THE DEPOSITS CHANNEL OF MONETARY POLICY*

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We present a new channel for the transmission of monetary policy, the deposits channel. We show that when the Fed funds rate rises, banks widen the spreads they charge on deposits, and deposits flow out of the banking system. We present a model where this is due to market power in deposit markets. Consistent with the market power mechanism, deposit spreads increase more and deposits flow out more in concentrated markets. This is true even when we control for lending opportunities by only comparing different branches of the same bank. Since deposits are the main source of liquid assets for households, the deposits channel can explain the observed strong relationship between the liquidity premium and the Fed funds rate. Since deposits are also a uniquely stable funding source for banks, the deposits channel impacts bank lending. When the Fed funds rate rises, banks that raise deposits in concentrated markets contract their lending by more than other banks. Our estimates imply that the deposits channel can account for the entire transmission of monetary policy through bank balance sheets. *JEL* Codes: E52, E58, G12, G21.

I. INTRODUCTION

We propose and test a new channel for the transmission of monetary policy, the deposits channel. We show that when the Fed funds rate rises, banks widen the interest spreads they charge on deposits, and deposits flow out of the banking system. Since banks rely heavily on deposits for their funding, these outflows induce a contraction in lending. The relationships we document are strong

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and their aggregate effects are large. We argue, both theoretically and empirically, that they are due to banks' market power over deposits.

Our results are important for two reasons. First, the deposits channel provides an explanation for how monetary policy impacts banks' funding and the supply of bank lending in the economy. Unlike existing theories of the bank lending channel (e.g., Bernanke and Blinder 1988), the deposits channel does not work through required reserves. This is important because the required reserves mechanism has come to be viewed as implausible, throwing the idea of a bank lending channel into question (Romer and Romer 1990; Bernanke and Gertler 1995; Woodford 2010).

Second, the deposits channel provides an explanation for how monetary policy affects the supply of safe and liquid assets in the economy. Deposits are the main source of such assets for households, and hence a major component of their aggregate supply. Another major component are U.S. Treasuries (Krishnamurthy and Vissing-Jørgensen 2012). When the supply of deposits contracts, the liquidity premium on all safe and liquid assets, including Treasuries, is predicted to rise. The deposits channel can thus explain the observed strong relationship between the Fed funds rate and the liquidity premium (Nagel 2016).

We provide a model of the deposits channel. In the model, households have a preference for liquidity, which they obtain from cash and deposits. Cash is highly liquid but pays no interest, while deposits are partially liquid and pay some interest, the deposit rate. The deposit rate is set by banks that have market power over their local deposit markets. Households can also invest in bonds, which provide no special liquidity and pay a competitive open-market rate set by the central bank, the Fed funds rate. The Fed funds rate thus equals the cost of holding cash, and the difference between the Fed funds rate and the deposit rate—the deposit spread—equals the cost of holding deposits. When the central bank raises the Fed funds rate, cash becomes more expensive to hold, and this allows banks to raise deposit spreads without losing deposits to cash. Households respond by reducing their deposit holdings, and deposits flow out of the banking system and into bonds.

We test the predictions of the deposits channel in aggregate, bank-level, and branch-level data for the United States. At the aggregate level, deposit spreads increase strongly with the Fed funds rate, suggesting substantial market power. Consistent with

our model, the rise in spreads is associated with large deposit outflows. Also consistent with our model, the effects are stronger for the most liquid types of deposits (checking and savings). The fact that deposit prices (spreads) and quantities (flows) move in opposite directions indicates that monetary policy shifts banks' deposit supply curve rather than households' demand curve.

The aggregate time series is subject to a common identification challenge: deposit supply may be responding to contemporaneous changes in banks' lending opportunities rather than directly to monetary policy. For instance, if banks' lending opportunities decline as the Fed raises rates, then we would see banks make fewer loans and consequently take in fewer deposits even absent a deposits channel.

We address this identification challenge by exploiting geographic variation in an observable determinant of market power, the concentration of local deposit markets. The deposits channel predicts that when the Fed funds rate rises, banks in more concentrated areas should increase deposit spreads by more and experience greater deposit outflows. Yet we cannot simply compare deposits across banks because different banks may have different lending opportunities. To control for bank-specific lending opportunities, we compare deposit spreads and flows across branches of the same bank located in areas with different concentrations. The identifying assumption for this within-bank estimation is that banks can raise deposits at one branch and lend them at another.

The results support the predictions of the deposits channel. Following a 100 basis points (bps) increase in the Fed funds rate, a bank's branches in high-concentration areas increase their spreads on savings and time deposits by 14 bps and 7 bps, respectively, relative to its branches in low-concentration areas. The corresponding deposit outflows are 66 bps larger at the high-concentration branches. These results are robust to a variety of specifications and also hold when we compare branches of different banks.

Our estimates suggest that monetary policy has an economically large effect on the aggregate deposit supply. The implied semi-elasticity of deposits with respect to deposit spreads is -5.3. Since a 100 bps increase in the Fed funds rate induces on average a 61 bps increase in spreads (among large banks), it is expected to generate a 323 bps contraction in deposits. Aggregate deposits stood at \$9.3 trillion in 2014, hence a typical 400 bps Fed hiking cycle is expected to generate \$1.2 trillion of deposit outflows.

To further establish a direct effect of monetary policy on deposit supply, we use weekly data to conduct an event study of the precise timing of changes in deposit spreads. We find that the difference in the responses of deposit spreads at high- versus low-concentration branches occurs within a week of a change in the Fed funds rate target. This precise timing makes it unlikely that our results are driven by something other than monetary policy.

We also examine the effect of expected Fed funds rate changes on deposit supply. Since deposits are short-lived, their rates should respond to a Fed funds rate change only when it is enacted, even if fully expected. This allows us to control for information that is released at the same time as the Fed changes rates. We find that our results for both deposit spreads and flows are unchanged when we use only the expected component of Fed funds rate changes, which is consistent with a direct effect of monetary policy on deposit supply.[1]

We conduct several additional robustness tests of our findings. First, we show that proxies for financial sophistication (age, income, and education), which our model shows is another source of market power for banks beyond concentration, produce results that are similar to our main findings. Second, the results are similar for small and large banks, consistent with the large aggregate effects we document. Third, our results are robust to a variety of deposit products beyond the most widely offered ones, and to alternative ways of measuring concentration and delineating the extent of a local deposit market.

Next we examine the effect of the deposits channel on lending. Our model predicts that the contraction in deposits induced by a rate increase causes a contraction in lending as banks cannot costlessly replace deposits with wholesale (nondeposit) funding. This assumption that deposits are special is standard in the banking literature. It can arise from the unique stability and dependability of deposits (Hanson et al. 2015), or from an increasing marginal cost of wholesale funding (Stein 1998).

1. In contrast to deposits, long-lived assets such as stocks and bonds incorporate expected rate changes in advance and react only to unexpected rate changes. Existing empirical studies (e.g., Bernanke and Kuttner 2005) therefore cannot disentangle the impact of monetary policy from the impact of information that is released contemporaneously with a rate change or conveyed through the rate change itself.

We compute the exposure of bank lending to the deposits channel at the bank level because banks can move deposits across branches. We do so by averaging the concentrations of all of a bank's branches. In order to ensure that banks face similar lending opportunities, we compare lending by different banks within the same county.

We implement this within-county estimation using data on small business lending by U.S. banks. Small business lending is inherently risky and illiquid, which makes it particularly reliant on stable deposit funding and hence especially useful for our analysis. We find that when the Fed funds rate rises, banks that raise deposits in more concentrated markets reduce their lending in a given county relative to other banks. We estimate that for a 100 bps increase in the Fed funds rate, a one standard deviation increase in bank-level concentration reduces new small business lending by 291 bps.[2]

We then aggregate our lending data up to the county level to examine the impact of the deposits channel on overall lending and economic activity. We find that counties served by banks that raise deposits in high-concentration markets experience a decrease in lending, as well as lower subsequent employment growth. These results hold even when we control for a county's own deposit market concentration. Thus, they are identified from variation in the concentration of the other markets where the county's banks raise their deposits.

We also verify that all of our results hold at the bank level using Call Reports data. We find that banks that raise deposits in more concentrated markets increase deposit spreads by more and contract deposits by more when the Fed funds rate rises. These banks partly offset the contraction in deposits with wholesale funding, but the net effect is a significant contraction in lending, securities, and total assets.

Finally, we propose a novel measure of banks' exposure to monetary policy. This measure is the deposit spread beta, the amount by which banks are able to raise deposit spreads when the Fed funds rate rises. Our model shows that deposit spread betas are a sufficient statistic for banks' market power, capturing

2. The within-county estimation allows us to control for the direct effect of local deposit market concentration using county-time fixed effects. We find no evidence that local deposit market concentration affects lending, which supports our earlier identification assumption that banks can move deposits across branches.

not only the impact of concentration but also of depositors' financial sophistication, attentiveness, and willingness to switch banks. Deposit spread betas thus represent a comprehensive measure of exposure to the deposits channel and we use them to quantify its full economic impact.

We estimate the deposit spread beta of each bank by regressing its deposit spread on the Fed funds rate. The average deposit spread beta is 0.54, indicating substantial market power. It is even higher, 0.61, for the largest 5% of banks. We show that deposit spread betas strongly predict the sensitivity of bank balance sheets to monetary policy. The relationships are even stronger for large banks. We use the estimates for large banks to assess the aggregate impact of the deposits channel. Relative to keeping rates unchanged, a typical 400 bps Fed hiking cycle induces a 1,458 bps reduction in deposits and a 995 bps reduction in lending. Based on 2014 figures, these numbers translate into a $1.35 trillion reduction in deposits, which is very close to our within-bank estimation result, and a $763 billion reduction in lending.[3] We show that our estimates are large enough to account for the entire transmission of monetary policy through bank balance sheets documented by the literature on the bank lending channel (Bernanke and Blinder 1992).

The rest of this article is organized as follows: Section II discusses the related literature, Section III presents aggregate evidence on deposits, Section IV presents the model, Section V describes our data, Section VI presents results on deposits, Section VII presents results on lending, Section VIII discusses broader implications, and Section IX concludes.

II. Related Literature

Our article relates to the large literature on the transmission of monetary policy to the economy. The prevailing framework is the New Keynesian model (e.g., Woodford 2003). While the deposits channel and the New Keynesian model may well work in tandem, there are important differences in how they operate. One

3. Since the Fed tends to raise rates during periods of high loan demand, the reduction in aggregate lending one would actually observe is confounded by endogeneity and would be smaller than this estimate. In other words, lending would grow much more strongly if rates were kept unchanged. This endogeneity problem is the main reason we use cross-sectional analysis throughout the article.

important difference is the role of the short-term interest rate. In the New Keynesian model changes in the short rate matter only insofar as they influence long-term rates. In contrast, in the deposits channel the short rate matters in its own right because it affects the supply of liquid assets and the cost and composition of banks' funding. This can explain why the Fed adjusts rates gradually rather than all in one shot (Bernanke 2004; Stein and Sunderam 2015). Another important difference is that what matters in the deposits channel is the level of the short rate, not just its deviation from the natural rate. Thus, any rate change, even one that absorbs a change in the natural rate or is fully expected, has an impact on the economy and therefore represents an act of monetary policy.

The deposits channel is closely related to the bank lending channel of monetary policy (Bernanke 1983; Bernanke and Blinder 1988; Kashyap and Stein 1994). Existing theories of the bank lending channel depend on required reserves: by setting their supply, the central bank controls the size of bank balance sheets. Yet as the literature has long recognized, reserves have been far too small to exert a meaningful influence on bank balance sheets since at least the 1980s (Romer and Romer 1990; Bernanke and Gertler 1995; Woodford 2010). This has left the bank lending channel without plausible theoretical underpinnings. Moreover, since 2008 the Fed has maintained a large balance sheet funded by interest-paying excess reserves, making reserve requirements slack going forward. The deposits channel provides a new mechanism for the bank lending channel: banks' market power over deposits. In doing so, it provides a new foundation for the large empirical literature on the bank lending channel (Bernanke and Blinder 1992; Kashyap, Stein, and Wilcox 1993; Kashyap and Stein 2000; Jiménez et al. 2014).

The deposits channel is also related to the balance sheet channel of monetary policy (Bernanke and Gertler 1989; Kiyotaki and Moore 1997; Gertler and Kiyotaki 2010; He and Krishnamurthy 2013; Brunnermeier and Sannikov 2014; Brunnermeier and Koby 2016). Under the balance sheet channel, a surprise increase in interest rates causes banks' assets to decline by more than their liabilities, depressing net worth and forcing banks to shrink their balance sheets. While the balance sheet channel works through surprise changes in long-term interest rates, the deposits channel works through the level of the short rate. Moreover, while the balance sheet channel predicts that banks cut all funding to

shrink their balance sheets, the deposits channel predicts that they increase wholesale funding to partly offset outflows of deposits, which is consistent with what we observe.[4]

Our article builds on work in the banking literature emphasizing the dual role of deposits in providing liquidity to households (Diamond and Dybvig 1983; Gorton and Pennacchi 1990) and as a stable and dependable source of funding for banks (Stein 1998; Kashyap, Rajan, and Stein 2002; Hanson et al. 2015). Our article shows how monetary policy drives the supply of deposits which in turn fulfills this dual role.

Our article also contributes to the literature on deposit pricing, which focuses on the path of adjustment of deposit rates following interest rate changes (Hannan and Berger 1989, 1991; Diebold and Sharpe 1990; Neumark and Sharpe 1992; Driscoll and Judson 2013; Yankov 2014). This literature shows that this adjustment is slow and asymmetric, more so in concentrated markets. It has interpreted this as evidence of price rigidities, as emphasized in the New Keynesian framework. In contrast, our theory and analysis focus on the permanent changes in the level of deposit spreads induced by interest rate changes. Moreover, we analyze deposit quantities, which are central to the deposits channel but are largely ignored by this literature.[5] Finally, we provide much improved identification using our within-bank estimation, and we extend the analysis to look at the relationship between deposits and the asset side of bank balance sheets.

III. Aggregate Time Series of Deposit Rates and Flows

Panel A of Figure I plots the average deposit rate and the Fed funds target rate from 1986 to 2013. The deposit rate is measured

4. One might think that the deposits channel predicts that banks' net worth rises with the short rate since deposits become more profitable as banks charge higher spreads. However, the present value of deposit profits does not rise because the higher profits are discounted at a higher rate. The deposits franchise is thus similar to a floating rate bond; its cash flows increase with the short rate but its present value is unchanged. In fact, the present value of the deposit franchise decreases due to the outflows triggered by higher spreads.

5. The papers that provide a model (e.g., Yankov 2014) predict that deposits flow in when interest rates rise, which is the opposite of what we see. The reason is that these papers follow the Monti-Klein tradition (Freixas and Rochet 2008, chapter 3), in which households can either consume or hold deposits, so when deposit rates go up they consume less and hold more deposits. In our model, there is a third asset (bonds), and so when rates rise and deposit spreads widen, deposits flow out and into bonds.

