511	238,267	101,048	12,599	574	108	0.018	0.067	9.702
0.030	65,508	238,762	101,289	12,855	641	108	0.019	0.067	9.720
0.035	65,504	239,320	101,504	13,197	713	109	0.019	0.067	9.740
0.040	65,496	239,992	101,672	13,699	794	109	0.019	0.066	9.765

Note: "LCR" stands for liquidity coverage ratio and "TA" for total assets.

assets gradually rises, given the higher yield. Comparing the columns of the top panel of Table D.2, the capital ratio and capital buffer are relatively unchanged, with the share of deposits in total assets growing very slightly. The most significant changes are in leverage and the LCR. Capital ratios remain fairly stable because mortgages, a risk-weighted asset, are increasing along with reserves in total assets. Meanwhile, both reserves and mortgages add to liquid assets so the LCR rises.

The lower panel of Table D.2 sheds light on greater leverage. Starting from reserves, F, higher r^f means more attractive yields for the bank, so demand is greater. To pay for the interest on reserves, the central bank must raise taxes, T, which causes household consumption, C, to fall. Higher taxes also somewhat reduces household savings supplied to the bank, evidenced by slow rise in interest paid on savings, r^s. The bank gathers more deposits to fund its reserves growth and additional investment in mortgages, M, given the spread of mortgage rates, r^m, over the cost of deposits, r^s, is still large relative to the interest rate spread earned on reserves. Because investment in mortgages by the bank is higher than the demand for mortgages by households, r^m is declining as r^f increases, leading to a slight uptake in demand for housing by households reflected in P. Leverage rises because slightly faster growth in deposits than reserves (or mortgages) drives the bank's balance sheet expansion.

Housing Preference (ψ) The parameter ψ governs the strength of household's demand for houses, which is reflected in the price of houses and demand for mortgage loans. As the first two columns of the top panel of Table D.3 demonstrate, increased demand for houses does not influence capital ratios much. On the other hand, leverage and LCR ratios move considerably, all falling as ψ increases. Shifts in the asset composition of the balance sheet explain the declines in LCR and leverage. As total assets increase, the share of mortgages grows at a much faster pace than reductions in the share of deposits and share of reserves. Since assets are expanding quickly and deposits are shrinking somewhat, equity rises and the leverage ratio falls. Because mortgages contribute to the outflows that banks must hold liquid assets to cover and reducing reserves shrinks liquid assets, the denominator of the LCR grows and the numerator shrinks as ψ increases, lowering the LCR ratio.

Weight of Deposits in Household Utility (ρ) As the weight of deposits in the utility function increases, the household values savings more and increases deposit balances even while receiving minimal interest, r^s (see bottom panel of Table D.3). Because the bank

Table D.3: Modeled Effect of Household Preferences on Key Bank Balance Sheet Ratios and Household Choices

Parameter Values	Capital Ratio	Capital Buffer	Leverage	LCR	LCR Buffer	$\frac{S}{(TA)}$	$\frac{F}{(TA)}$	$\frac{M}{(TA)}$	TA
Increasing Housing Preference (ψ)									
0.33	0.105	0.065	9.748	0.835	0.161	0.897	0.050	0.369	261,694
0.34	0.105	0.065	9.740	0.831	0.158	0.897	0.049	0.378	265,367
0.35	0.105	0.065	9.732	0.828	0.154	0.897	0.049	0.386	269,013
0.36	0.104	0.064	9.725	0.825	0.151	0.897	0.049	0.394	272,630
0.37	0.104	0.064	9.718	0.822	0.148	0.897	0.048	0.402	276,220
0.38	0.104	0.064	9.711	0.819	0.146	0.897	0.048	0.409	279,783
0.39	0.105	0.065	9.685	0.817	0.143	0.897	0.047	0.412	280,989
Increasing Deposits Utility Weight (ρ)									
0.175	0.105	0.065	9.672	0.827	0.153	0.897	0.049	0.375	263,797
0.195	0.103	0.063	9.844	0.837	0.163	0.898	0.050	0.390	271,389
0.215	0.102	0.062	10.007	0.850	0.176	0.900	0.052	0.403	279,024
0.235	0.100	0.060	10.163	0.869	0.195	0.902	0.055	0.415	286,729
0.255	0.099	0.059	10.319	0.900	0.226	0.903	0.058	0.426	294,585
0.275	0.098	0.058	10.492	0.962	0.288	0.905	0.064	0.434	302,886
0.285	0.098	0.058	10.606	1.029	0.355	0.906	0.070	0.435	307,570
0.295	0.097	0.057	10.777	1.168	0.494	0.907	0.083	0.432	313,330
0.315	0.097	0.057	11.336	1.680	1.006	0.912	0.127	0.410	328,712
0.335	0.097	0.057	11.961	2.213	1.540	0.916	0.174	0.386	345,111