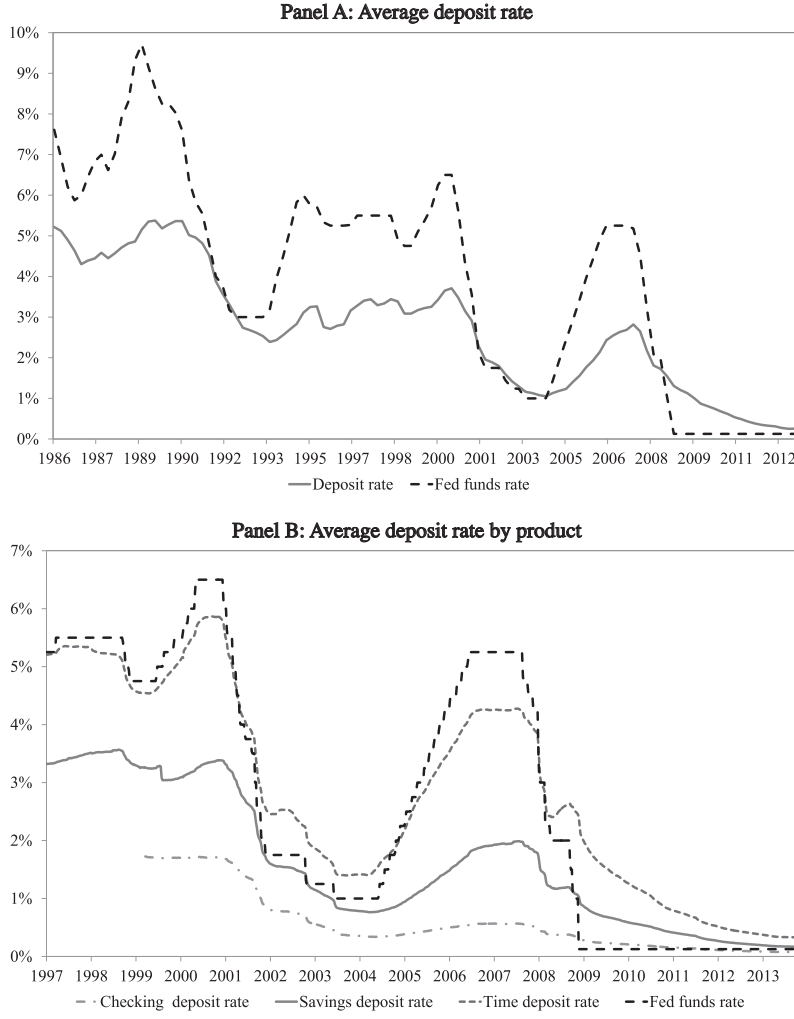


FIGURE I

Deposit Rates and Monetary Policy

The figure plots the Fed funds rate and the average interest rate paid on core deposits. Panel A plots the average deposit rate for the commercial banking sector. The data are from U.S. Call Reports covering the years 1986 to 2013. Panel B plots the Fed funds rate and the rate paid on new accounts for the three most widely offered deposit products (checking, savings, and small time deposits). The data are from RateWatch covering the years 1997 to 2013.

as the average interest rate paid on core deposits, obtained from bank balance sheet data. Core deposits are the sum of checking, savings, and small time deposits and are considered to be banks' most stable and dependable source of funding (Federal Deposit Insurance Corporation 2011). They are also by far the largest source of banks' funding, totaling $9.3 trillion or 79% of bank liabilities in 2014.

The figure reveals a striking fact: banks raise deposit rates far less than one-for-one with the Fed funds rate. For every 100 bps increase in the Fed funds rate, the spread between the Fed funds rate and the deposit rate increases by 54 bps. For instance, during the 425 bps Fed hiking cycle of the mid 2000s, the deposit spread rose by 245 bps. This spread represents the opportunity cost of holding deposits, hence deposits become much more expensive to hold when the Fed funds rate rises.

Panel B of Figure I plots the rate on the most widely offered deposit product within each of the three main categories of deposits: savings, checking, and small time deposits. In 2014, these categories accounted for $6.5 trillion, $1.7 trillion, and $1.1 trillion, respectively. Savings and checking deposits are demandable and hence highly liquid, while time deposits are locked in for term and hence relatively illiquid. We see that when the Fed funds rate rises, the increase in spreads is much stronger for the more liquid deposits. For instance, the spreads on savings and checking deposits increased by 340 bps and 470 bps, respectively, during the mid-2000s, while the spread on time deposits increased by 105 bps.

Figure II shows that deposit quantities respond strongly to these large price changes. It plots the year-over-year change in the Fed funds rate against the percentage growth rate in the aggregate amounts of core deposits (Panel A), savings (Panel B), checking (Panel C), and small time deposits (Panel D). The relationships are clear and striking. From Panel A, the growth rate of core deposits is strongly negatively related to changes in the Fed funds rate (the correlation is −49%). The effects are economically large with year-over-year growth rates ranging from −1% to +18%. Panels B and C show even larger effects for the liquid savings and checking deposits (the correlations are −59% and −33%, respectively), while Panel D shows the opposite relationship for the illiquid small time deposits (23% correlation). Thus, as the Fed funds rate rises and liquid deposits become relatively more expensive, households partly substitute toward less liquid

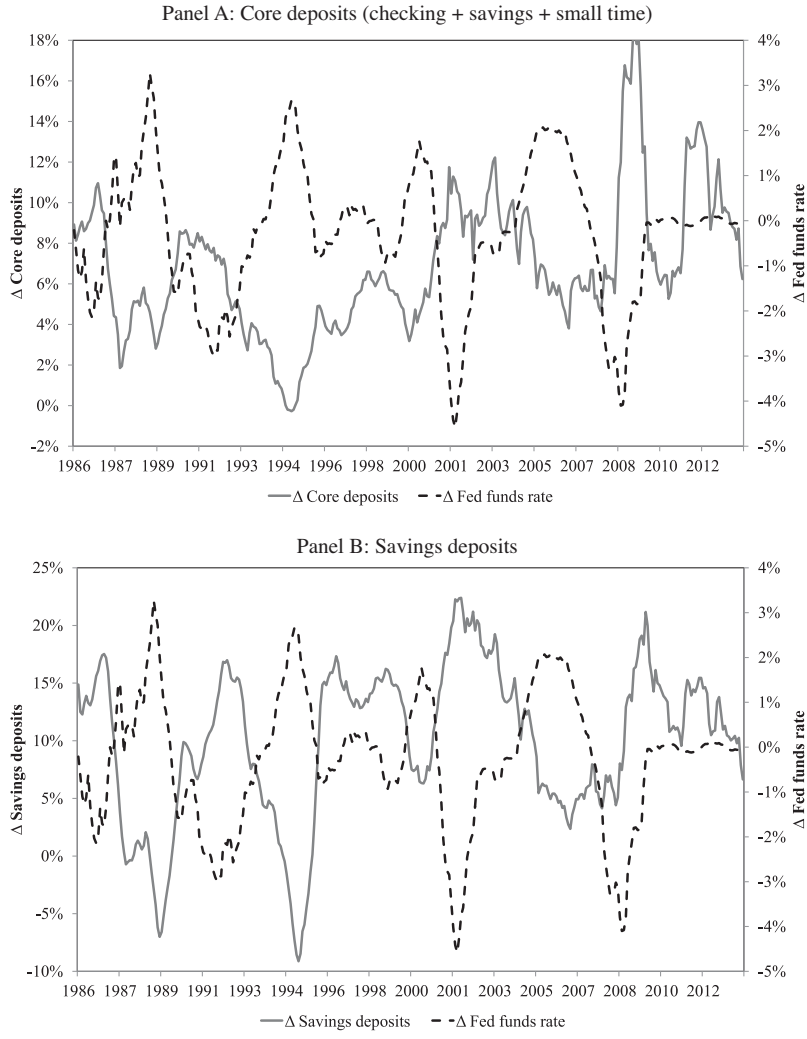


FIGURE II

Deposit Growth and Monetary Policy

This figure plots year-over-year changes in core deposits (Panel A), savings deposits (Panel B), checking deposits (Panel C), and small time deposits (Panel D) against year-over-year changes in the Fed funds rate. Core deposits are the sum of checking, savings, and small time deposits. The data are from the Federal Reserve Board's H.6 release. The sample is from January 1986 to December 2013.

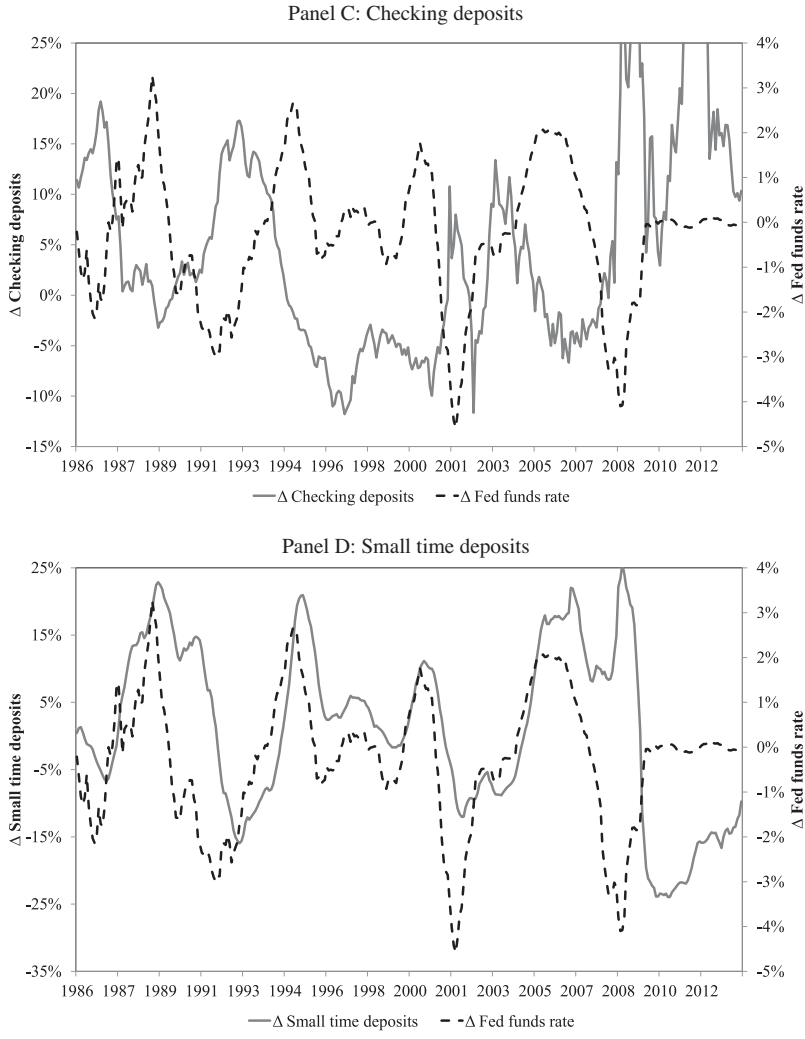


FIGURE II
(CONTINUED)

deposits. Nevertheless, since checking and savings deposits are much larger than small time deposits, the net effect is that total core deposits shrink.

From Figures I and II, monetary policy appears to shift banks' supply of deposits rather than households' demand for deposits.

This follows from the fact that prices (deposit spreads) and quantities (deposit growth) move in opposite directions. By contrast, a shift in demand would cause prices and quantities to move in the same direction. The figures also show that the shift is more pronounced for more liquid deposits. Hence, when the Fed funds rate increases, the premium for liquidity rises and the supply of liquidity shrinks.

IV. A Model of the Deposits Channel

We present a model to explain the observed relationships between monetary policy and deposit supply, as well as derive their implications for bank lending. We leave detailed derivations and proofs for the Online Appendix.

For simplicity, the economy lasts for one period and there is no risk. We think of it as corresponding to a local market—a county in our empirical analysis. The representative household maximizes utility over final wealth, W, and liquidity services, l, according to a CES aggregator:

$$u(W_0) = \max \left(W^{\frac{\rho-1}{\rho}} + \lambda l^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}}, \tag{1}$$

where λ is a share parameter, and ρ is the elasticity of substitution between wealth and liquidity services. A preference for liquidity arises in many models. For example, it arises from a cash-in-advance constraint (e.g., Galí 2009) or from a preference for extreme safety (e.g., Stein 2012). In either case, it is natural to think of wealth and liquidity as complements, hence we focus on the case $\rho < 1$.

Liquidity services are themselves derived from holding cash, M, and deposits, D, also according to a CES aggregator:

$$l(M, D) = \left(M^{\frac{\epsilon-1}{\epsilon}} + \delta D^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}}, \tag{2}$$

where ϵ is the elasticity of substitution between cash and deposits and δ measures the liquidity of deposits relative to cash. We think of cash as consisting of currency and zero-interest checking accounts. We think of deposits as representing the relatively liquid

types of household deposits, such as savings deposits.[6] Because cash and deposits both provide liquidity, they are substitutes, hence $\epsilon > 1$.

Deposits are themselves a composite good produced by a set of N banks:

$$D = \left(\frac{1}{N} \sum_{i=1}^{N} D_i^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}, \tag{3}$$

where η is the elasticity of substitution across banks. Each bank has mass $\frac{1}{N}$ and produces deposits at a rate D_i, resulting in an amount $\frac{D_i}{N}$. If all banks produce deposits at the same rate, then $D_i = D$. Deposits at different banks are imperfect substitutes, $1 < \eta < \infty$. This gives banks market power, allowing them to sustain nonzero profits.[7]

Households can also invest in a third class of assets, which provide no special liquidity (or at least less so than cash and deposits). We refer to this asset class as "bonds," but we interpret it broadly as including not only bonds but also other assets such as stocks and different types of mutual funds. These assets trade in competitive markets and can therefore be thought of as offering a common risk-adjusted rate of return. We think of this rate as being set (or at least influenced) by the central bank; hence we refer to it as the Fed funds rate and denote it by f.

Banks earn profits by raising deposits and investing in assets. For simplicity, we first assume that banks can only invest in bonds, earning the competitive rate f. In Section IV.B, we introduce profitable lending opportunities that allow banks to earn a spread in excess of f. On the deposit side, each bank i charges a spread s_i, paying a deposit rate $f - s_i$. The spread is set to maximize the bank's profits, $D_i s_i$, which gives the condition

$$\frac{\partial D_i}{\partial s_i} \frac{s_i}{D_i} = -1. \tag{4}$$

6. We model a single type of deposits for simplicity. It is straightforward to extend the model to allow for multiple deposits with varying degrees of liquidity.

7. Note that we are modeling the preferences of the representative household for the county. This representative household can be interpreted as an aggregation of many individual households, each of whom has a preference for holding deposits in whichever bank is most convenient. As a result, the representative household substitutes deposits imperfectly across banks as in equation (3).

The bank raises its spread until the elasticity of demand for its deposits is -1, at which point a further increase becomes unprofitable.

To understand the representative household's demand for deposits, it is useful to introduce the weighted average deposit spread $s \equiv \frac{1}{N}\sum_{i=1}^{N}\frac{D_i}{D}s_i$. The household's budget equation can be written as

$$W = W_0(1+f) - Mf - Ds. \tag{5}$$

Households earn the rate f on their initial wealth, forgo f on their cash holdings, and pay the deposit spread s on their deposit holdings.

Using the fact that s captures the overall cost of deposits D, we can show that in a symmetric equilibrium the elasticity of demand for bank i's deposits is given by

$$\frac{\partial D_i}{\partial s_i}\frac{s_i}{D_i} = \frac{1}{N}\left(\frac{\partial D}{\partial s}\frac{s}{D}\right) - \eta\left(1-\frac{1}{N}\right). \tag{6}$$

Equation (6) shows that as bank i increases its spread s_i, it faces outflows from two sources. The first is an aggregate effect: the increase in s_i raises the average deposit spread s at a rate of $\frac{1}{N}$, making deposits more expensive overall and inducing outflows from deposits to other assets at a rate given by the aggregate elasticity $\left(\frac{\partial D}{\partial s}\frac{s}{D}\right)$. This effect is larger in more concentrated markets because each individual bank's spread s_i has a larger impact on the overall cost of deposits s.