Parameter Values	C	S	M^b	F	T	P	r^s	r^m
Increasing Deposits Utility Weight (ρ)								
0.175	65,536	236,522	98,946	12,851	695	107	0.020	0.068
0.195	65,445	243,821	105,725	13,664	718	111	0.016	0.064
0.215	65,332	251,141	112,439	14,585	745	114	0.013	0.061
0.235	65,200	258,517	119,052	15,677	778	118	0.010	0.058
0.255	65,046	266,038	125,479	17,106	822	121	0.007	0.055
0.275	64,864	274,018	131,451	19,435	896	124	0.004	0.052
0.285	64,751	278,570	133,936	21,634	968	126	0.003	0.051
0.295	64,600	284,257	135,439	25,891	1,109	126	0.002	0.050
0.315	64,169	299,715	134,871	41,841	1,638	126	0.002	0.049
0.335	63,703	316,258	133,195	59,916	2,237	125	0.002	0.049

Note: "LCR" stands for liquidity coverage ratio and "TA" for total assets. The dashed line indicates where growth in mortgages stalls and then reverses.

can pay less on deposits, its cost of funds fall and the bank offers more mortgages to take advantage of the growing spread between return on mortgages, r^m, and the interest paid on deposits, r^s. While increasing mortgages, the bank also increases reserves, F, which drives up taxes, T, and reduces household consumption, C. The reduced consumption somewhat dampens household demand for houses, but the rapid growth in supply lowers r^m, so demand for houses still increases on net, reflected in the rising P. Of note, the growth in mortgages stalls and reverses after ρ passes 0.285.

To understand the behavior of mortgages, changes in key balance sheet ratios must be taken into account. The first three columns of middle panel of Table D.3 illustrate that as the share of deposits and mortgages increases, the capital ratio falls and leverage rises. However, the bank still maintains its capital buffer above 5.8 percent as ρ climbs from 0.175 to 0.285. Once the capital buffer falls below 5.8 percent, beyond ρ of 0.285, the bank cuts back on mortgage growth (see column eight) and begins to rebuild its capital. For levels of deposit demand beyond 0.285, the bank dramatically increases the level and share of reserves in total assets accompanying deposit growth. Thus, the capital buffer is a binding constraint on mortgage growth and influences the reallocation of assets on the bank's balance sheet.

E Demand for Deposits: Alternative Specifications and Robustness Checks

E.1 Fed Funds Rate Differential, Inflation, and Specification Tests

Given the concentrated nature of the U.S. banking industry, where the top five institutions by size make up roughly half of total sector assets, the ability of banks to set interest rates on deposits is an important factor to consider. Drechsler, Savov, and Schnabl (2017) argue that banks choose deposit rates in response to movements in the Fed funds rate to affect the spread, essentially controlling the cost of liquidity for households. In their model, as in mine, households have preferences for liquidity, so demand for deposits responds readily to changes in the liquidity premium. Since we are interested in measuring the shift in demand for deposits, we want to isolate the component of deposit rates driven by supply factors to better measure the demand curve.

Table E.1 summarizes results from a specification that considers the influence of banks over the Fed funds spread. Column (1) is the baseline model. The estimated equation