The second source of outflows is interbank competition: when bank i raises its spread by one percent, the average spread goes up by $\frac{1}{N}$ percent, and hence bank i's deposit spread increases by $1-\frac{1}{N}$ percent relative to the average. This then induces outflows from bank i at a rate η, the elasticity of substitution across banks.

Substituting equation (6) into equation (4), we get the equilibrium condition

$$-\frac{\partial D}{\partial s}\frac{s}{D} = 1-(\eta-1)(N-1) \equiv \mathcal{M}. \tag{7}$$

The endogenous quantity $\mathcal{M}$ captures the market power of the banking sector as a whole (i.e., of the representative bank). This market power is higher if there is less interbank competition, either because the market is more concentrated ($\frac{1}{N}$ is high) or

because deposits are less substitutable across banks (η is low). In the extreme, $\mathcal{M} = 1$, and the representative bank behaves like a pure monopolist.

To solve equation (7) for the equilibrium value of s, we need to obtain the aggregate deposit elasticity. We can do so in closed form by letting $\lambda \to 0$, which removes the impact of the cost of liquidity on total wealth and simplifies the resulting expression:

$$-\frac{\partial D}{\partial s}\frac{s}{D} = \left[\frac{1}{1+\delta^{\epsilon}\left(\frac{f}{s}\right)^{\epsilon-1}}\right]\epsilon + \left[\frac{\delta^{\epsilon}\left(\frac{f}{s}\right)^{\epsilon-1}}{1+\delta^{\epsilon}\left(\frac{f}{s}\right)^{\epsilon-1}}\right]\rho. \tag{8}$$

Equation (8) shows that households' elasticity of demand for deposits is equal to a weighted average of their elasticity of substitution to cash, ϵ, and bonds, ρ. The weight is a function of the Fed funds rate f. When f is high, cash is a comparatively expensive source of liquidity, hence any substitution out of deposits is almost entirely to bonds. Therefore, the elasticity of demand is close to ρ, which is a low number since bonds do not provide liquidity. Thus, a high f makes households' demand for deposits relatively inelastic, allowing banks to set a high spread s without incurring large outflows. Conversely, when f is low, cash becomes a less expensive source of liquidity, and hence the elasticity of demand for deposits moves toward ϵ, which is a high number since cash and deposits are substitutes. Deposit demand is then relatively elastic, forcing banks to set a low spread to avoid large outflows.

Combining equations (7) and (8) gives banks' optimal spread and the following result:

PROPOSITION 1. Let $\rho < 1 < \epsilon$, η, let $\mathcal{M} = 1 - (\eta - 1)(N - 1)$ as in equation (7), and consider the limiting case $\lambda \to 0$. If $\mathcal{M} < \rho$, then the deposit spread s is 0. Otherwise,

$$s = \delta^{\frac{\epsilon}{\epsilon-1}}\left(\frac{\mathcal{M}-\rho}{\epsilon-\mathcal{M}}\right)^{\frac{1}{\epsilon-1}} f. \tag{9}$$

It follows that

(i) the deposit spread increases with the Fed funds rate f;
(ii) $\frac{\partial s}{\partial f}$, the deposit spread beta, is increasing in banks' market power $\mathcal{M}$.

Proposition 1 shows that the deposit spread rises with the Fed funds rate. A high Fed funds rate makes demand for deposits more inelastic, effectively giving banks more market power. Banks take advantage of this and optimally charge a higher deposit spread.

Proposition 1 also shows that the deposit spread is more sensitive to f, that is, the deposit spread beta is higher, in areas where banks' market power $\mathcal{M}$ is high. Where $\mathcal{M}$ is high, banks compete less with each other and more with households' alternative source of liquidity, cash.[8] Consequently, the deposit spread depends strongly on f (the cost of cash), and the deposit spread beta is high. In contrast, where market power is low, banks compete mainly with each other, and the deposit spread beta is low.

In the empirical section we use this result to test the market power mechanism underpinning our model. Although ideally we would be able to observe $\mathcal{M}$ directly, it is sufficient to be able to measure one source of variation in $\mathcal{M}$. The source we use is geographic variation in the local level of market concentration. We proxy for this with the Herfindahl index of banks' shares of the deposit market in each county (which equals $\frac{1}{N}$ in the model).

IV.A. Limited Financial Sophistication and Market Power

Concentration is only one source of market power. Another source, which is likely important in practice, is households' level of financial sophistication. In this section we extend the model to incorporate this source. We consider two aspects of financial sophistication. The first, which we analyze here, is that some households do not keep track of deposit rates offered at other banks. They are therefore not a threat to leave their bank when it raises its deposit spread. We call these households nonswitchers. The second, which we leave for the Online Appendix, is that some households are not aware of or do not participate in the bond market. As we show, in both cases the form of the solution is very similar to that of the baseline model, but with the expression generalized to incorporate the influence of low financial sophistication on banks' market power. In the case of nonswitchers, we have the following result:

8. Although banks face competition from cash, in equilibrium they set the deposit spread so that outflows to cash are small. Indeed, as the elasticity of substitution between cash and deposits ϵ is increased, households' equilibrium cash holdings become arbitrarily small and cash is in effect just an outside option.

PROPOSITION 2. Let α_{ns} be the fraction of nonswitchers. The solution for the deposit spread remains as in equation (9), but with $\mathcal{M}$ replaced by

$$\mathcal{M}_{ns} = 1 - (\eta - 1)\left[\frac{1}{\alpha_{ns} + (1 - \alpha_{ns})\frac{1}{N}} - 1\right]. \tag{10}$$

It follows that the deposit spread beta $\frac{\partial s}{\partial f}$

(i) increases in market concentration $\frac{1}{N}$ and the fraction of nonswitchers α_{ns};
(ii) increases less in market concentration if α_{ns} is high; and
(iii) remains positive even as market concentration approaches zero ($\frac{1}{N} \to 0$), provided α_{ns} is sufficiently large (specifically, $\alpha_{ns} > \frac{\eta-1}{\eta-\rho}$).

Part (i) of Proposition 2 shows that deposit spread betas increase with the proportion of nonswitchers, because they are an additional source of market power for banks.[9] Spread betas also increase with market concentration, just as in the baseline model. However, part (ii) shows that nonswitchers flatten the relationship between concentration and spread betas. In particular, whereas in the baseline model spread betas converge to zero as market concentration approaches zero, this is no longer the case with nonswitchers (part (iii)). With a sufficiently high proportion of nonswitchers, spread betas remain strictly positive and can be large, even in areas with zero market concentration.

Finally, Proposition 2 highlights that the deposit spread beta provides a comprehensive measure of banks' market power, even when it comes from multiple sources (e.g., concentration, nonswitchers). This is also true for the second extension we develop in the Online Appendix.

IV.B. Effects on Lending and Wholesale Funding

In the baseline model banks earn the competitive rate f on their assets and hence set the size of their balance sheets solely to maximize deposit rents. We now enrich the model to allow banks to earn an additional spread on their lending, subject to decreasing marginal returns. We also allow them to borrow funds in

9. Despite this, nonswitchers do not perceive an incentive to change their behavior since they pay the same spread as switchers.

wholesale (i.e., nondeposit) markets, subject to a cost spread that is increasing in the amount borrowed. We model these two spreads using a simple quadratic cost function, so that the bank's problem is now

$$\Pi_i = \max_{D_i, H_i} \left(f + l_0 - \frac{l_1}{2} L_i \right) L_i - \left(f + \frac{h}{2} H_i \right) H_i - (f - s_i) D_i, \tag{11}$$

where $L_i = H_i + D_i$ is total lending, H is the quantity of wholesale funding, and l_0, l_1, $h > 0$ are parameters that control the bank's lending opportunities and wholesale funding costs.[10] The bank earns a profit from lending (first term), pays a cost for wholesale funding (second term), and earns profits from its deposit franchise (third term). If the bank has more deposits than profitable lending opportunities, we assume it simply buys securities that pay the competitive rate f.

The case $l_1 > 0$ captures the idea that the bank has a limited pool of profitable lending opportunities. Similarly, $h > 0$ captures a limited pool of wholesale funding, which makes the cost of wholesale funding increasing in the amount borrowed. This could arise because, unlike deposits, wholesale funding is uninsured and hence subject to adverse selection (Stein 1998), or because it is unstable, so that the bank perceives relying on wholesale funding as costly (Hanson et al. 2015).[11]

The optimality condition for wholesale funding is:

$$H_i = \frac{l_0}{l_1 + h} - \frac{l_1}{l_1 + h} D_i. \tag{12}$$

Since it has profitable lending opportunities, the bank offsets a decrease in deposits with an increase in wholesale funding. However, since wholesale funding is costly ($h > 0$), it is an imperfect substitute for deposits and hence the offset is only partial (the Modigliani-Miller theorem fails). Total lending thus depends on the level of deposits,

$$L_i = \frac{l_0}{l_1 + h} + \frac{h}{l_1 + h} D_i, \tag{13}$$

and a contraction in deposits induces a contraction in lending L_i.

10. For simplicity, we include the bank's equity funding in H.

11. The instability of wholesale funding is formally recognized by regulators (Federal Deposit Insurance Corporation 2011).

The optimality condition for deposits is now

$$(14) \qquad 0 = \frac{\partial \Pi_i}{\partial D_i} = \left(\frac{h}{l_1 + h}\right)(l_0 - l_1 D_i) + s_i \left(1 + \frac{\partial s_i}{\partial D_i}\frac{D_i}{s_i}\right).$$

The first term on the right is the marginal lending profit the bank earns from raising another dollar of deposits. The second term is the marginal profit on the bank's deposit franchise from raising this dollar. In the baseline model ($l_0 = l_1 = 0$), the deposit franchise is the bank's only source of profits, so the bank increases deposits until this marginal profit is zero. With profitable lending opportunities the bank goes further and continues raising deposits until the marginal loss of deposit rents offsets the marginal profit from lending. The bank thus gives up some of its deposit rents in order to fund a large balance sheet and take advantage of profitable lending opportunities. Nevertheless, a change in the Fed funds rate has the same effect as in the baseline model, as the following proposition shows:

PROPOSITION 3. Let $\mathcal{M} > \rho$ and consider the limiting case $\lambda \to 0$. Then the equilibrium deposit spread is positive ($s > 0$) and increases in the Fed funds rate f. In response to an increase in the rate f, banks

(i) reduce deposits D,
(ii) increase wholesale funding H, and
(iii) reduce lending L.

As in the baseline model, a higher interest rate increases banks' effective market power and induces them to contract deposit supply (the second term on the right of equation (14) is more negative). They partially offset the contraction with the expensive wholesale funding, but on net lending declines.[12] Thus, the effect of the deposits channel on bank lending is the same with profitable lending opportunities and access to wholesale funding.

12. If banks are highly liquidity-constrained, as in a crisis, then the increase in the flow of profits from deposits following a Fed funds rate increase could help alleviate their liquidity constraint and reduce their cost of wholesale funding (i.e., h would decline in f). This would partly offset the negative impact of the rate increase on lending. We stress that for such an effect to exist, it must be that the liquidity constraint is relaxed by an increase in the flow of profits, not their present value (banks' net worth) since their present value actually declines (see note 4). Our results on lending imply that if such an effect exists, it is typically small.

V. Deposits Data and Summary Statistics

V.A. Data Sources

1. Deposit Holdings. The data on deposit quantities are from the Federal Deposit Insurance Corporation (FDIC). The data cover the universe of U.S. bank branches at an annual frequency from June 1994 to June 2014. The data set has information on branch characteristics such as the parent bank, address, and geographic coordinates. We use the unique FDIC branch identifier to match it with other data sets.

2. Deposit Rates. The data on deposit rates are from Ratewatch. Ratewatch collects weekly branch-level data on deposit rates by product from January 1997 to December 2013. The data cover 54% of all U.S. branches as of 2013. We merge Ratewatch data with FDIC data using the FDIC branch identifier, focusing on counties with at least two banks. The data report whether a branch actively sets deposit rates or whether the branch uses rates that are set by another branch. We limit the analysis to branches that actively set rates to avoid duplication of observations.[13] The data contain deposit rates on new accounts by product. Our analysis focuses on the two most commonly offered deposit products across all U.S. branches, money market deposit accounts with an account size of $25,000 ($25K money market accounts) and 12-month certificates of deposit with an account size of $10,000 ($10K 12-month CDs). These products are representative of savings and time deposits, which are the two main deposit types.

3. Bank Data. The bank data are from U.S. Call Reports provided by the Federal Reserve Bank of Chicago. We use data from January 1994 to December 2013. The data contain quarterly data on the income statements and balance sheets of all U.S. commercial banks. We match the bank-level Call Reports to the branch-level Ratewatch and FDIC data using the FDIC bank identifier.

4. Small Business Lending Data. We collect data on small business lending from the National Community Reinvestment Coalition (NCRC). The data cover small business lending by bank and county at an annual frequency from January 1997 to December 2013. We compute total new lending as the total amount of new loans of less than $1 million. We include all bank-county

13. Our analysis shows that there is enough variation among rate-setting branches to identify the effect of market power on deposits. There is about one rate-setting branch for every three non–rate-setting branches in the data.

observations with at least $100,000 of new lending. We merge the data with the Call Reports using the Call Reports identifier.

5. Fed Funds Data. We collect the Fed funds target rate and the one-year T-bill rate from Federal Reserve Economic Data (FRED). We compute the average of the upper and lower Fed funds rate target after the introduction of a target rate corridor in 2008. We collect Fed funds futures rates from Datastream. We compute the expected component of the change in the Fed funds rate in a given quarter as the difference between the three-month Fed funds futures rate and the Fed funds rate target as of the end of the previous quarter.

6. County Data. We collect data on county characteristics from the 2000 U.S. Census and County Business Patterns. We collect data on total employment and wage bill per county and year from the Bureau of Labor Statistics.

V.B. Summary Statistics

Our empirical analysis uses variation in market concentration, which we measure using a standard Herfindahl index (HHI). This measure is used by bank regulators and the U.S. Department of Justice to evaluate the effect of bank mergers on competition. The HHI is calculated by summing up the squared deposit-market shares of all banks that operate branches in a given county in a given year, and then averaging over all years. We then assign to each bank branch in our data the HHI of the county in which it is located, and refer to it as its Branch-HHI.

Figure III presents a map of Branch-HHI across the United States. A lower number indicates a lower level of concentration and hence a higher level of competition. There is significant variation across counties, from a minimum Branch-HHI of 0.06 to a maximum of 1.

Panel A of Table I provides summary statistics at the county level for all counties with at least one bank branch. We find that low-concentration (low HHI) counties are larger than high-concentration (high HHI) counties, with an average population of 150,081 versus 28,717. They also have a higher median household income ($45,816 versus $38,550), a lower share of individuals over age 65 (14% versus 15%) and a higher share of college graduates (19% versus 14%).

Panel B presents branch-level summary statistics for the FDIC data. The average branch holds $67 million worth of

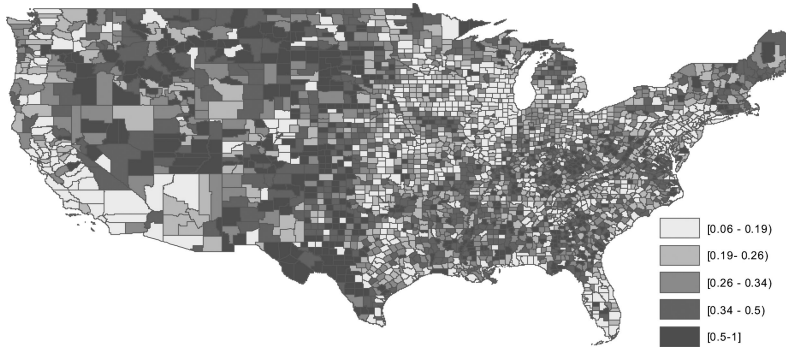


FIGURE III

Concentration in Local Deposit Markets

This map shows the Herfindahl index for each U.S. county. The Herfindahl is calculated each year using the deposit market shares of all banks with branches in a given county and then averaged over the period from 1994 to 2013. The underlying data are from the FDIC.

deposits. Branches in low-concentration areas are slightly smaller ($59 million versus $75 million) and have higher deposit growth (8.6% versus 6.8%), than branches in high-concentration areas. Panel C provides branch-level summary statistics for the Ratewatch data. The average branch in Ratewatch is larger than those in the FDIC data with average deposits of $143 million. The deposit spread is computed quarterly as the difference between the Fed funds rate and the rate paid on a given type of deposit.[14] Changes in savings deposit spreads ($25K money market accounts) have a mean of −3 bps and a standard deviation of 49 bps (this includes variation in both the cross section and time series). For time deposits ($10K 12-month CDs) the mean is 0 bps, and the standard deviation is 37 bps.

Panel D presents summary statistics at the bank level. For our bank-level analysis we compute a bank-level measure of concentration, Bank-HHI, which is defined as the weighted average of Branch-HHI across all of a bank's branches, using branch deposits for the weights. Banks with low Bank-HHI are slightly smaller, $805 million versus $1,230 million, and have slightly fewer branches (9 versus 11). Both low- and high-Bank-HHI banks

14. In addition to the deposit spread, households also incur fees when holding deposits. Omitting fees does not affect our analysis because they do not vary with the Fed funds rate (Stiroh 2004).

TABLE I

DESCRIPTIVE STATISTICS

	All		Low HHI		High HHI	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Panel A: County characteristics (2000 census)						
Population	90,845	294,719	150,081	394,457	28,717	85,292
Area (sq. mile)	1,057	2,484	903	1,279	1,217	3,299
Median income ($)	42,183	9,844	45,816	10,155	38,550	8,021
Over 65 (%)	14.78	4.14	14.18	4.02	15.37	4.17
College degree (%)	16.55	7.81	18.82	8.53	14.27	6.23
Branch-HHI	0.35	0.20	0.20	0.05	0.49	0.20
Obs. (counties)	3,104		1,552		1,552	
Panel B: Branch characteristics (FDIC)						
Deposits (mill. $)	67.18	878.2	59.47	271.5	74.89	1,212.0
Deposit growth (%)	7.71	25.36	8.58	26.62	6.84	24
ΔFF	−0.25	1.44	−0.26	1.44	−0.24	1.44
Branch-HHI	0.22	0.11	0.15	0.03	0.29	0.11
Obs. (branch×year)	1,310,111		654,840		655,271	
Panel C: Branch characteristics (Ratewatch)						
Deposits (mill. $)	142.6	1,108	112.9	408.4	172.3	1,512
ΔSpread (savings)	−0.03	0.49	−0.03	0.49	−0.03	0.49
ΔSpread (time)	0.00	0.37	0.00	0.37	−0.01	0.37
Branch-HHI	0.22	0.09	0.15	0.03	0.29	0.07
Obs. (branch×quarter)	412,008		205,749		206,259	
Panel D: Bank characteristics (Call Reports)						
Assets (mill. $)	1,028	21,961	805	12,308	1,230	28,004
Deposits/Liab. (%)	94.19	7.09	93.92	7.21	94.44	6.97
Branches	10.01	81.81	9.05	71.77	10.93	90.32
Bank-HHI	0.24	0.14	0.15	0.04	0.33	0.13
Obs. (bank×quarter)	558,739		279,364		279,375	
Panel E: Small business lending (NCRC)						
New lending (mill. $)	5.76	22.99	6.31	24.44	5.22	21.43
New lending (log)	6.88	1.63	6.95	1.65	6.82	1.61
Assets (bill. $)	132.1	308.2	121.9	306.1	142.4	310.0
Bank-HHI	0.26	0.14	0.18	0.04	0.34	0.15
Obs. (bank×county×year)	620,443		310,210		310,233	

Notes. This table provides summary statistics at the county, branch, bank, and county-bank levels. All panels provide a breakdown by high and low Herfindahl (HHI) using the median HHI for the respective sample. Panel A presents county characteristics for all U.S. counties with at least one bank branch. The underlying data are from the 2000 census. Panel B presents data on deposit holdings and deposit growth. The underlying data are from the FDIC from June 1994 to June 2013. Panel C presents data on deposit spreads. The underlying data are from Ratewatch from January 1997 to December 2013. Panel D presents data on bank characteristics. The underlying data are from the Call Reports from 1994 to 2013. Panel E presents small business lending data. The underlying data are from the NCRC for the years 1997 to 2013.

are highly dependent on deposits, which make up about 94% of their total liabilities.

Panel E provides summary statistics on small business lending, which is reported at the bank-county level. The average annual amount of new lending by a given bank in a given county is $5.8 million. The average loan is made by a bank with total assets of $132 billion.

VI. Results on Deposits

The aggregate evidence in Section III shows that a higher Fed funds rate is associated with an inward shift of the deposit supply curve (higher prices, lower quantities). Yet showing that this is a direct causal effect as implied by our theory is challenging because of the potential for omitted variables. The most important omitted variable is banks' lending opportunities. If raising the Fed funds rate causes lending opportunities to decline, then this could explain why banks contract deposit supply even absent a deposits channel.[15] Thus, to establish a direct causal effect of monetary policy on deposit supply, we must control for lending opportunities.

VI.A. Identification Strategy

We address this challenge by turning to the cross section, where we exploit geographic variation in market power induced by differences in the concentration of local deposit markets. Under the deposits channel, deposit supply should be more sensitive to monetary policy in more concentrated deposit markets. This prediction forms the basis of our analysis, and it gets directly at the market power mechanism underpinning our theory.

A valid test requires variation in concentration that is independent of banks' lending opportunities. We obtain such variation by comparing the supply of deposits across branches of the same bank located in counties with different concentration. Since a bank can raise a dollar of deposits at one branch and lend it at another, the decision of how many deposits to raise at a given branch is independent of the decision of how many loans to make

15. It is also plausible that lending opportunities are positively related to the Fed funds rate, since the Fed tends to tighten when the economy is booming. Since better lending opportunities ought to increase deposit supply, not decrease it, the aggregate time series may be understating the magnitude of the deposits channel. Our cross-sectional estimates in Section VIII.B support this view.

at that branch. By comparing across branches of the same bank, we can control for the bank's lending opportunities and identify the effect of concentration on the sensitivity of deposit supply to monetary policy. We refer to this approach as within-bank estimation.

The identifying assumption behind our within-bank estimation is that banks allocate funds internally to equalize the marginal return to lending across their branches.[16] This assumption is implied by the banks' profit maximization motive. It is supported empirically by our results on lending in Section VII, which show that a bank's lending in a given county is unrelated to local deposit-market concentration. It is also supported by the evidence in the banking literature (Gilje, Loutskina, and Strahan 2016), which shows that banks channel deposits to areas with high loan demand.

VI.B. Branch-Level Estimation

Before implementing the within-bank estimation, we analyze the behavior of deposit spreads and flows across all branches of all banks. We do so by running the following time-series regression for each branch i:

$$\Delta y_{it} = \alpha_i + \beta_i \Delta FF_t + \varepsilon_{it}, \tag{15}$$

where Δy_{it} is either the change in the deposit spread or the log change in total deposits (deposit flow) of branch i from t to $t+1$, and ΔFF_t is the contemporaneous change in the Fed funds target rate. The frequency is quarterly for deposit spreads (Ratewatch data). It is annual for flows (FDIC data), and we require at least 20 observations per branch given the high volatility of branch-level flows. Depending on the specification, we refer to β_i as either the spread or flow beta of branch i. It captures the sensitivity of the price of deposits (spread beta) or quantity of deposits (flow beta) at branch i to changes in the Fed funds rate.[17]

16. A slightly weaker version of the identifying assumption is that any frictions to allocating funds internally are uncorrelated with concentration at the branch level.

17. We use the deposit spread as the outcome variable because it measures the price of deposits in terms of forgone interest income. Using the deposit rate instead would give the same result because the sensitivity of the deposit rate to changes in the Fed funds rate is by construction $1 - \beta_i$.

We relate these spread and flow betas to local concentration. We first average the betas of all branches within each county, winsorizing at the 1% level to minimize the influence of outliers. We then sort all counties into twenty equal-sized bins according to their concentration as measured by their Herfindahl index (HHI). Each bin contains about 131 counties. We look separately at the spreads on savings deposits ($25K money market accounts) and small time deposits ($10K 12-month CDs), and at total deposit flows.

Panel A of Figure IV presents the results for savings deposit spreads. It shows that spreads increase more with the Fed funds rate in more concentrated counties. The average spread beta increases from 0.63 in low-concentration counties (HHI below the 10th percentile) to 0.75 in high-concentration counties (HHI above the 90th percentile). In other words, following a 100 bps increase in the Fed Funds rate, savings deposit spreads rise by 12 bps more in high-concentration counties than low-concentration counties. The relationship is roughly linear across all bins, indicating that the result is robust.

Panel B presents the results for small time deposit spreads. Here we use the one-year T-bill rate instead of the Fed funds rate to match the maturity of the deposit.[18] As with savings deposits, the spreads on time deposits increase more with the T-bill rate in more concentrated counties. The average spread beta is 0.26 in low-concentration counties and 0.31 in high-concentration counties. The fact that the spread betas for small time deposits are lower than for savings deposits is consistent with the aggregate evidence in Figure I.

Panel C presents the results for deposit growth. It shows that when the Fed funds rate rises deposits flow out more in more concentrated counties. The average flow beta is 0.18 in low-concentration counties and −0.20 in high-concentration counties. Thus, following a 100 bps increase in the Fed Funds rate, deposits flow out by 38 bps more in high-concentration counties than low-concentration counties.

Taken together, Panels A, B, and C of Figure IV show that when the Fed funds rate rises, banks raise deposit spreads by more and experience greater outflows in more concentrated markets.[19] This shows that the sensitivity of deposit supply to

18. The results are robust to using the Fed funds rate instead.

19. As with the aggregate time series, our cross-sectional results indicate a shift in the deposit supply curve as prices (spreads) and quantities (deposit growth)

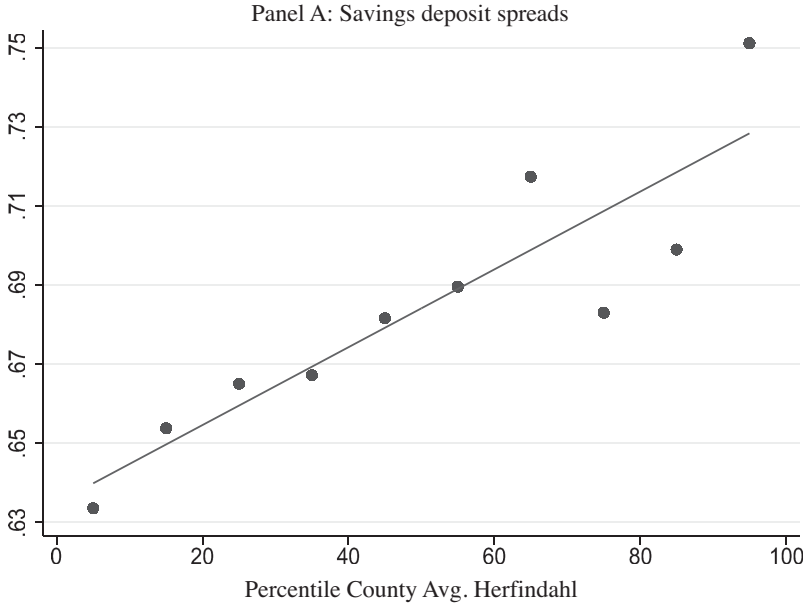


FIGURE IV

Spread and Flow Betas by Market Concentration

This figure shows the relationship between market concentration and the sensitivities of deposit spreads and flows to the Fed funds rate. The figure is constructed in two steps. The first is to estimate spread and flow betas using a time-series regression for each branch i: $\Delta y_{it} = \alpha + \beta_i \Delta FF_t + \varepsilon_{it}$, where Δy_t is either the change in the deposit spread or the log change in deposits (deposit flow) from date t to $t + 1$ and ΔFF_t is the change in the Fed funds target rate from t to $t + 1$. The second step is to average betas by county and then sort counties into 20 bins by market concentration and compute average betas by bin. Panel A shows the results for savings deposit spreads. Panel B shows the results for time deposit spreads. Panel C shows the results for deposit flows. The data for Panels A and B are from Ratewatch covering January 1997 to December 2013. The data for Panel C are from the FDIC covering January 1994 to December 2013.

monetary policy is increasing in concentration, as predicted by the deposits channel.

VI.C. Within-Bank Estimation

We now implement our within-bank estimation strategy to control for differential changes in banks' lending opportunities.

move in opposite directions. They therefore cannot be explained by changes in household demand for deposits. For instance, if deposit demand increased by more in more concentrated counties, then deposit spreads in these counties would rise by more, but so would deposit growth, which is the opposite of what we see.

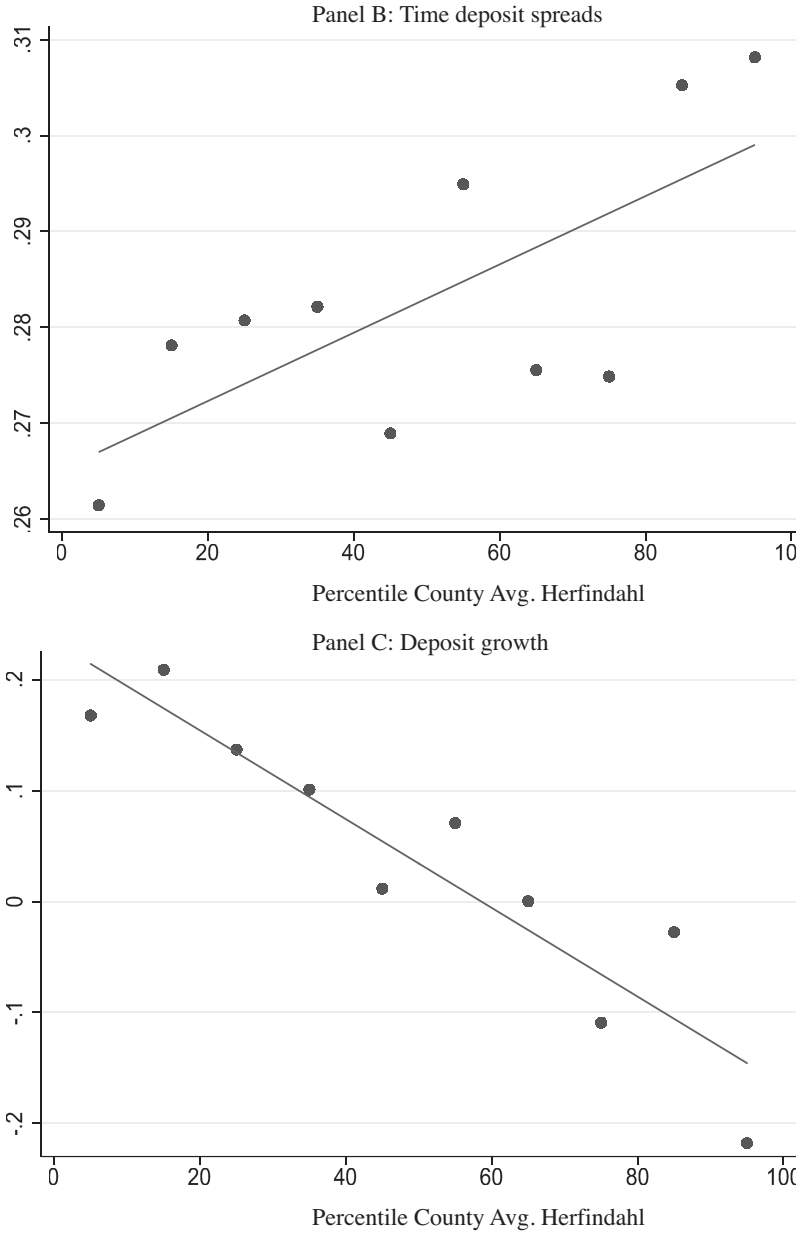


FIGURE IV
(CONTINUED)

We do so by including bank-time fixed effects (among others) in the following panel regression:

$$(16)\quad \Delta y_{it} = \alpha_i + \zeta_{c(i)} + \lambda_{s(i)t} + \delta_{j(i)t} + \gamma \Delta FF_t \times \text{Branch-HHI}_i + \varepsilon_{it},$$

where Δy_{it} is either the change in the deposit spread or the log change in total deposits (deposit flows) of branch i from t to $t+1$, ΔFF_t is the contemporaneous change in the Fed funds target rate, Branch-HHI$_i$ is the concentration of the county where branch i is located, $\delta_{j(i)t}$ are bank-time fixed effects for bank j which owns branch i, and α_i, $\zeta_{c(i)}$, and $\lambda_{s(i)t}$ are branch, county, and state-time fixed effects, respectively.[20] We cluster standard errors at the county level.