Table E.1: Arellano-Bond Estimation of Deposit Demand, Modified Instruments

	Dependent Variable: $lnM = ln(\text{Deposits})_{it} - ln(\text{GDP Deflator})_{it}$			
	(1)	(2)	(3)	(4)
lnM_{t-1}	0.473*** (0.0296)	-0.003 (0.0554)	0.112 (0.1041)	0.378*** (0.0652)
$t-2$			0.107 (0.0915)	
$t-3$			-0.014 (0.0552)	
$t-4$			-0.057 (0.0874)	
lnY	0.081*** (0.0125)	0.168* (0.0792)	0.095 (0.0715)	-0.143 (0.0758)
$t-1$	0.052*** (0.0112)	0.101*** (0.0149)	0.087*** (0.0194)	0.349*** (0.0642)
$t-2$		0.059*** (0.0098)	0.039* (0.0177)	
$t-3$		0.047*** (0.0115)	0.028 (0.0227)	
$t-4$		0.027 (0.0583)	0.045 (0.0565)	
lnW	0.172*** (0.0111)	-0.119* (0.0600)	-0.032 (0.0902)	0.033 (0.0485)
$t-1$		0.232*** (0.0456)	0.152* (0.0758)	0.085 (0.0439)
Inflation	-0.007*** (0.0003)	(0.0018)	(0.0019)	(0.0020)
$t-1$		-0.003*** (0.0006)	-0.004** (0.0011)	-0.001** (0.0005)
10-Year Treasury	-0.010*** (0.0009)	-0.010*** (0.0012)	-0.010*** (0.0019)	-0.009*** (0.0011)
$t-1$		-0.003* (0.0016)	-0.004* (0.0021)	-0.000 (0.0014)
$\widehat{\text{Own rate}}$	0.002 (0.0009)	0.006*** (0.0016)	0.008*** (0.0020)	0.008** (0.0026)
$t-1$		-0.005*** (0.0015)	-0.003 (0.0030)	-0.009*** (0.0023)
Post-2008	0.041*** (0.0032)	0.032*** (0.0044)	0.035*** (0.0086)	0.023*** (0.0052)
N	22,074	17,319	17,319	18,565
Instruments	97	27	41	33
Arellano-Bond Test for zero autocorrelation in first-differenced errors ($H_0 : E(\nu_{it}, \nu_{it-2}) = 0$)				
Z-stat	-0.00	-0.53	-1.23	0.05
Prob> Z	0.99	0.60	0.22	0.96
Sargan's Test for over-identifying restrictions				
χ^2-stat	250.90	27.98	18.18	30.68
Prob> χ^2	0.00	0.01	0.75	0.08
Hansen's Test for over-identifying restrictions				
χ^2-stat	220.33	17.91	27.00	25.98
Prob> χ^2	0.00	0.12	0.26	0.21
Difference-Hansen's Test for exogeneity of instruments (H_0 : instruments are exogenous)				
χ^2-stat	35.46	4.79	1.70	8.61
Prob> χ^2	0.00	0.69	0.98	0.20

Note: Regressions are performed on a county-level panel from 2000 to 2015. Windmeijer corrected robust standard errors are listed in parentheses next to estimated coefficients. Statistical significance is denoted as * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$.

Table E.2: Arellano-Bond Estimation of Deposit Demand, Modified Instruments Excluding High Inflation Counties

	Dependent Variable: $lnM = ln(\text{Deposits})_{it} - ln(\text{GDP Deflator})_{it}$			
	(1)	(2)	(3)	(4)
lnM_{t-1}	0.474*** (0.0330)	-0.050 (0.0520)	0.101 (0.1046)	0.435*** (0.0658)
$t-2$			0.020 (0.1237)	
$t-3$			-0.013 (0.0641)	
$t-4$			-0.096 (0.0961)	
lnY	0.085*** (0.0139)	0.085 (0.0719)	0.051 (0.0786)	-0.208* (0.0872)
$t-1$	0.025* (0.0118)	0.103*** (0.0131)	0.081*** (0.0204)	0.297** (0.0939)
$t-2$		0.055*** (0.0111)	0.042* (0.0202)	
$t-3$		0.044*** (0.0094)	0.044* (0.0207)	
$t-4$		0.055 (0.0595)	0.101 (0.0594)	
lnW	0.140*** (0.0105)	-0.120 (0.0663)	-0.033 (0.0958)	0.060 (0.0560)
$t-1$		0.214*** (0.0472)	0.127 (0.0733)	0.046 (0.0456)
Inflation	-0.006*** (0.0003)	(0.0018)	(0.0019)	(0.0020)
$t-1$		-0.003*** (0.0009)	-0.003 (0.0016)	-0.002* (0.0008)
10-Year Treasury	-0.010*** (0.0010)	-0.011*** (0.0012)	-0.010*** (0.0021)	-0.011*** (0.0012)
$t-1$		-0.005*** (0.0015)	-0.006*** (0.0019)	-0.001 (0.0015)
$\widehat{\text{Own rate}}$	0.001 (0.0010)	0.007*** (0.0019)	0.007* (0.0029)	0.008* (0.0038)
$t-1$		-0.004** (0.0015)	-0.001 (0.0029)	-0.006* (0.0028)
Post-2008	0.036*** (0.0032)	0.031*** (0.0046)	0.039*** (0.0080)	0.025*** (0.0062)
N	21,405	16,776	16,776	17,999
Instruments	97	27	41	33
Arellano-Bond Test for zero autocorrelation in first-differenced errors ($H_0 : E(\nu_{it}, \nu_{it-2}) = 0$)				
Z-stat	0.04	-0.55	-0.23	0.19
Prob> Z	0.97	0.58	0.81	0.85
Sargan's Test for over-identifying restrictions				
χ^2-stat	280.25	25.09	16.82	35.70
Prob> χ^2	0.00	0.01	0.81	0.02
Hansen's Test for over-identifying restrictions				
χ^2-stat	258.54	11.89	24.90	33.31
Prob> χ^2	0.00	0.46	0.35	0.04
Difference-Hansen's Test for exogeneity of instruments (H_0 : instruments are exogenous)				
χ^2-stat	68.78	7.55	7.56	19.34
Prob> χ^2	0.00	0.37	0.37	0.00