The key set of controls are the bank-time fixed effects $\delta_{j(i)t}$, which absorb all time-varying differences between banks. Intuitively, we are comparing branches of the same bank and asking whether, following an increase in the Fed funds rate, the bank's branches in more concentrated counties raise deposit spreads more and experience larger outflows relative to its branches in less concentrated counties. Doing so controls for any changes in banks' lending opportunities under our identifying assumption that banks are able to allocate funds internally.

The remaining sets of fixed effects serve as additional controls. Branch fixed effects control for branch-specific characteristics (e.g., the quality of the branch's management). County fixed effects control for county-specific factors (e.g., local economic trends).[21] We also interact the county fixed effects with a dummy variable for the zero-lower bound period (after December 2008) to control for regional differences during this prolonged period when the Fed funds rate, our key right-hand variable, remained constant. State-time fixed effects control for state-level changes in deposit markets (e.g., changing state-level regulation). Finally, whenever we take out the bank-time fixed effects, we add time

20. By running our estimation in first differences we are implicitly assuming that deposit supply adjusts contemporaneously to changes in the Fed funds rate. This is preferable to estimation in levels from an identification standpoint because it controls for other factors that might vary with monetary policy over longer periods of time or with a lag. As a robustness test, in the Online Appendix we also run regressions in levels, which allows for slower adjustments in deposit supply, and find similar results.

21. Branch and county fixed effects are highly collinear in joint specifications as only a tiny fraction of branches ever change counties.

fixed effects to absorb average changes in deposit spreads and flows. We run several specifications with different combinations of fixed effects to gauge their effects and the robustness of our results.

As before, we use quarterly data for deposit spreads (Ratewatch data) and annual data for deposit flows (FDIC data). We focus on the sample of banks with branches in at least two counties because the coefficient of interest, γ, is not identified for single-county banks when bank-time fixed effects are included. For comparison, we also provide estimates for the full sample of banks but without the bank-time fixed effects.[22]

Panel A of Table II reports the results for savings deposit spreads. Column (1) contains our preferred specification with the full set of fixed effects. It confirms that the sensitivity of savings deposit spreads to the Fed funds rate is increasing in concentration, even within banks. When the Fed funds rate rises by 100 bps, banks raise deposit spreads by 14 bps more at their branches in high-concentration counties than at their branches in low-concentration counties.[23] Column (2) omits the state-time fixed effects, while column (3) features only county and time fixed effects. The coefficients are similar to those in column (1). Columns (4) to (6) estimate the same specifications as in columns (1) to (3) but for the full sample without bank-time effects. The coefficients are slightly larger, consistent with the intuition that pricing power varies somewhat more across banks than within them.

Panel B of Table II reports similar results for small time deposit spreads. As before, we replace the Fed funds rate with the one-year T-bill rate to match the maturity of time deposits (results are similar if we use the Fed funds rate). Column (1) shows that the sensitivity of small time deposit spreads to the T-bill rate is 7 bps higher for high-concentration branches than for low-concentration branches of the same bank. This result continues to hold when we take out the state-time fixed effects (column (2)) or include only county and time fixed effects (column (3)). As with savings deposit spreads, the coefficients for the full

22. By construction, when bank-time fixed effects are included the coefficient estimates for the full sample are identical to those for the sample of banks with branches in at least two counties.

23. Using a different methodology and sample, Neumark and Sharpe (1992) estimate coefficients that imply a similar sensitivity with respect to concentration.

TABLE II

DEPOSIT SPREADS AND MONETARY POLICY

	ΔSpread					
	≥2 Counties			All		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Savings deposits						
ΔFF × Branch-HHI	0.140***	0.101***	0.099**	0.199***	0.155***	0.159***
	(0.033)	(0.031)	(0.043)	(0.028)	(0.026)	(0.026)
Bank × quarter f.e.	Y	Y	N	N	N	N
State × quarter f.e.	Y	N	N	Y	N	N
Branch f.e.	Y	Y	N	Y	Y	N
County f.e.	Y	Y	Y	Y	Y	Y
Quarter f.e.	Y	Y	Y	Y	Y	Y
Observations	117,683	117,683	117,683	412,008	412,008	412,008
R^2	0.810	0.799	0.559	0.659	0.650	0.645
Panel B: Time deposits						
ΔT-bill × Branch-HHI	0.074***	0.073***	0.156***	0.156***	0.119***	0.119***
	(0.025)	(0.026)	(0.037)	(0.026)	(0.024)	(0.023)
Bank × quarter f.e.	Y	Y	N	N	N	N
State × quarter f.e.	Y	N	N	Y	N	N
Branch f.e.	Y	Y	N	Y	Y	N
County f.e.	Y	Y	Y	Y	Y	Y
Quarter f.e.	Y	Y	Y	Y	Y	Y
Observations	121,990	121,990	121,990	430,050	430,050	430,050
R^2	0.808	0.796	0.442	0.513	0.492	0.488

Notes. This table estimates the effect of Fed funds rate changes on deposit spreads. The data are at the branch-quarter level and covers January 1997 to December 2013. In columns (1) to (3) the sample consists of banks with branches in two or more counties. In columns (4) to (6) the sample consists of all banks. ΔSpread is the change in branch-level deposit spread, which is equal to the change in the Fed funds target rate minus the change in the deposit rate. Branch-HHI measures market concentration in the county where a branch is located. ΔFF is the change in the Fed funds target rate. ΔT-bill is the change in the one-year T-bill rate. Panel A reports the results for savings deposits. Panel B reports the results for time deposits. The data are from Ratewatch. Fixed effects (f.e.) are denoted at the bottom of each panel. Standard errors are clustered by county. **, *** indicates significance at the 0.05 and 0.01 levels, respectively.

sample without bank-time fixed effects (columns (4)–(6)) tend to be slightly larger.

Table III presents the results for deposit flows. It confirms that an increase in the Fed funds rate leads to bigger outflows in more concentrated markets. Column (1) shows that a 100 bps Fed funds rate increase leads to 66 bps greater deposit outflows at high-concentration branches than at low-concentration branches belonging to the same bank. The effect is slightly larger when we omit the state-time fixed effects (column (2)) or include only county and time fixed effects (column (3)). The effect is also slightly larger for the full sample without bank-time fixed effects (columns (4)–(6)).

TABLE III

DEPOSIT GROWTH AND MONETARY POLICY

	Δlog Deposits					
	≥2 Counties			All		
	(1)	(2)	(3)	(4)	(5)	(6)
ΔFF × Branch-HHI	−0.661***	−1.008***	−0.826***	−1.827***	−1.796***	−0.963***
	(0.254)	(0.331)	(0.246)	(0.198)	(0.242)	(0.212)
Bank × year f.e.	Y	Y	N	N	N	N
State × year f.e.	Y	N	N	Y	N	N
Branch f.e.	Y	Y	N	Y	Y	N
County f.e.	Y	Y	Y	Y	Y	Y
Quarter f.e.	Y	Y	Y	Y	Y	Y
Observations	1,150,049	1,150,049	1,150,049	1,310,111	1,310,111	1,310,111
R^2	0.344	0.336	0.025	0.230	0.221	0.025

Notes. This table estimates the effect of Fed funds rate changes on deposit growth. The data are at the branch-year level and cover the years 1994 to 2013. In columns (1) to (3) the sample consists of all banks with branches in two or more counties. In columns (4) to (6) the sample consists of all banks. Deposit growth is the log change in deposits at the branch level. Branch-HHI measures market concentration in the county where a branch is located. ΔFF is the change in the Fed funds target rate. The data are from the FDIC. Fixed effects are denoted at the bottom of the table. Standard errors are clustered by county. *** indicates significance at the 0.01 level.

The estimates in Tables II and III are consistent with profit maximization as required by our model. In particular, our estimates imply that profits from deposit taking increase more with the Fed funds rate in more concentrated markets.[24]

The results in Tables II and III show the effect of concentration on the sensitivity of deposit spreads and flows to monetary policy. Yet as highlighted by the model, concentration is just one source of market power. To help assess the overall effect of market power, we compute the semi-elasticity of deposit flows to deposit spreads implied by our estimates. This semi-elasticity is −5.3, hence there is a 530 bps contraction in deposits per 100 bps increase in the deposit spread.[25] Since deposit spreads on average rise by 61 bps per 100 bps rise in the Fed funds rate, this number is economically large. As we show in Section VIII.A, we get a very

24. Assuming that the cost of operating a deposit franchise is largely fixed, the percentage change in profits before fixed costs is equal to the percentage change in deposit spreads plus the percentage change in deposit quantities. The average deposit spread in our sample is about 108 bps, hence the 14 bps increase in Table II represents a 13% increase in deposit spreads, which easily offsets the 66 bps outflow in Table III.

25. The semi-elasticity is computed as the coefficient in column (1) of Table III divided by the weighted average of the coefficients in Table II, Panels A and B, column (1) using the relative share of savings and small time deposits as weights.

similar estimate using a comprehensive measure of market power that does not rely on concentration, and this estimate can account for the entire transmission of monetary policy to bank balance sheets documented by the bank lending channel literature.

VI.D. Event Study Analysis

In this section we exploit the weekly frequency of our deposit rate data to conduct an event study. Every six weeks or so, the Fed's Open Market Committee (FOMC) announces an updated target for the Fed funds rate. By looking at deposit spreads over a narrow window around FOMC announcements, we can pinpoint the direct effect of monetary policy on deposit pricing.

We focus on savings deposits because they have zero maturity, and hence their rates should respond within a short period of a rate change.[26] We run the event study by estimating the following OLS regression:

$$(17)\quad \Delta y_{it} = \alpha_t + \zeta_{c(i)} + \sum_{\tau=-5}^{5} \gamma_\tau \text{Branch-HHI}_{c(i)} \times \Delta FF_{t-\tau} + \varepsilon_{it},$$

where Δy_{it} is the change in the deposit spread of branch i from week t to $t+1$, $\Delta FF_{t-\tau}$ is the change in the Fed funds target rate from week $t-\tau$ to $t-\tau+1$, Branch-HHI$_{c(i)}$ is the concentration of county $c(i)$ in which branch i is located, α_t are time fixed effects, and $\zeta_{c(i)}$ are county fixed effects. We include five leads and lags of the change in the Fed funds rate to encompass the full six-week FOMC window. We compute the running sum of the coefficients γ_τ (i.e., $\sum_{\tau=-5}^{t} \gamma_\tau$, $t = -5, \ldots, 5$), which captures the cumulative differential response of deposit spreads to Fed funds rate changes in low- versus high-concentration counties. We also compute the associated 95% confidence intervals, taking into account the covariances between the errors in the coefficient estimates.

Figure V plots the result. It shows that savings deposit spreads at high-concentration branches rise relative to those at low-concentration branches in response to an increase in the Fed funds rate. Importantly, the differential response occurs almost immediately at the time of a Fed funds rate change in week 0. There is no differential response in the weeks leading up to the rate change. In the week of the rate change, the differential

26. By contrast, time deposits have longer maturities, and hence their rates should adjust ahead of time.

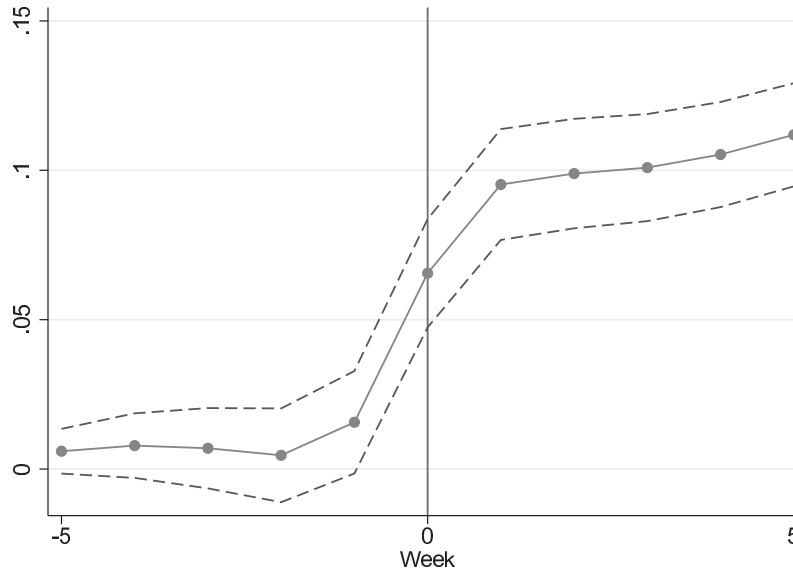


FIGURE V

Deposit Spreads and Monetary Policy (Event Study)

This figure shows the effect of Fed funds rate changes on deposit spreads at a weekly frequency. The figure plots the coefficient sum $\sum_{-5}^{t} \gamma_\tau, t = -5, \ldots, 5$ (week 0 corresponds to an FOMC meeting), and associated 95% confidence interval, estimated from the regression $\Delta y_{it} = \alpha_t + \zeta_{c(i)} + \sum_{\tau=-5}^{5} \gamma_\tau \text{Branch-HHI}_{c(i)} \times \Delta FF_{t-\tau} + \varepsilon_{it}$, where Δy_{it} is the change in the savings deposit spread of branch i from week t to $t+1$, $\Delta FF_{t-\tau}$ is the change in the Fed funds target rate from week $t-\tau$ to $t-\tau+1$, and Branch-HHI$_{c(i)}$ is the concentration of county $c(i)$ in which branch i is located. The data are from Ratewatch covering January 1997 to December 2013.

response is about 6 bps. It then accumulates to about 11 bps over the next two weeks and remains constant after that. The result is strongly statistically significant.

This finding provides strong evidence for a direct effect of monetary policy on deposit pricing that increases with market concentration. The cumulative magnitude is very close to the estimates from the quarterly regressions in Table II, suggesting that the effect is permanent. The precise timing of the effect strongly suggests that it is a direct response to the FOMC announcement.