Note: Regressions are performed on a county-level panel from 2000 to 2015. Windmeijer corrected robust standard errors are listed in parentheses next to estimated coefficients. Statistical significance is denoted as * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$.

modifies Equation 24 by adding one lag of y_{it} and replacing $(r_t - own_{it})$ with $\widehat{\text{Own rate}}$. The $\widehat{\text{Own rate}}$ is obtained by regressing deposit rates on the spread between the Fed funds rate and deposit rate. We do this to capture the variation in deposit rates that is related to bank's funding costs, to try and control for the portion of deposit rates that may be determined by rate setting bank branches. At the same time, we limit the instrument count to run overidentification tests and gauge model validity.[50] For the Arellano-Bond estimation, we do not constrain the number of lags used for the GMM difference estimator of lnM and all RHS variables are taken as exogenous. Columns 2 through 4 are alternative versions of the baseline model in 1, with additional lags to RHS variables and modifications to the assumptions used in GMM difference estimation to obtain a model that passes all specification tests (Arellano-Bond, Sargan, Hansen, and Difference-Hansen's tests).[51] Of note, throughout, the coefficient value for Post-2008 remains consistently positive throughout and is only slightly below the baseline estimate of around 0.4 from Table 9 in the specification with 41 instruments that passes all model validity tests.

Table E.2 presents the same set of regressions as Table 9, excluding counties that exhibit extremely high levels of inflation. Inflation matters for deposit demand because higher levels of inflation erode the real value of cash and deposits, and households may respond by drastically cutting holdings of deposits. High inflation would bias predicted deposits demanded downward, potentially pushing up the coefficient on the post-2008 dummy given higher actual levels of deposits in the post-crisis period. Removing the high inflation counties, which consist of 79 small counties across Arizona, Colorado, Louisiana, New Mexico, Oklahoma, and Texas, with large oil and gas industries relative to the size of the local economy, does little to alter the results of Table E.1.

E.2 Stock Market Investment and Deposits

One alternative source of return not considered in the analysis is the stock market. Stock market returns may matter for a couple of reasons. In the theoretical model, households do not explicitly hold stock, but they do receive dividends as owners of the banks. If stock

[50] Misspecification and overidentification tests are very sensitive to proliferation of instruments, so provide unreliable results for models with hundreds of instruments like our baseline case in Section 6.1.2. See Roodman (2009) for a more detailed discussion about the problem of too many instruments.

[51] (2) uses third and fourth lags for GMM difference estimator of lnM. The first lags of lnW, inflation, own rate, the contemporaneous 10-yr Treasury rate, and first through third lags of lnY are assumed to be exogenous. Column (3) uses fifth through eighth lags for GMM difference estimator of lnM, while other instruments match (2). The model in column (4) uses fifth through seventh lags for GMM difference estimator of lnM and other instruments match (2).

Table E.3: Arellano-Bond Estimations of Deposit Demand with Stock Returns

	Dependent Variable: $lnM = ln(\text{Deposits})_{it} - ln(\text{GDP Deflator})_{it}$ Two-Step, Specific GMM-Instruments for Lagged RHS			
for Fed funds	3+	3-11	3-9	3-7
for y	4+	4-11	4-9	4-7
other RHS	2+	2-11	2-9	2-7
lnM_{t-1}	0.852*** (0.031)	0.845*** (0.034)	0.834*** (0.035)	0.833*** (0.032)
lnY	0.166*** (0.037)	0.161*** (0.043)	0.153*** (0.043)	0.155*** (0.045)
lnW	0.253*** (0.051)	0.248*** (0.049)	0.260*** (0.051)	0.284*** (0.046)
$t-1$	-0.158** (0.055)	-0.158** (0.052)	-0.154** (0.056)	-0.189*** (0.049)
Inflation	-0.006*** (0.001)	-0.006*** (0.001)	-0.006*** (0.001)	-0.006*** (0.001)
$t-1$	0.001** (0.000)	0.001** (0.000)	0.001** (0.000)	0.001* (0.000)
10-year Treasury	-0.005 (0.002)	-0.004* (0.002)	-0.004 (0.002)	-0.003 (0.002)
$t-1$	0.000 (0.003)	-0.001 (0.003)	-0.000 (0.003)	-0.002 (0.003)
Stocks	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000* (0.000)
$t-1$	-0.000*** (0.000)	-0.000*** (0.000)	-0.000*** (0.000)	-0.000*** (0.000)
Fed funds	0.000 (0.003)	0.001 (0.003)	0.001 (0.004)	0.004 (0.004)
$t-1$	0.000 (0.003)	0.000 (0.003)	0.002 (0.003)	-0.000 (0.003)
Post-2008	0.028 (0.015)	0.032* (0.014)	0.038** (0.014)	0.042** (0.015)
Year	-0.002 (0.001)	-0.003* (0.001)	-0.003* (0.002)	-0.004** (0.001)
Lags of y	3	3	3	3
N	18,565	18,565	18,565	18,565
Instruments	500	501	435	337

Note: Regressions are performed on a county-level panel from 2000 to 2015. Windmeijer corrected robust standard errors are listed in parentheses next to estimated coefficients. Assumed inflation is exogenous. Statistical significance is denoted as * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$. "RHS" stands for right-hand side variables.

returns and dividends are high, household wealth increases and this may boost demand for deposits. Another concern is that, as Lin (2020), explains, when the stock market is booming, people tend to move out of deposits and into equity markets. Along those lines, a plausible mechanism driving the upward shift in demand for deposits could be lower stock returns in the post crisis period. To test if this could be an important omitted variable driving results, we obtain gross annual market returns from Ken French's website.[52] We then construct our stock market return differential at the county level by subtracting from gross annual market returns average interest rates on deposits for each county. There are 33,288 stock return differential observations, with an average of 6.28 percent, standard deviation of 18.83

[52]The original data are from from Ibbotson Associates and are constructed as the value-weight return of all Center for Research in Security Prices (CRSP) firms incorporated in the U.S. and listed on the NYSE, AMEX, or NASDAQ that have a CRSP share code of 10 or 11 at the beginning of month t, good shares and price data at the beginning of t, and good return data for t.

percent. The largest differentials are around 35% in absolute value. Table E.3 replicates the Aerllano-Bond regressions run in columns one through four of Table 9 with the new stock market return measure in the estimation.[53]

The coefficient for stock market return spreads over deposit rates is negative, as expected, but statistically and economically insignificant for all variations of the estimation. Compared to values in Table 9, the magnitude of the post-2008 shift in deposit demand is slightly weaker, but still positive and significant throughout. Also, the size of the coefficient for the post-2008 dummy approaches the bounds of the biased OLS and fixed effect regressions, suggesting inclusion of stock market returns improves the estimation but does not alter the main results.

F The Relationship Between Bank Deposit Ratios and Cash or Mortgage Ratios: Regression Data

Summary statistics for variables considered in the regressions are presented in Table F.1. As mentioned in the main text, we perform minor variable cleaning by winsorizing extreme values at the one percent level and limiting the sample to banks with at least a year of data.

Table F.1: Summary of FR Y-9C Data used in Deposit Ratio Analyses

	Obs	Mean	Std. Dev.	Min	Max
capital buffer	74,489	0.0835	0.0414	-0.016	0.293
Δ log(cash)	74,573	0.0176	0.3569	-2.700	2.784
Δ log(mortgages)	72,804	0.0192	0.0586	-3.471	2.160
Δ cash ratio	72,997	0.0003	0.0193	-0.322	0.323
Δ deposits ratio	72,997	0.0001	0.0198	-0.234	0.271
Δ mortgage ratio	74,573	0.0016	0.0197	-0.343	0.384
Δ capital buffer	72,929	-0.0001	0.0105	-0.354	0.315

[53] Reducing the maximum number of instruments to the sixth lag affected coefficients significantly, so we do not repeat the same exercise here.