VI.E. Expected Rate Changes

The results of the event study establish a direct effect of monetary policy on deposit pricing. This effect could come from the

actual Fed funds rate change or new information that is conveyed at the same time. Specifically, the Fed has access to private information (e.g., through its role as a bank supervisor) and FOMC announcements may contain news beyond the change in the Fed funds rate target. Disentangling Fed funds rate changes from the news they convey is a challenging problem that confounds nearly all empirical studies of monetary policy (e.g., Kuttner 2001; Bernanke and Kuttner 2005). We are uniquely able to address it in our setting by examining the impact of expected Fed funds rate changes.

Expected rate changes by construction do not convey any news and therefore control for the release of information. Yet typically they cannot be used because most assets (e.g., stocks and bonds) are long-lived, hence their prices incorporate information about future rates in advance and only react to unexpected rate changes. Savings deposits, on the other hand, have zero maturity and should therefore react to a rate change when it occurs, regardless of whether it is expected or unexpected. This allows us to disentangle the effect of the Fed funds rate itself from any confounding news release.

We implement this approach by replacing the total Fed funds rate change in the deposit spreads regression (16) with its expected and unexpected components, which we compute using Fed funds futures prices. Table IV presents the results. As column (1) shows, a 100 bps expected increase in the Fed funds rate raises deposit spreads in high-concentration counties by 22 bps relative to low-concentration counties. The effect of an unexpected increase is somewhat smaller at 11 bps, but the difference is not statistically significant. The results are similar in specifications without state-time fixed effects (column (2)), with only county and time fixed effects (column (3)), and in the full sample (columns (4)–(6)). The result on expected rate changes in particular indicates that monetary policy affects deposit pricing through the Fed funds rate itself, as implied by our model.

VI.F. Financial Sophistication and Market Power

Our tests so far exploit differences in market concentration as a source of variation in banks' market power. Yet our model shows that market power is also a function of other characteristics such as the financial sophistication and attentiveness of depositors (Proposition 2). Our model predicts that deposit spreads are

TABLE IV

DEPOSIT SPREADS AND EXPECTED CHANGES IN MONETARY POLICY

	ΔSpread					
	≥2 Counties			All		
	(1)	(2)	(3)	(4)	(5)	(6)
ΔExp. FF × Branch-HHI	0.217***	0.148**	0.190**	0.256***	0.186***	0.190***
	(0.074)	(0.072)	(0.076)	(0.047)	(0.046)	(0.045)
ΔUnexp. FF × Branch-HHI	0.114*	0.081	0.016	0.200***	0.156***	0.161***
	(0.061)	(0.056)	(0.071)	(0.040)	(0.035)	(0.036)
Bank × quarter f.e.	Y	Y	N	N	N	N
State × quarter f.e.	Y	N	N	Y	N	N
Branch f.e.	Y	Y	N	Y	Y	N
County f.e.	Y	Y	Y	Y	Y	Y
Quarter f.e.	Y	Y	Y	Y	Y	Y
Observations	117,683	117,683	117,683	412,008	412,008	412,008
R^2	0.810	0.799	0.559	0.659	0.650	0.645

Notes. This table estimates the effect of expected Fed funds rate changes on deposit spreads. The data are at the branch-quarter level from January 1997 to December 2013. In columns (1) to (3) the sample consists of banks with branches in two or more counties. In columns (4) to (6) the sample consists of all banks. The analysis focuses on savings deposits because they have zero maturity. ΔExp. FF is the expected change in the Fed funds rate computed as the Fed Funds target rate minus the three-month Fed funds futures rate at the start of a quarter. ΔUnexp. FF is the unexpected change in the Fed funds rate, computed as the difference between the realized change and the expected change. The other variables are defined in Table II. Fixed effects are denoted at the bottom of each panel. Standard errors are clustered by county. *, **, *** indicates significance at the 0.1, 0.05, and 0.01 levels, respectively.

more sensitive to changes in the Fed funds rate in areas with low levels of financial sophistication.

We test this prediction using three common proxies for financial sophistication that are available at the county level: age (share of individuals over 65), income (natural log of median household income), and education (share of college graduates). We include these proxies interacted with the Fed funds rate change in our benchmark regressions (16) for deposit spreads and flows.

Panel A of Table V presents the results for savings deposit spreads. We use the full sample and control for branch, county, and state-time fixed effects. We find that low financial sophistication has the same effect as market concentration. As columns (1) to (3) show, branches in counties with an older population, lower median household income, and less college education increase spreads by more than branches in other counties when the Fed funds rate rises. When we include all three proxies in the same regression, college education remains statistically significant while the other

TABLE V
DEPOSITS, MONETARY POLICY, AND FINANCIAL SOPHISTICATION

	ΔSpread			
	(1)	(2)	(3)	(4)
Panel A: Deposit spreads				
ΔFF × Branch-HHI	0.144***	0.086***	0.086***	0.073**
	(0.029)	(0.029)	(0.028)	(0.029)
ΔFF × Age	0.402***			0.026
	(0.072)			(0.076)
ΔFF × Income		−0.127***		−0.035*
		(0.015)		(0.021)
ΔFF × College			−0.315***	−0.256***
			(0.034)	(0.046)
All f.e.	Y	Y	Y	Y
Observations	411,976	411,976	411,976	411,976
R^2	0.659	0.659	0.659	0.659
	Δlog Deposits			
	(1)	(2)	(3)	(4)
Panel B: Deposit growth				
ΔFF × Branch-HHI	−1.273***	−1.512***	−1.597***	−1.268***
	(0.197)	(0.213)	(0.209)	(0.204)
ΔFF × Age	−6.458***			−6.476***
	(0.681)			(0.825)
ΔFF × Income		0.452***		0.046
		(0.158)		(0.244)
ΔFF × College			0.936***	−0.114
			(0.310)	(0.472)
All f.e.	Y	Y	Y	Y
Observations	1,299,505	1,299,505	1,299,505	1,299,505
R^2	0.231	0.231	0.231	0.231

Notes. This table estimates the effect of financial sophistication on deposit spreads and deposit growth. The data are at the branch-quarter level from January 1997 to December 2013 (Panel A) and the branch-year level from 1994 to 2013 (Panel B). Panel A reports results on savings deposit spreads. Panel B reports results for deposit growth. Age is the county share of the population aged 65 or older. Income is the natural log of county-level median household income. College is the county share of the population with a college degree. All other variables are defined in Table 2. All regressions include state-time, branch, and county fixed effects. Standard errors are clustered by county. *, **, *** indicates significance at the 0.1, 0.05, and 0.01 levels, respectively.

proxies lose their significance. The effect of concentration remains statistically significant in all specifications.[27]

27. The statistical significance of the financial sophistication variables varies when we add bank-time fixed effects. The effect of market concentration is robust across all specifications.

Panel B of Table V presents the results for deposit flows, using the same sets of fixed effects as in Panel A. Columns (1) to (3) show that the financial sophistication proxies have statistically significant effects and the expected signs. The joint specification in column (4) shows that age is the most informative of these proxies. The effect of market concentration remains robust and statistically significant in all specifications.

Overall, the results in Table V indicate that low financial sophistication is associated with a higher sensitivity of deposit supply to monetary policy. This is consistent with our model where low financial sophistication represents an additional source of market power for banks.

VI.G. Robustness

We summarize the results from a number of robustness tests which we report in full in the Online Appendix. First, the results are similar for large banks, consistent with the large aggregate effects in Figures I and II. Second, the results are similar if we define a local deposit market using a smaller geographic area than a county; if we use lagged time-varying measures of concentration; and if we define concentration based on branch shares instead of bank shares. Third, restricting the sample to the precrisis period does not change the results. This is unsurprising since there is no variation in the Fed funds rate in our postcrisis sample. Fourth, the results on deposit spreads are robust to using alternative deposit products. Fifth, they are also robust to estimation in levels instead of changes.

VII. Results on Lending

VII.A. Identification Strategy

In this section we analyze the effect of the deposits channel on lending. Our model predicts that the contraction in deposit supply induced by a Fed funds rate increase should cause a contraction in lending (Proposition 3). The key condition for this prediction is that deposits are a special source of funding for banks, one that is not perfectly substitutable with wholesale funding. Under this condition, when banks contract deposits to take advantage of greater market power, they also contract their lending. And if firms cannot costlessly replace bank loans with other funding, then real activity declines.

Given that banks can allocate deposits across branches, the impact of the deposits channel on a bank's lending is determined by the average concentration of its branches. We therefore construct a bank-level measure of concentration, Bank-HHI, by averaging the concentrations of a bank's branches (Branch-HHI), weighting each branch by its share of the bank's deposits. Our model predicts that when the Fed funds rate rises, banks that raise deposits in high-concentration markets (high Bank-HHI banks) should reduce lending relative to banks that raise deposits in low-concentration markets (low Bank-HHI banks).

Testing this prediction is challenging because it again requires controlling for differences in lending opportunities. However, precisely because banks can allocate deposits across branches, this time we cannot rely on our within-bank estimation strategy. Instead, we compare the lending of different banks in the same county, ensuring that they face similar local lending opportunities.

This within-county estimation for lending is the analog of our within-bank estimation for deposits. Moreover, it is fully consistent with our earlier identification assumption that banks can allocate deposits across branches. In fact, we can use it to test this assumption by including local market concentration as an additional control. If banks are indeed able to allocate deposits, then their lending in a given county should depend on their bank-level concentration (Bank-HHI), not on the local county's concentration (Branch-HHI).[28]

VII.B. Within-County Estimation

We apply our within-county estimation strategy using data on small business lending, which is available at the bank-county level.[29] Small business lending is particularly well suited for our analysis because it is a highly illiquid yet economically important form of lending.

28. Local lending can be affected by local lending concentration (Scharfstein and Sunderam 2014). We control for this by including county-time fixed effects.

29. This data set is heavily weighted toward large banks, as only banks with over $1 billion in assets are required to report their small business lending (the reporting threshold was $250 million until 2004). In addition, because the unit of observation is a bank-county, and because large banks are active in multiple counties, they are further overrepresented within the data set itself.

We run the following OLS regression, which is analogous to our deposits regression (16):

$$y_{jct} = \alpha_{jc} + \delta_{ct} + \beta \text{Bank-HHI}_{jt-1} + \gamma \Delta FF_t \times \text{Bank-HHI}_{jt-1} + \varepsilon_{jct}, \tag{18}$$

where y_{jct} is the log of new lending by bank j in county c from year t to $t+1$, Bank-HHI_{jt-1} is the bank-level concentration of bank j in year $t-1$, ΔFF_t is the change in the Fed funds target rate from t to $t+1$, α_{jc} are bank-county fixed effects, and δ_{ct} are county-time fixed effects. We double-cluster standard errors at the bank and county level.

The key set of controls are the county-time fixed effects, which absorb changes in local lending opportunities. We also include county-bank fixed effects, which absorb time-invariant characteristics such as local brand effects. In some specifications, we also include local concentration (Branch-HHI_c) interacted with the Fed funds rate change to test whether local concentration has a direct effect on lending.

The results are presented in Table VI. Column (1) includes the full set of controls. It shows that when the Fed funds rate rises, banks that raise deposits in more concentrated markets reduce lending relative to banks that raise deposits in less concentrated markets: a one standard deviation increase in Bank-HHI reduces lending by 291 bps per 100 bps increase in the Fed funds rate. Note that this estimate captures the change in new lending, not the stock of loans on bank balance sheets. It is economically significant, as well as statistically significant at the 1% level. It provides strong evidence that the deposits channel affects the provision of new loans.

Column (2) includes local concentration (Branch-HHI) and interacts it with the Fed funds rate change (this requires omitting the county-time fixed effects). We find that local concentration has no effect on the sensitivity of local lending to monetary policy. In contrast, the coefficient on bank-level concentration (Bank-HHI$\times \Delta FF$) is almost unchanged from column (1) and remains statistically significant. This result indicates that lending decisions are made at the bank level, validating our earlier assumption that banks allocate funds across branches.

Column (3) drops the county-bank fixed effects. The coefficient on the interaction of bank-level concentration with the Fed

TABLE VI
DEPOSITS CHANNEL AND NEW LENDING (BANK-COUNTY RESULTS)

	log(new lending)			
	(1)	(2)	(3)	(4)
ΔFF × Bank-HHI	−0.208**	−0.197**	−0.168**	−0.166**
	(0.085)	(0.088)	(0.076)	(0.075)
ΔFF × Branch-HHI		0.026	0.010	
		(0.016)	(0.023)	
Time f.e.	Y	Y	Y	Y
County f.e.	Y	Y	Y	Y
Bank f.e.	Y	Y	Y	Y
County-bank f.e.	Y	Y	N	N
County-time f.e.	Y	N	N	N
Observations	620,443	620,443	620,443	620,443
R^2	0.830	0.815	0.246	0.246

Notes. This table estimates the effect of the deposits channel on new small business lending. The data are at the bank-county-year level from 1997 to 2013. Log(new lending) is the log of the total amount of new small business loans originated by a given bank in a given county and year. Bank-HHI is the bank-level average of Branch-HHI using lagged deposit shares across branches as weights. All other variables are defined in Table II. The regression includes a control for Bank-HHI (coefficient not shown). The data are from the NCRC. Fixed effects are denoted at the bottom. Standard errors are clustered by bank and county. ** indicates significance at the 0.05 level.

funds rate change remains large and significant. Column (4) drops the control for local deposit concentration and finds the same coefficient. These results indicate that the effect of bank-level concentration on the sensitivity of local lending to monetary policy is robust.

VII.C. County-Level Lending and Employment

In this section we aggregate our data at the county level and examine whether the deposits channel generates changes in total lending and employment. Our left-hand variables are total small business lending, employment, and total wages at the county-year level. Employment and wages are from the Bureau of Labor Statistics, from 1997 to 2013.

The key right-hand variable is a county-level concentration measure, County-HHI, defined as the weighted average of Bank-HHI across all banks lending in a given county, using their lagged lending shares as weights. This measure captures the extent to which a county is served by banks that raise deposits in concentrated markets. Under the deposits channel, high County-HHI should predict a reduction in lending and employment when the

TABLE VII

DEPOSITS CHANNEL, NEW LENDING, AND EMPLOYMENT (COUNTY-LEVEL RESULTS)

	log(new lending)		ΔEmployment		ΔWage bill	
	(1)	(2)	(3)	(4)	(5)	(6)
ΔFF × County-HHI	−0.093***	−0.097***	−0.014***	−0.008***	−0.011***	−0.009**
	(0.025)	(0.028)	(0.003)	(0.003)	(0.003)	(0.004)
ΔFF × Branch-HHI		0.003		−0.004***		−0.001
		(0.009)		(0.001)		(0.001)
Time f.e.	Y	Y	Y	Y	Y	Y
County f.e.	Y	Y	Y	Y	Y	Y
Observations	54,107	54,107	54,107	54,107	54,107	54,107
R^2	0.948	0.948	0.201	0.202	0.272	0.272

Notes. This table estimates the effect of the deposits channel on new small business lending and employment. The data are at the county-year level covering the years 1997 to 2013. Log(new lending) is the log of the total amount of new small business loans originated by county per year. ΔEmployment is the change in total employment by county and year. ΔWage Bill is the change in the total wage bill by county and year. County-HHI is county-level average of Bank-HHI using one-year lagged lending shares across banks as weights. All other variables are defined in Table II. The data are from the NCRC and the Bureau of Labor Statistics. Fixed effects are denoted at the bottom. Standard errors are clustered by county. **, *** indicates significance at the 0.05 and 0.01 levels, respectively.

Fed funds rate rises. We estimate the following OLS regression:

$$y_{ct} = \alpha_c + \delta_t + \beta \text{County-HHI}_{ct-1} + \gamma \Delta FF_t \times \text{County-HHI}_{ct-1} + \varepsilon_{ct}, \tag{19}$$

where y_{ct} is the log of new lending, the log growth in employment, or the log growth in the total wage bill in county c from date t to $t+1$, County-HHI$_{ct-1}$ is the weighted average of Bank-HHI$_{bt-1}$ for all banks operating in county c weighted by their lending shares on date $t-1$, α_c are county fixed effects and δ_t are time fixed effects. As in the previous section, we also include local deposit concentration (Branch-HHI) interacted with the change in the Fed funds rate, which improves identification by ensuring that we are using variation in concentration coming from counties other than the one where the lending is taking place. We cluster standard errors at the county level.

Table VII presents the results. Column (1) reports the benchmark specification using new lending as the outcome variable. It shows that counties whose banks raise deposits in more concentrated markets see a reduction in lending relative to other counties: a one standard deviation increase in County-HHI (0.06) reduces new lending by 58 bps per 100 bps increase in the Fed funds rate. The result is statistically significant. Column (2) adds

local deposit concentration as a control. The coefficient on County-HHI remains unchanged while local deposit concentration has no effect, as predicted. These results support the prediction that the deposits channel affects overall bank lending.

Columns (3) and (4) present the results for employment. We find that a one standard deviation increase in County-HHI reduces employment growth by 9 bps per 100 bps increase in the Fed funds rate. The result is statistically significant. Column (4) adds the local deposit concentration control. The coefficient on County-HHI is slightly reduced but remains significant. Columns (5) and (6) find similar results using total wage growth as the outcome variable. These results provide evidence that the contraction in lending induced by the deposits channel reduces real economic activity.

VII.D. Bank-Level Analysis

In this section we examine the effects of the deposits channel on the components of bank balance sheets. This provides a more detailed picture of how banks absorb the contraction in deposits induced by a rise in the Fed funds rate. It also allows us to verify the robustness of our earlier results on deposits and lending using an entirely different data set (namely, U.S. Call Reports). We run the following OLS regression, where the unit of observation is now a bank-quarter:

$$\begin{aligned}\Delta y_{bt} &= \alpha_b + \delta_t + \beta \text{Bank-HHI}_{bt-1} \\ &\quad + \gamma \Delta FF_t \times \text{Bank-HHI}_{bt-1} + \varepsilon_{bt},\end{aligned} \tag{20}$$

where Δy_{bt} is the log change in a given balance sheet component (e.g., loans) of bank b from date t to $t+1$, ΔFF_t is the change in the Fed funds target rate from t to $t+1$, Bank-HHI$_{bt-1}$ is the bank-level deposit concentration of bank b at $t-1$, α_b are bank fixed effects and δ_t are time fixed effects. We cluster standard errors at the bank level.[30]

Panel A of Table VIII presents the results for deposits and other types of liabilities. Consistent with our branch-level analysis, columns (1) and (2) show that when the Fed funds rate rises, banks that raise deposits in more concentrated markets

30. Following the specification of the deposits regressions, we also include bank fixed effects interacted with a post-2008 indicator to ensure that the results are not driven by the zero lower bound period.

TABLE VIII

DEPOSITS CHANNEL, BANK LIABILITIES, AND LENDING (BANK-LEVEL RESULTS)

	ΔTotal deposits (1)	ΔDeposit spread (2)	ΔSavings deposits (3)	ΔTime deposits (4)	ΔWholesale funding (5)	ΔTotal liabilities (6)
Panel A: Liabilities						
ΔFF ×	−1.478***	0.076***	−1.209***	−2.144***	2.438***	−1.280***
Bank HHI	(0.144)	(0.010)	(0.242)	(0.212)	(0.945)	(0.138)
Bank f.e.	Y	Y	Y	Y	Y	Y
Quarter f.e.	Y	Y	Y	Y	Y	Y
Observations	558,502	558,502	558,502	558,502	558,502	558,502
R^2	0.162	0.400	0.078	0.170	0.033	0.175
	ΔTotal assets (1)	ΔCash (2)	ΔSecurities (3)	ΔTotal loans (4)	ΔReal estate loans (5)	ΔC&I loans (6)
Panel B: Assets						
ΔFF ×	−1.204***	−2.477***	−0.952***	−0.462***	−0.824***	−0.913***
Bank HHI	(0.123)	(0.666)	(0.335)	(0.150)	(0.196)	(0.350)
Bank f.e.	Y	Y	Y	Y	Y	Y
Quarter f.e.	Y	Y	Y	Y	Y	Y
Observations	558,502	558,502	558,502	558,502	558,502	558,502
R^2	0.176	0.051	0.063	0.223	0.176	0.059

Notes. This table estimates the effect of the deposits channel on bank-level outcomes. The data are at the bank-quarter level and cover all commercial banks from January 1994 to December 2013. Panel A examines the change in bank liabilities. ΔTotal deposits, ΔSavings deposits, ΔTime deposits, ΔWholesale funding, and ΔTotal liabilities are calculated as quarterly log changes. ΔDeposit spread is the change in the Fed funds target rate minus the change in the annualized deposit rate (computed as total domestic deposit expense divided by total domestic deposits) over a quarter. Panel B examines the change in bank assets. ΔTotal assets, Δcash, Δsecurities, Δtotal loans, Δreal estate loans, and ΔC&I loans are calculated as quarterly log changes. All other variables are defined in Tables II and VI. Fixed effects are denoted at the bottom. Standard errors are clustered by bank. *** indicates significance at the 0.01 level.

experience greater deposit outflows and a greater increase in deposit spreads (measured as the Fed funds rate minus deposit interest expense divided by total deposits). The estimated coefficients are similar to our earlier estimates using branch-level data. Columns (3) and (4) show similar results for savings and time deposits. Column (5) shows that banks partly offset the contraction in deposits by raising wholesale funding. Nevertheless, as column (6) shows the net effect on total liabilities is strongly negative.

Panel B of Table VIII presents the results for loans and other types of assets. Column (1) verifies that total assets decline in line with total liabilities. Columns (2) and (3) show that banks absorb part of this decline by reducing their cash and securities buffers (these two categories represent 5% and 25% of the balance sheet, respectively). Even so, as column (4) shows, total loans

also contract significantly. Finally, columns (5) and (6) show a strong decline in the two main loan categories, real estate and commercial and industrial (C&I) loans.

The results in Table VIII support the predictions of the deposits channel for lending as given by Proposition 3. Banks face a trade-off between maximizing profits from deposits and financing a large balance sheet. Consistent with this trade-off, we find that banks that raise deposits in more concentrated markets contract their assets by more in response to an increase in the Fed funds rate. The contraction occurs across the board, including in securities and loans. Hence, the deposits channel gives rise to a bank lending channel.

VIII. Broader Implications of the Deposits Channel

VIII.A. A New Measure of Banks' Exposure to Monetary Policy

Under the deposits channel, a bank's exposure to monetary policy depends on its market power. One important determinant of market power which we use for identification throughout the paper is market concentration. Yet as our model shows, banks also derive market power from other sources. These include product differentiation, the willingness of depositors to switch banks, their rate of participation in other markets, and depositors' financial sophistication and attentiveness. A comprehensive measure of a bank's exposure to monetary policy under the deposits channel must account for all of these sources of market power.

Our model provides a simple way to construct such a measure. A sufficient statistic for a bank's market power is the sensitivity of its deposit spread to the Fed funds rate, which we call the deposit spread beta (see Propositions 1 and 2). Intuitively, while all banks charge a low spread when the Fed funds rate is low, banks with a lot of market power are able to raise their spreads more aggressively when the Fed funds rate rises; that is, they have high deposit spread betas. In Section VI.B, we calculated deposit spread betas at the branch level and related them to concentration. In this section we calculate deposit spread betas at the bank level and relate them to bank-level outcomes.

We estimate bank-level deposit spread betas by running the following OLS regression for each bank in the Call Reports data:

$$\Delta y_{it} = \alpha_i + \sum_{\tau=0}^{4} \beta_i^{\tau} \Delta FF_{t-\tau} + \varepsilon_{it}, \tag{21}$$

where Δy_{it} is the change in the deposit spread of bank i from date t to $t+1$ and ΔFF_t is the change in the Fed Funds target rate from t to $t+1$. We allow for lags because the Call Reports data are based on average deposit interest expense and because it takes time for the rates on nonzero maturity deposits to reset. Our estimate of bank i's deposit spread beta, Spread-β_i, is the sum of the β_i^τ coefficients in regression (21).

Our estimates show that banks have significant market power as they are able to substantially raise deposit spreads when the Fed funds rate rises. The average deposit spread beta is 0.54; that is, on average banks raise deposit spreads by 54 bps per 100 bps increase in the Fed funds rate. Deposit spread betas also differ substantially in the cross section. They range from 0.31 at the 10th percentile to 0.89 at the 90th percentile. This large variation in exposure to the deposits channel allows us to assess its ability to explain bank-level outcomes.

We relate the deposit spread betas to the sensitivity of bank balance sheets to monetary policy. We measure this sensitivity by rerunning regression (21) with the log growth of deposits, assets, securities, and loans as dependent variables. We refer to the estimated sensitivities as flow betas.

We provide a graphical representation of the relationship between spread betas and flow betas by sorting banks into 100 bins by their deposit spread betas (winsorized at the 10% level to reduce the impact of outliers) and plotting the average flow beta within each bin. The slope of this relationship measures the impact of increased exposure to the deposits channel on the various components of banks' balance sheets.[31]

Figure VI presents the results. As shown in Panel A, banks with higher deposit spread betas have more negative deposit flow betas. The effect is large: banks at the 90th percentile of the spread beta distribution are predicted to have a 209 bps greater outflow of deposits than banks at the 10th percentile for every 100 bps increase in the Fed funds rate. Panels B–D show similar effects for total assets (148 bps), securities (207 bps), and loans (124 bps).

Panel A of Table IX provides formal estimates from cross-sectional regressions of flow betas on spread betas for the universe of all banks. Columns (1) to (4) correspond to the panels in

31. The level (or intercept) of the relationship is not identified because it includes the impact of lending opportunities, which are likely to be positively correlated with increases in the Fed funds rate.

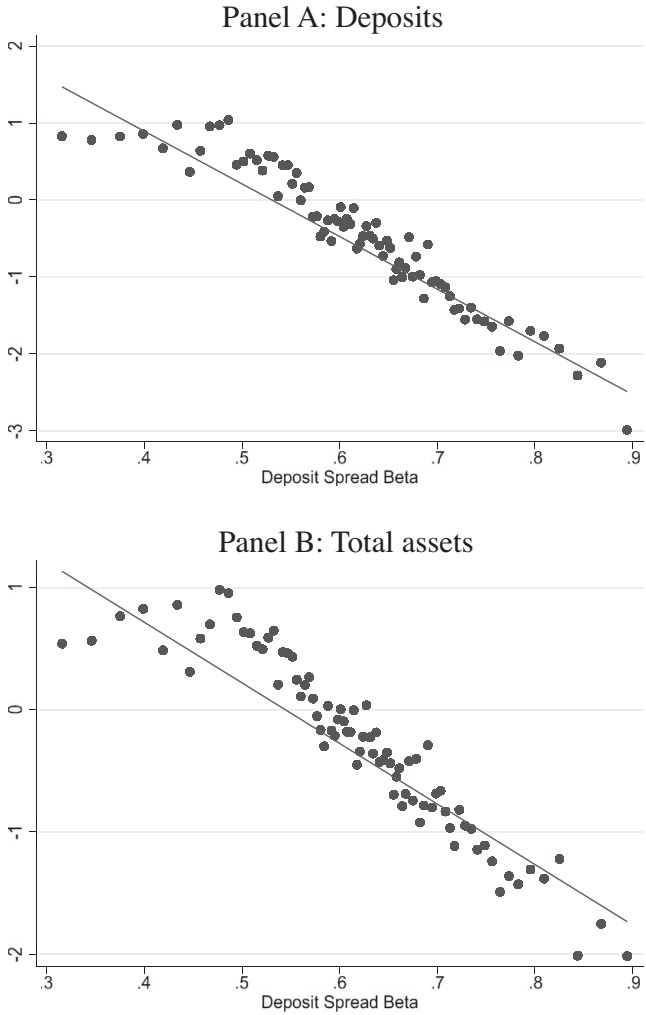


FIGURE VI

Spread Beta, Deposits, and Lending (All Banks)

This figure shows the relationship between exposure to the deposits channel and bank-level outcomes. The figure is constructed in two steps. The first is to estimate bank-level exposure to the deposits channel as the sensitivity of a bank's deposit rate to the Fed funds rate ("spread beta"). The second step is to compute the corresponding sensitivity for bank-level outcomes ("flow beta"). The third step is to sort banks by spread beta into one hundred bins and compute the average spread and flow beta by bin. Panel A shows the results for total deposits, Panel B shows the results for total assets, Panel C shows the results for securities, and Panel D shows the results for total loans. The sample is all U.S. commercial banks from 1994 to 2013 (11,091 banks).

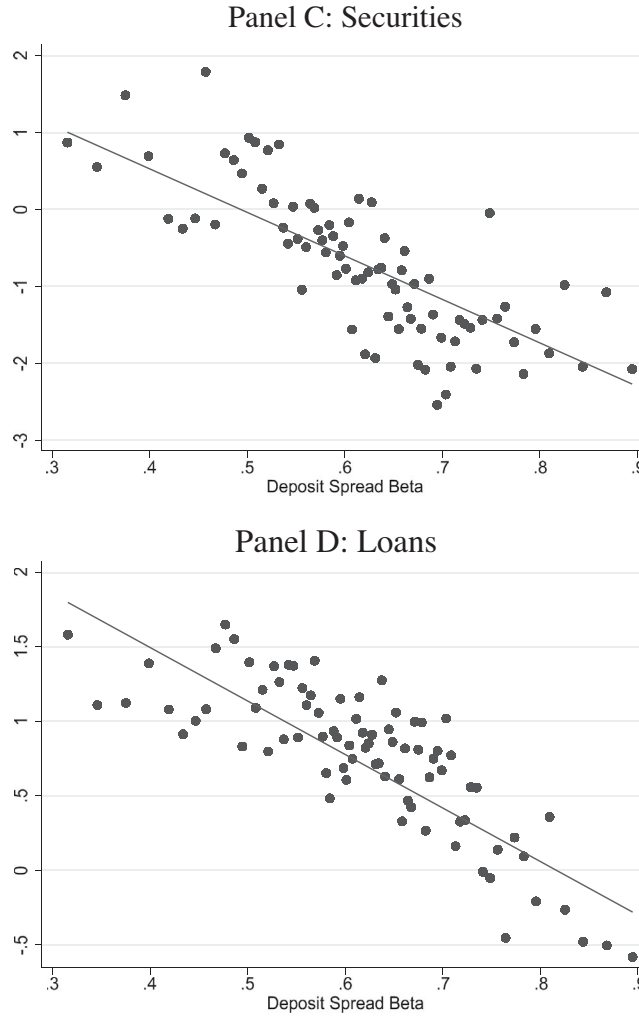


FIGURE VI
(CONTINUED)

Figure VI, while columns (5) and (6) break out real estate and C&I loans (the two largest categories). The estimates, which can be interpreted as semi-elasticities, are statistically significant and their magnitudes are large. The semi-elasticity for deposits (−3.6) is similar to the one obtained from our within-bank estimation in Section VI.C (−5.3). Overall, these results show that banks'

TABLE IX

BANKS' MARKET POWER, DEPOSITS, AND LENDING

	Deposit-β (1)	Assets-β (2)	Securities-β (3)	Loans-β (4)	RE loans-β (5)	C&I loans-β (6)
Panel A: All banks						
Spread-β	−3.610***	−2.555***	−3.569***	−2.141***	−2.493***	−3.187***
	(0.203)	(0.187)	(0.511)	(0.204)	(0.254)	(0.517)
Observations	11,091	11,091	11,091	11,091	11,091	11,091
R^2	0.132	0.085	0.023	0.045	0.042	0.018
Panel B: Large banks						
Spread-β	−5.978***	−4.027***	−8.149***	−4.084***	−5.394***	−6.279***
	(0.615)	(0.546)	(1.806)	(0.796)	(0.814)	(1.431)
Observations	555	555	555	555	555	555
R^2	0.318	0.209	0.111	0.171	0.196	0.104

Notes. This table analyzes the relationship between bank market power and bank-level outcomes. The analysis covers U.S. commercial banks from 1994 to 2013. Panel A covers all banks and Panel B covers the largest 5% of banks by assets. We measure bank market power using Spread-β, which is estimated as the sensitivity of a bank's deposit rate to changes in the Fed funds rate. We compute the corresponding Flow-β as the sensitivity of bank-level outcomes to changes in the Fed funds rate. We estimate Flow-β for deposit growth (column (1)), asset growth (column (2)), log change in security holdings (columns (3)), loan growth (column (4)), real estate (RE) loan growth (column (5)) and commercial and industrial (C&I) loan growth (column (6)). We report coefficients from regressing Flow-β on Spread-β. We report robust standard errors. ***indicates significance at the 0.01 level.

market power, as measured by their ability to raise deposit spreads, strongly influences the sensitivity of bank balance sheets to monetary policy.

VIII.B. Large Banks and Aggregate Effects

In order to have a significant aggregate effect, the deposits channel must affect large banks. Since the aggregate time series is dominated by large banks, it shows that large banks raise deposit spreads (Figure I) and contract deposit supply (Figure II) when the Fed funds rate rises, as predicted by the deposits channel.[32] Yet, because monetary policy is endogenous, we cannot use the aggregate series to estimate its impact on large banks' lending. Instead, we again turn to the cross section and reestimate the relationship between spread betas and flow betas for the subset of the 5% largest banks (this cutoff is commonly used in the banking literature; e.g., Kashyap and Stein 2000).

This analysis is informative because there remains substantial cross-sectional variation in deposit spread betas even among

32. In Section VI.G, we also verified that our cross-sectional results on deposits are similar for large banks.

large banks (their distribution is very similar to the full sample). Large banks also appear to have substantial market power over deposits: their average spread beta is 0.61, which is slightly higher than for the full sample.

Figure VII shows the relationship between the flow and spread betas of large banks. The results are similar to the full sample, and are in fact somewhat stronger. Panels A and B show that large banks with higher spread betas have greater deposit outflows and lower asset growth following Fed funds rate increases. Panel C and D show that they also sell more securities and contract loan growth by more. Panel B of Table IX provides the corresponding regression estimates. The effect on lending is larger than in the full sample: banks at the 90th percentile of the spread beta distribution reduce loan growth by 237 bps relative to banks at the 10th percentile per 100 bps increase in the Fed funds rate.

We can use the numbers in Panel B of Table IX to estimate the aggregate effect of the deposits channel on bank lending. Given the average deposit spread beta of 0.61, a 100 bps increase in the Fed funds rate is expected to induce a 365 bps outflow of deposits and a 249 bps reduction in lending. These estimates imply that a typical 400 bps Fed hiking cycle induces a 1,458 bps reduction in deposits and a 995 bps reduction in lending (relative to keeping rates unchanged). Based on 2014 figures, these numbers translate into a $1.35 trillion reduction in deposits and a $763 billion reduction in lending.[33]

To put these estimates in the context of the literature, we compare them to the seminal work of Bernanke and Blinder (1992) on the bank lending channel. Using a VAR, Bernanke and Blinder (1992) estimate that a one standard deviation increase in the Fed funds rate (31 bps) induces deposit outflows of 81 bps, and reductions in securities and loans of 123 bps and 57 bps, respectively, over a one-year period. Our corresponding estimates are 113 bps, 154 bps, and 77 bps, respectively. This shows that the deposits channel can account for the full magnitude of the transmission of monetary policy through bank balance sheets as documented by Bernanke and Blinder (1992).

33. Drechsler, Savov, and Schnabl (2017a) show that banks with high deposit spread betas hold assets with significantly longer maturity. The contraction in lending is therefore likely to be concentrated among long-term assets.

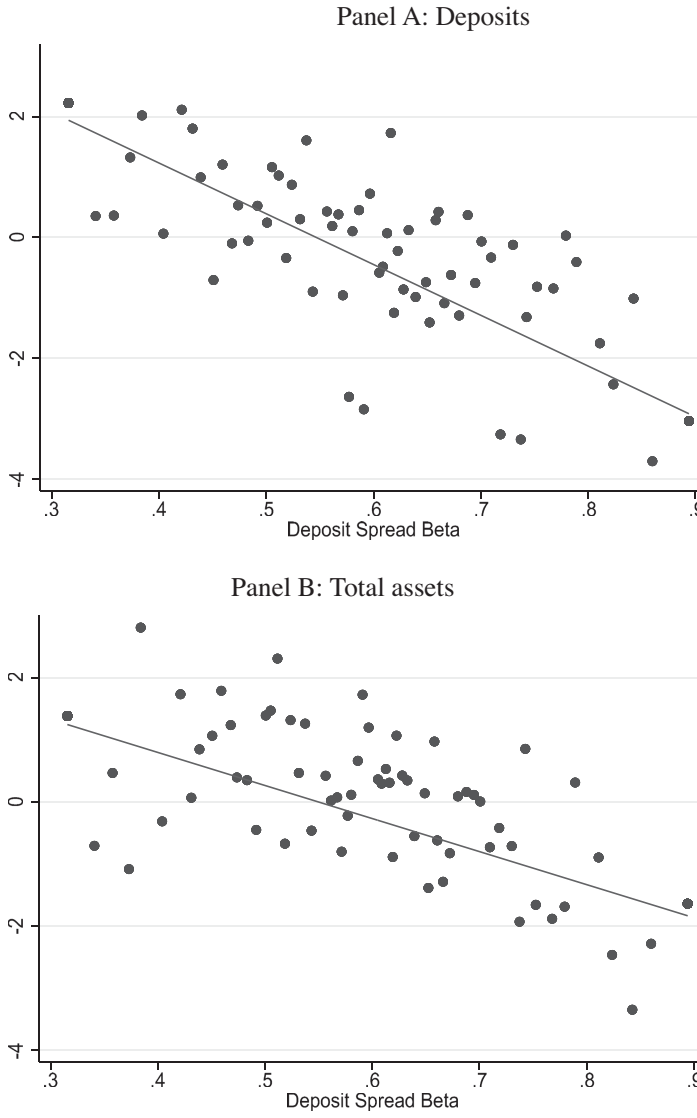
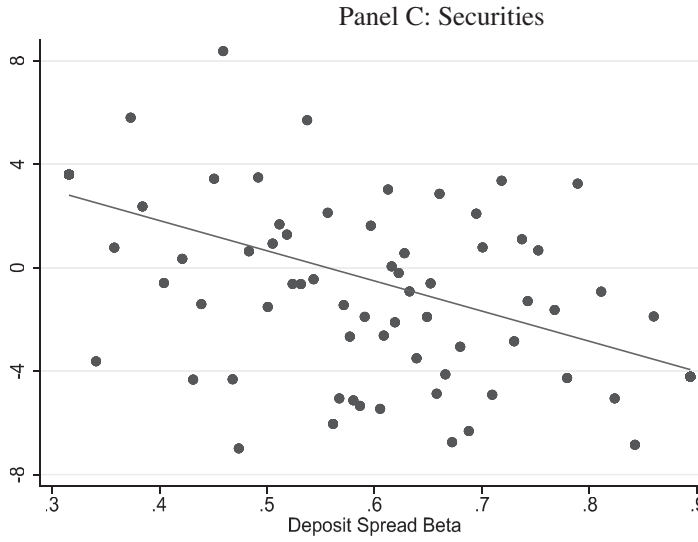


FIGURE VII

Spread Beta, Deposits, and Lending (Large Banks)

This figure shows the relationship between exposure to monetary policy and bank outcomes for large banks. Large banks are banks at or above the 95th percentile of the bank size distribution (555 banks). The figure is constructed the same way as Figure VI. Panel A shows the results for total deposits, Panel B shows the results for total assets, Panel C shows the results for securities, and Panel D shows the results for total loans.



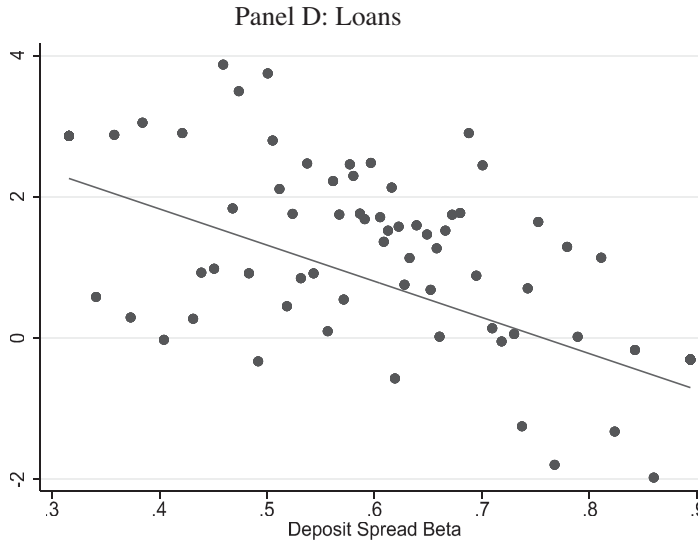


FIGURE VII
(CONTINUED)

VIII.C. Implications for the Liquidity Premium

The deposits channel has important implications for the liquidity premium in financial markets. Since deposits are the main source of liquid assets for households, the contraction in deposit supply induced by the deposits channel is likely to reduce the overall supply of liquid assets and push up the premium for other liquid assets such as Treasuries. This will occur as long as there is not a fully offsetting expansion in the supply of other liquid assets produced by the financial system. Such an offsetting expansion is unlikely because the wholesale funding instruments that banks issue to (partly) offset the loss of deposits provide households with less liquidity, as evidenced by their significantly higher yields.[34] Moreover, the contraction in lending means that there is a net reduction in bank liabilities of any liquidity.

Since the liquidity premium is an aggregate variable, we cannot use cross-sectional data to test this prediction, as we have done so far. It is nevertheless instructive to plot the time series of the liquidity premium against the price of deposits. We measure the liquidity premium as the spread between the Fed funds rate and the T-bill rate. While both Fed funds loans and T-bills are extremely safe short-term securities, T-bills provide a higher level of liquidity services to a broader range of investors, and therefore command a liquidity premium. Figure VIII plots this liquidity premium measure against the aggregate deposit spread, which we compute from the Call Reports, for the period from 1986 to 2013. As the figure shows, there is a striking positive relationship between the two series. Their correlation is 90%, and their co-movement is strong both in the cycle and in the trend.

This result suggests that the deposits channel is a main driver of the liquidity premium. This can explain the otherwise puzzling high correlation between the liquidity premium and the Fed funds rate documented by Nagel (2016). To our knowledge, there is no plausible alternative theory for the large fluctuations in the supply of liquid assets required to generate this correlation. Ultimately, the liquidity premium affects all financial institutions that rely on liquid assets as a buffer against a loss of funding. In addition to banks, these include hedge funds, broker dealers, and

34. These instruments include large time deposits and commercial paper. Households invest in them primarily via prime money market funds. Some of the withdrawn deposits also flow into government money market funds which buy Treasuries and hence directly push up their liquidity premium.

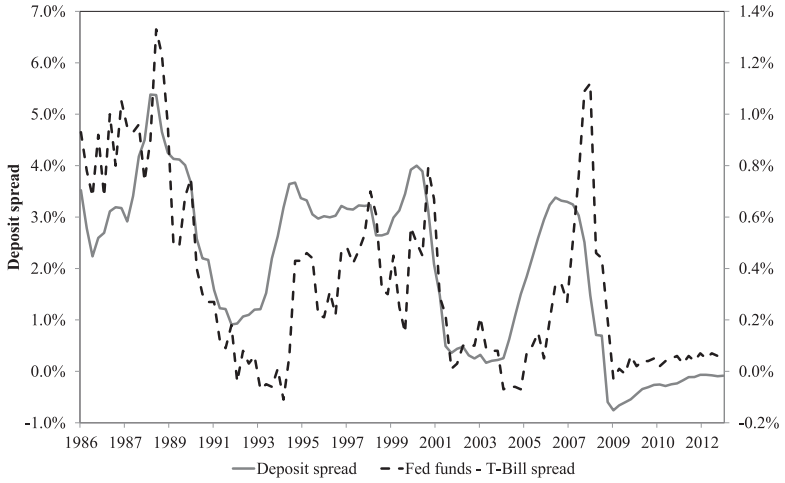


FIGURE VIII

The Aggregate Deposit Spread and the Liquidity Premium

This figure plots the aggregate deposit spread against the T-bill liquidity premium. The deposit spread is equal to the Fed funds rate minus the value-weighted average deposit rate paid by banks, computed from the quarterly Call Reports. The T-bill liquidity premium is equal to the Fed funds rate minus the three-month T-bill rate. Both the Fed funds rate and T-bill rate are calculated as quarterly averages. The data are from January 1986 to December 2013.

mutual funds. As the liquidity premium fluctuates, it affects their ability to take leverage, and consequently affects asset prices and firms' cost of capital (Drechsler, Savov, and Schnabl 2017b). This general equilibrium effect of the deposits channel is above and beyond the effect on lending discussed above.

IX. CONCLUSION

We show that monetary policy has a strong effect on the supply of deposits, a large and important asset class. When the Fed funds rate rises, the spread between the Fed funds rate and deposit rates also rises, triggering large deposit outflows. We argue that these relationships are due to banks' market power. When rates are low, banks face competition from cash in supplying liquidity to households, which forces them to charge a low spread on deposits. When rates are high, banks' competition is mainly from other banks, which allows them to increase spreads, especially in markets that are concentrated, or where depositors are

financially unsophisticated and unlikely to switch banks. Households respond by decreasing their deposit holdings. We call this mechanism the deposits channel.

We provide evidence for the deposits channel using cross-sectional data on deposit rates and flows. We control for changes in banks' lending opportunities by comparing branches of the same bank located in different markets. We find that when the Fed funds rate rises, branches located in more concentrated markets raise their deposit spreads by more, and experience greater outflows, than branches located in less concentrated markets.

Deposits are the main source of funding for banks. Their stability makes them particularly well suited for funding risky and illiquid assets. As a result, when banks contract deposit supply they also contract lending. We find evidence to support this prediction in both bank-level and disaggregated data on bank lending. Our estimates suggest that the deposits channel can account for the entire transmission of monetary policy through bank balance sheets. It does so without relying on required reserves, a foundation of existing theories of the bank lending channel that has become quantitatively implausible.

Deposits also represent the main source of safe and liquid assets for households. The deposits channel therefore also affects the overall supply of safe and liquid assets in the economy and the liquidity premium in financial markets.

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SUPPLEMENTARY MATERIAL

An Online Appendix for this article can be found at *The Quarterly Journal of Economics* online. Data and code replicating the tables and figures in this paper can be found in Drechsler, Savov, and Schnabl (2017c), in the Harvard Dataverse, doi:10.7910/DVN/KHNXYJ.

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